INDIA
Science & Technology 2008

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National Institute of Science, Technology And Development Studies (NISTADS), CSIR

About the Cover:

The cover for INDIA Scientific & Technology 2008 depicts one of the most exciting and ambitious projects ever undertaken by India: an artistic perception of the *Chandrayaan* with a photographic image of the Earth as viewed by Chandrayaan on 29 October 2008 at a distance of 9,000 km from the Earth.

The *Chandrayaan* mission has not only left its imprint on the Moon, it has also positioned ISRO as one of the world's top space agencies. It was launched using the mighty Polar Satellite Launch Vehicle (PSLV) launch pad with a 44.4 metre tall rocket. India's most talked about space project thundered off into space at 6.22 a.m. on 22 October 2008. Costing Rs 386 crores, which included Rs 100 crores for establishing the Indian Deep Space Network at Byalalu, 40 km from Bangalore, the *Chandrayaan* project is the cheapest mission to the Moon ever. Eighteen minutes into the flight the *"Chandrayaan"* was successfully placed in its initial orbit. The launch was successful and 22 October 2008 becomes a day to remember in India's space and national history.

Dr A.P.J. Abdul Kalam, Former President of India said *"The Moon cannot be left to a few countries. In another four decades, the Earth, Moon and Mars will attain strategic and economic importance."*

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Foreword

A scientist often does not worry about how scientific research would assist the economic and social development of the country. An administrative executive and a policy maker might focus only on immediate concerns and may not be aware of how science and technology (S&T) impact those concerns. A lay citizen might simply be not aware of how S&T can be used to find solutions to his problems. There is therefore a need to bring awareness about the progress of science and technology and how it is being harnessed to serve the society. This present ‘India S&T Report 2008’is the first in series of reports on the progress of science and technology and its applications seen by science policy researchers.

‘India S&T 2008’ is a first report of this kind from NISTADS and may be from our country itself. This report resulted from an analysis of the developmental agenda of the S&T in our country. Similar reports but often with different focus have been brought out by the National Science Foundation (NSF) of the USA, and by several other countries such as Japan, Korea, China, and Taiwan. The NSF reports stand upon accumulated experience and data on S&T. Needless to mention that each country while looking at comparators emphasizes issues and parameters relevant to their environments.

I am very happy that colleagues at NISTADS under the leadership of Dr. P. Banerjee, Director has undertaken the challenge of preparing this report. They have been helped in this by experts from many other institutions. A periodic and regular stock taking helps us knowing where do we stand and what revisions in the policy framework needs to be adopted and which paths and goals to be revisited.

It has been a pleasure for me to interact with my colleagues at NISTADS who have worked very hard in preparing this report. I found my interaction with them very educative for me. I hope this report would prove needful to many who are concerned with use of science and technology for the development of our society. In today’s context science and technology is of council importance for our country’s development.

This is an extended summary of the full report, which is voluminous and available as open document at http:www.nistads.res.in; and we at NISTADS would like to make such a report to appear every alternate year and would look forward to get feedback from readers to improve the report.

(Professor S.K. Joshi)

Chairman, Research Council, NISTADS, CSIR

April 15, 2009

Acknowledgements

On behalf of all my colleagues may I acknowledge the great support in the form of a research grant of a Supra-institutional project provided by Prof. S.K.Brahmachari, Director General, CSIR, and Dr. Naresh Kumar, Head, RDPD, CSIR and Dr. Chandra Gupt, RDPD, CSIR, that made possible research undertaken to writing this Report. We must mention that without the support from this Supra project grant this research would have been impossible.

Since its inception the Research Council of NISTADS, with its Chairman Prof. S.K.Joshi, and members Sh. R.Rajamani, Prof. S. Khanna, Prof. Anil Gupta, Dr. H.R.Bhojwani, Dr. Anuj Sinha, Dr. S.K.Rastogi, Dr. Gangan Prathap, Dr. Prasanna Hota, Dr. Chandra Gupt and Prof. Ashok Chandra et al took special care to interact very regularly with all contributing colleagues and by reviewing as well guiding the research from time to time. The suggestions the Council chairman and members provided were most vital. We acknowledge gratefully their contribution.

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Several scholars read through the voluminous full report of nearly 1500 pages. We are obligated to them for the interest they shown on this work and for the comments they provided and for the time they spent on reading the full report. Special mention must be made of Dr. Rangan Dutta, Prof. Biswatosh Saha, Dr. P.K.Biswas, Sh. R.Rajamani and Dr. H.R.Bhojwani and several others who very kindly took care in making better the full report.

Several other research and academic colleagues participated at various stages of development of this report; their number is large and we acknowledge our debts to all of them. The inability to publish all such names be condoned.

Several academic and researcher colleagues from institutes and universities outside the CSIR system have contributed to this report; especially Prof. P.K.Biswas and Dr. S.Pohit have contributed in more than many ways. Support provided by Dr. A.K. Verma (Advisor S&T, Planning Commission) and his colleagues is duly acknowledged. My young colleagues from NISTADS spent months of hard working days and nights; they are the contributors and it must be mentioned that without their dedication this would not have been possible. Our colleagues from administration, finance and purchase sections and other technical officers have contributed in many ways and finally, Mr. Pradip Banerjee and his team at NISCAIR and Dr. Gangan Prathap, Director, NISCAIR must be acknowledged for printing this extended summary.

(P. Banerjee)

Director, NISTADS

April 15, 2009

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Acronyms and Abbreviations

ABLE	Association of Biotechnology Led Enterprises
AICCIP	All India Coordinated Crop Improvement Project
AICRP	All India Coordinated Research Projects
AIIMS	All India Institute of Medical Sciences
AMPRI	Advanced Materials and Processes Research Institute
ARAI	Automotive Research Association of India
ASI	Annual Survey of Industries
ATIRA	Ahmedabad Textile Industry Research Association
ATS	Apprenticeship Training Scheme
AYUSH	Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homoeopathy
BARC	Bhabha Atomic Research Centre
BCIL	Biotech Consortium India Limited
BHU	Banaras Hindu University
BIPP	Biotechnology Industry Partnership Programme
BIRAC	Biotechnology Industry Research & Development Assistance Council
BIS	Bureau of Indian Standards
BMTPC	Building Materials and Technology Promotion Council
BPL	Below Poverty Line
BT	Biotechnology
CAPART	Council for Advancement of People's Action and Rural Technology
CBRI	Central Building Research Institute
CBSE	Central Board of Secondary Education
CCFS	Central Committee for Food Standards
CCH	Central Council of Homeopathy
CCIM	Central Council for Indian Medicine
CCT	Controlled Clinical Trial
CC	Clinical Conference
C-DAC	Centre for Development in Advanced Computing
CDMA	Code Division Multiple Access
CDRI	Central Drug Research Institute
CFTRI	Central Food Technological Research Institute
CGCRI	Central Glass and Ceramic Research Institute
CII	Confederation of Indian Industries
CIPHET	Central Institute of Post Harvest Engineering & Technology
CLRI	Central Leather Research Institute
CMIE	Centre for Monitoring Indian Economy
CMRI	Central Mining Research Institute
CMTI	Central Manufacturing Technology Institute
COE	Centre of Excellence

CRAM	Contract Research and Manufacturing
CRO	Contract Research Organization
CSA	Centre for Sustainable Agriculture
CSIR	Council of Scientific and Industrial Research
CSO	Central Statistical Organisation
CT	Clinical Trial
CTS	Craftsmen Training Scheme
DAE	Department of Atomic Energy
DARE	Department of Agricultural Research and Education
DBT	Department of Biotechnology
DCI	Dental council of India
DDWS	Department of Drinking Water Supply
DGE&T	Directorate General of Employment & Training
DGSD	Directorate General of Supplies & Disposals
DOD	Department of Defence
DOS	Department of Space
DOT	Department of Telecommunications
DRDA	District Rural Development Agencies
DRDO	Defence Research & Development Organisation
DSIR	Department of Scientific & Industrial Research
DST	Department of Science & Technology
DWCRA	Development of Women and Children in Rural Areas
EDC	Entrepreneurship Development Cell
EOU	Export Oriented Unit
EWS	Economically Weaker Sections
FDA	Food & Drug Administration (USA)
FDI	Foreign Direct Investment
FMTTI	Farm Machinery Training & Testing Institute
GATT	Global Agreement of Trade and Traffic
GDP	Gross Domestic Product
GERD	Gross Expenditure on R&D
GMP	Good Manufacturing Practice
GNP	Gross National Product
GSM	Global System for Mobile Communications
HAL	Hindustan Aeronautics Limited
HUDCO	Housing and Urban Development Corporation Limited
HYV	High Yielding Varieties
IARI	Indian Agricultural Research Institute
IAY	Indira Awas Yojana
ICAR	Indian Council of Agricultural Research
ICFRE	Indian Council of Forestry Research and Education
ICMR	Indian Council of Medical Research
ICT	Information and Communications Technology
IDBI	Industrial Development Bank of India
IDP	Instrumentation Development Programme

IF	Impact Factor
IFS	International Food Standard
IICT	Indian Institute of Chemical Technology
IIL	Indian Immunological Ltd
IIM	Indian Institute of Management
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
ILO	International Labour Organization
INC	Indian Nursing Council
INPADOC	International Patent Documentation Centre
INSPIRE	Innovation in Science Pursuit for Inspired Research
IPC	International Patent Classification
IPR	Intellectual Property Rights
ISO	International Organisation for Standardization
ISRO	Indian Space Research Organisation
IT	Information Technology
ITI	Industrial Training Institute
IVRI	Indian Veterinary Research Institute
IWDP	Integrated Watershed Development Program
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
KVIC	Khadi and Village Industries Commission
KVK	Krishi Vigyan Kendra
KVPY	Kishore Vaigyanik Protsahan Yojana
MCI	Medical Council of India
MNC	Multinational Corporation
MNRE	Ministry of New and Renewable Energy
MOEF	Ministry of Environment and Forests
MOP	Ministry of Power
MS	Multicenter Study
MSME	Micro, Small and Medium Enterprises
NABARD	National Bank for Agriculture and Rural Development
NAL	National Aerospace Laboratory
NBAGR	National Bureau of Animal Genetic Resources
NBCC	National Building Construction Corporation
NBFC	Non Banking Financial Company
NCERT	National Council of Education Research and Training
NCIPM	National Centre of Integrated Pest Management
NCL	National Chemical Laboratory
NDWM	National Drinking Water Mission
NFBS	National Family Benefit Scheme
NGO	Non-Governmental Organisation
NGP	Nirmal Gram Puraskar
NHHDC	Nagaland Handloom & Handicrafts Development Cooperation
NHRM	National Rural Health Mission
NIF	National Innovation Foundation

NISCAIR	National Institute of Science Communication and Information Services
NIRD	National Institute of Rural Development
NISTADS	National Institute of Science Technology and Development Studies
NMBS	National Maternity Benefit Scheme
NMITLI	New Millennium India Technology Leadership Initiatives
NML	National Metallurgical Laboratory
NNRMS	National Natural Resources Management System
NOAPS	National Old Age Pension Scheme
NPL	National Physical Laboratory
NPO	Non-Profit Organisation
NPV	Net Present Value
NRDC	National Research Development Corporation
NREGA	National Rural Employment Guarantee Act
NRWSP	National Rural Water Supply Program
NSAP	National Social Assistance Program
NSF	National Science Foundation
NSIC	National Small Industries Corporation
NSSO	National Sample Survey Organisation
NSTEDB	National Science & Technology Entrepreneurship Development Board
NTSE	National Talent Search Examination
OCM	Ocean Colour Monitor
OECD	Organisation for Economic Co-operation and Development
OSDD	Open Source Drug Discovery
PASTER	Programme Aimed at attaining Technological Self–Reliance
PCI	Pharmacy Council of India
PCT	Patent Cooperation Treaty
PGI	Post Graduate Institute of Medical Sciences
PGS	Public Guarantee System
PHM	Post Harvest Management
PMGSY	Pradhan Mantri Gram Sadak Yojna
PPP	Public Private Partnership
PRI	Panchayati Raj Institutions
R&D	Research & Development
RCT	Randomised Controlled Trial
RNFS	Rural Non-Farm Sector
RRC	Review of Reported Cases
RRL	Regional Research Laboratory
S&T	Science & Technology
SAY	Samagra Awas Yojana
SBIRI	Small Business Innovation Research Initiative
SEETOT	Scheme to Enhance the Efficacy of Transfer of Technology
SGRY	Sampoorna Grameen Rozgar Yojana
SGSY	Swarnjayanti Gram Swarozgar Yojana
SHG	Self-Help Group
SIDBI	Small Industries Development Bank of India

SITRA	Supply of Improved Tool Kits to Rural Artisans
SMOI	Silk Mark Organization of India
SPREAD	Sponsored Research and Development Programme
SRA	Strengthening Revenue Administration
STAG	Science and Technology Advisory Group
STARD	S&T Application for Rural Development
STAWS	S&T Application for Weaker Sections
STPI	Software Technology Parks of India
TBT	Technical Barriers to Trade
TCAG	Technology Coordination and Action Group
TDB	Technology Development Board
TDPP	Technology Development and Demonstration Program
TDPU	Technology Promotion, Development and Utilization
TePP	Technopreneur Promotion Programme
TIFAC	Technology Information, Forecasting & Assessment Council
TIFR	Tata Institute of Fundamental Research
TRIPS	Trade-Related Aspects of Intellectual Property Rights
TRYSEM	Training of Rural Youth for Self Employment
TUFS	Technology Up-gradation Fund Scheme
UGC	University Grants Commission
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
USPTO	United States Patent and Trademark Office
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Introduction

The country is entering the age of knowledge when increasing returns would be ubiquitous. Surpassing the boundaries of traditional modes of industry based upon decreasing returns, the knowledge based generation of income and wealth should now permeate into agriculture, education and services. At this crossroad the demands on S&T are novel and ambitious. Such expectations require beyond a hefty raise in the allocated percentages of gross national products to the S&T, a deep as well as expansive redrawing of institutions that are dedicated to S&T, but more importantly of other economic social and educational institutions as well. Situated within this backdrop of expectations the ambition of offering a set of S&T indicators for the Indian system was given up in favor of a broad set of analytic descriptions of states-of-affairs, because any dedicated set of indicators must apprehend the potential future while describing the past. This future is currently contested. Old institutions primarily of decreasing returns are overwhelmingly dominant and the indicators would therefore portray a skewed picture. This report thus draws upon facets of economic, social and educational life; where S&T has its footprints.

The democratic governance structures of this country have evolved, over the course of six decades, sets of complex institutions systems and practices that bind or otherwise relate S&T to the other spheres. With about four thousand research and development organizations, large organized systems of knowledge production, millions of knowledge workers and an even larger number of citizens engaging in knowledge-based activities ranging from agriculture through semi-skilled workers to industrial workers, coupled with the fact of the country being especially gifted with immense diversity in natural resources — the opportunity set of potential outcomes are immense and invigorating.

Coordination and Governance

Governance of S&T is currently intertwined with governance of other institutions. One strategic shift that the knowledge age demands is about putting S&T at the helm of governance. Such a shift could address together the twin related issues of governance of S&T and of other systems and institutions. The desired restructuring, in for example economic or educational institutions, could be achieved through allocating to S&T a strategic fraction of the total funds dedicated to economic restructuring. Fund based coordination could indeed offer better solutions to the problem of bridging, for example, the gap between S&T and the economic entities. Over the last few years this country has adopted a few such fund-based mechanisms. Coordination through fund dedicated to a national problem such as TB offers important learnings.

At present S & T participation is absent from several key executive governance systems of the country, at the several tiers of government from the central to the local. Most executive functions however, employ S&T in practice. The country has thus generated multiple islands of knowledge generation and utilization. Coordination between such knowledge agencies could bring about strategic focusing of S&T, while allowing fulfillment of democratic aspirations in the formulation of contesting S&T agendas. Directed research and in particular directed basic research would open up novel possibilities. Fund based in contrast to executive dependent directedness opens up even finer variations. The federated executive of the country has historically employed diversity in adopting agenda, making decisions and in evaluating outcomes. S&T especially has enriched from diversity of research agendas. Indeed this country can exhibit to the global societies how diversified S&T agendas could be functional and remain governed. Indian achievement in democratizing the agenda formulation of S&T is possibly amongst the best in the world. However, India has miles to travel to embolden the feeble voice of poor millions and express their aspirations as well as demands from the S&T, in shaping research agenda or the S&T outcome.

The long twentieth century in Indian S&T based developmental experiments, in particular at grass roots, has thrown up immense volumes of data, facts and artifacts. The governance system, however, failed short of accumulating such results and giving shape to such experiments in the country's S&T based planning processes. Participation of district non-governmental organizations or self-help groups and similar social forms in the governance process offers potentially rewarding outcomes. Similarly, the flow of demands bottom-up from within S&T organizations would offer another important envelope of developmental alternatives based upon S&T. Indeed, today one major challenge to the country is how to support transition of currently existing S&T organizations from states of relative inactivity to imaginative centers of resources.

Inclusive Growth and Well Being

In spirit and since the early years of the formulation of S&T policies and plans, this country often tacitly accepted that S&T based restructuring and innovation are redistributive and justice could be brought about through S&T and innovation. This radical definition of innovation as the key to undertaking redistribution of income and rights to assets and to generation of future assets opens up the door. Innovation can be thus several. This definition informs that there are several non-corporate innovators ranging from individuals through social groups to tiny or small enterprises. Innovation accordingly offers not simply profit but more importantly asset outcomes that by definition would be sustainable over a period.

Bringing about inclusive growth and well being for the country's population are the agenda of S&T based innovations. Enabling the ignorant with S&T driven skills, offering the potential entrepreneur and self help groups with S&T based innovative product or process solutions, empowering the country's population to shift consumption frontiers to the innovated products and services, and helping sustain regeneration of resources for inter-generational justice are among the few important goals of S&T driven inclusive growth.

Geographies and Balance

A related dimension of justice and accesses to resources, current and future, is shaped by the geographical outcomes. Regions and states in the knowledge-age specialize more intensely, spill over happens with greater ease and opportunities are offered differentially in different areas. Such a movement has been happening through inter-country movements of resources that have different values and across districts, regions and states within the country. Geography based specializations and inter-geography competitive balance through several modes of commerce, therefore become leading determinants of development of S&T.

Globalization of high value resources, such as the highly trained human resources or special skills and products including of finance are currently shaping up the contours of geographic capacities and capabilities. This country has in germinal form several types of inter-geographic consultation mechanisms and instruments for transfer of resources, while the country has in lesser strength similar functionaries to address globalization and inter-country regionalization. On both counts Indian efforts would need strengthening up.

Agencies for S&T and Innovation

An important mode of redistribution has been the profit motives of corporations and their large shareholders. This country faces now the challenge from managerial corporations and finances; and yet much of recent policies suggest that Indian initiatives in S&T and innovation have recognized the importance of redistribution achievable through entrepreneurship and several forms of social networks and groups. Increasing returns grow and vanish with ultra rapidity. Contemporary S&T institutions need to recognize such features.

For long organizations have remained agents undertaking S&T and innovation. Corporate valuation and transfers of resources have remained the most significant drivers of growth. Nevertheless it has been organizations again who as incumbents fiercely resisted innovative changes. Increasing returns based institutions in contrast often depended less on large corporations, while drawing sustenance from nimble small entities and social networks. In recognition Indian S&T and related institutions have initiated steps. Yet much would be demanded in the coming years.

R&D as the Set Aside

An important proof of efforts towards generation of new resources has been the set asides defined as investments in R&D. With continuous lowering of R&D life cycles especially in corporate accounting practices along with opportunistic definitions on what constitutes R&D, a time has arrived where public investment for long term set asides assume greater importance. The closest to such long term investments are achieved in training very highly skilled human resources. In contrast the most liquid investments are made in very short life cycle S&T and skill-development education. Investments in generic high technologies offer rather long term scopes. The preparedness of a country to withstand radical shocks brought about by ultra quick changes in knowledge and skills is an important determinant of technology strength to withstand scorched earth blitzkrieg.

Permeating and widespread capacities to undertake R&D and similarly permeating capacities to educate and undertake S&T would thus prove essential for the future. Investments in S&T and related institutions of education and skill as well as in instruments and in workshops, for the long term would provide the strongest bulwark against vicissitudes of technological changes.

S&T Data

A crucial issue emerges from this investigation. The country very badly needs a strong mechanism to capture data related to S&T and innovation right from the regulatory or executive levels to source-points where S&T output or innovations get generated. Indian economics statistics is enviably good. Borrowing from the success of that economic data system, the country needs to put in place a similar system of data capture, transmission, processing and distribution of S&T data.

The Roadmap

This Report presents several facets of Indian S&T. In lieu of attempting the development of a set of traditionally known indicators of S&T, the attempt here has been to capture multiple facets of Indian economy and society where S&T makes contributions. With unstated theoretical bases, contributors presented research conclusions in the form of several portrayals. Given the fact that S&T interfacing the economy and society has very large dimensions this Report could take up only a handful. Such a collage offers albeit a picture of where Indian S&T is located.

Divided over six broad themes — human resources, finance, structures and infrastructure, industry, output and rural India — the presentation might appear to offer a linear approach to S&T and innovation where inputs processed through a black-box offer the desired output. The complex of Indian S&T, however, is not amenable to such simple linear flows. This Report thus is crisscrossed with mentions of resources of skills, for example, at the putative input stage, black-box system phase as also in output phase. Similarly finance or output appears in multiple locations where output becomes an input or output becomes an indicator of capacity and capability.

For convenience of a reader the Report presents a ready-reckoner on nearly all aspects of Indian S&T. Contributors refrained from highlighting achievements and presented in each case syntheses of previous research on that subject as- is done in a review of the state-of-art, while not loading a contribution at all with academic footprints. This document is targeted at a wide readership ranging from policy makers and advisors to academic readers as well as the common person.

This map of Indian S&T therefore captured facets of human resources, for example, with greater emphases on issues of quality, performance right from high school, access, migration, vocational education or specialized education including the investments the country has been making. Similarly, the subsequent theme took up financing of S&T by multiple agencies especially post-liberalization, in multiple areas including on higher education and specific areas of research, distributive dimensions of financing, the investments in R&D and on S&T, definitional ambiguities, issues of funding related to coordination and governance.

The third theme takes up structures and thus the infrastructure of S&T in the country. Laying great emphasis on hastened investment needed in S&T infrastructure this theme looks into the relation of governance with the structure. It brings out issues of coordination, the complex web of Indian S&T structures, description of sector targeted structures and policy instruments in particular on high technology areas, the S&T parks, the structures of technology transfers, and similar others. The S&T structure diffuses into the public space where science is talked about and with brief exposures the media presence of S&T, and the access to S&T resources have been presented. The next theme on industry and S&T begins with the macro view and then looks into economy-wide and inter-sector aspects of technological changes, and high technology trade. This theme looks further into two dimensions of S&T interfacing with industry: first mode captures the R&D and the second mode presents non-R&D aspects. On R&D including on data capture and definitions this theme presents the impact of policy instruments that are primarily fiscal in nature. The non-R&D dimension asserts that for a developing country the productivity raising aspects of innovation are important and a detailed sector wise map gets presented. Further down this theme are issues of specific sectors, achievements of fund-based technological changes as in textiles, and then other sectors of telecommunication, biotechnology, pharmaceuticals, automobiles, biomedical offer instances of learning's from Indian S&T sector policies.

The fifth theme is about tangible outputs from the S&T system. Detailed analyses offers pictures of publications and patents, the two most central forms of outputs, and offer glimpses into regional achievements, agency wise evaluations, inter-country comparisons and research collaborations, and sectors where the country has been performing. The patent picture similarly offers a look into post-liberalization activities, and dips into sectors such as biotechnology or information and communication technologies; and finally glosses on the capability of this country to appropriate its knowledge assets. The last theme is related to S&T for rural areas. Contributors consciously refrained from delving into S&T for farming. The focus is on non-farm areas and particularly on manufacturing generative as well as agriculture-integrative areas where S&T can quickly but sustainably, offer scopes for income and employment generation, asset generation and resources regeneration. Beginning with mapping out rural off-farm potentials this theme looks into aspects of low cost housing, farm implements and hand tools, fisheries, mushroom, horticulture, tiny scale manufacturing, biopesticides, sericulture, and similar others. Brief discussion on public programs and schemes and policy mechanisms offer a look into the preparedness of the country to bring into the developmental fold most of its poor people.

Endnote

This printed version is about one fourth of the full Report, available at *http://www.nistads.res.in/*; and this is the first of its kind from this country. An earlier attempt was made by the INSA and was undertaken at the NCAER. The present Report is the first in this series. There are plans to bring out similar reports regularly at two year intervals in future.

S&T Human Resources

Overview

The role of S&T human resources in innovation and in the economic growth of a country cannot be disputed. Skilled and educated, innovative and creative people remain the most important engine of growth. This assumes greater importance for India, with the world's largest number of young to be educated and where knowledge-economy is being considered fundamental to the path of progress or the key to economic growth. S&T manpower includes artisans, technicians and technologists, researchers, educators, and managers. In addition, many others use their skills in a variety of nominally non-S&T occupations (such as writers, salesmen, financial managers, and legal consultants), and many niches in the human resource market require them to interpret and use the S&T knowledge. Two dimensions of human resources remain crucial: quantity and quality. Most importantly, what policies and institutions could induct ever larger numbers of people into the fold of S&T happens to be the cardinal issue.

A very large number of potentially school-going children, demands near astronomical expansion of educational capacity right from pre-school level to doctorate level. At present the proportion of school-goers finally finishing higher education and in particular doctorates is astonishingly small. Capacity creation remains therefore the key policy imperative. With only a very large number of educated persons this country can take to the path of knowledge based growth. This implies that the quality of education must remain at least modestly high and also contemporary. A moot question would then be what mode of accretion of capacity engenders quality; could these two dimensions be woven together! Further, the advanced society of the future would require advanced and contemporary knowledge. Mere addition to the stock might not meet the expectations of the future unless quality is hastened and contemporaneity gets ensured. Given the fact of longer expected lifespan, the country's policies on education must also look into the dynamic capability of social and production systems to keep a person engaged meaningfully for no less than five decades. Our current policies take care of only the first two and a half decades of the life of a person.

There is a shortage of S&T staff, in India. There is also a decline in the number of students opting for science as career at higher secondary schooling, college and higher education levels. Shortage has multiple dimensions: gap in quantity that is serious; gap between demand and supply of skill types; gaps in quality; gaps existing in continuous learning including on-the-job; gaps in social institutions that can monitor and redirect schooling at all levels; and of course gaps created through outflow or cross-sector flows of the skilled and educated.

This *theme* starts with a description of the Indian state-of-affairs, underpinning generation of human resources, through the enrolment pattern at different educational levels. This reflects upon the structural and institutional capacity. The subsequent discussion on vocational education looks at the structure of vocational studies in India, the premier institutes imparting training and new initiatives in the 11th Five year plan. Thereafter the description is on educational infrastructure, highlighting the distribution across states. Then students' performance in sciences at secondary/higher secondary levels is analyzed. Private investment in the education sector in the post 90's has resulted in a number of private educational institutions; however, the quality of education might not have improved. The following parts look into interstate (secondary level) and international migration of students respectively. The next discussion looks into measures to promote basic science. It analyses the functioning of some schemes implemented by the government to promote basic science. Subsequently, higher education and research training in S&T areas has been captured through data on the production of doctorates. Subsequently an overview of generation of medical manpower in India and then on gender dimensions, in recognition of the role gender plays in shaping scientific careers in India, have been discussed.

The full text of these extended summaries is available at *http://www.nistads.res.in*

Here the status of enrolment at various levels of education in India is presented. The information and data is gathered from different sources. Figure 1-01.01 indicates that 44% of children (5-14 yrs) are unable to reach up to the school level education. Till the middle (standard 8th) level the drop out becomes 78% of the total population. The situation becomes more critical at UG and PG levels with 92% and 97.5% dropout, respectively. At PhD level the total strength is a meager 0.02% of the total population.

Enrolment Trends at Different Levels

At primary level, enrolment of male and female students as a percentage of total enrolment is depicted in Fig 1-01.02. It is clear that the enrolment was around 76% in 1991 and stands at 81% in 2007, which means

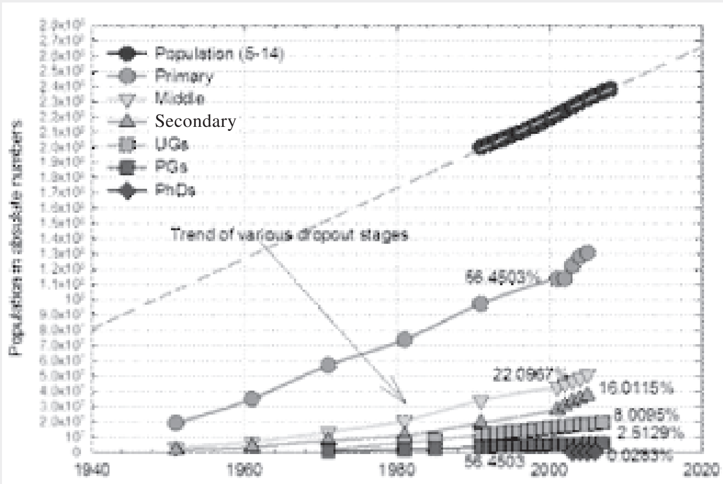


Fig 1-01.01: Stages of Education w.r.t the Population between 5-14 years (% for one year)

Source: *Computed from various sources, MHRD, UGC, Datamonitor, OECD database*

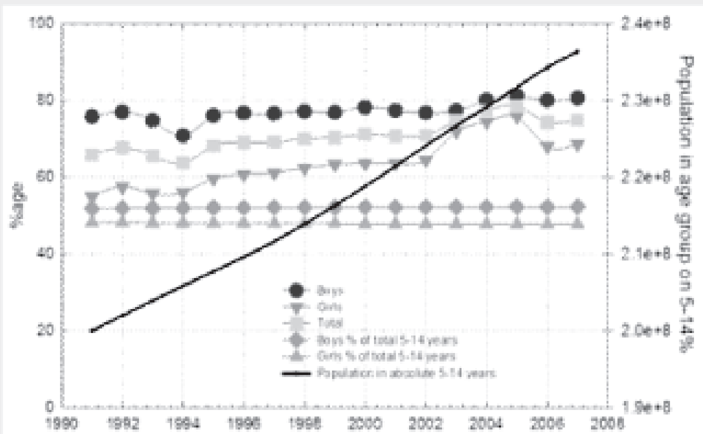


Fig 1-01.02: Break-up of Enrolment at Primary Level

Source: *IAMR, Yearbook-2008, HRD Report 2005, UGC Report 2006* a very small annual growth rate of 0.36%. In case of female students, the rise is more than for male students, as it was 66% in 1991 and touched almost 75% in 2007 with a growth rate of 1.32%. At secondary and higher secondary levels, the gross enrolment for males was nearly 12% in 1991 and rose to 19% in 2007, with an annual growth rate of 2.6%. For females, though in 1991 it was only 6.53%, but it increased substantially to 15.6% in 2007, with a growth rate of 5.25%. The overall growth rate for secondary remained at 3.6%. However, growth of male and female students as percentage of total enrolment is nearly static (Fig 1-01.03).

At UG level the enrolment was 5.6% in 1991 and it increased to 8.3% in 2007, with an annual growth rate of 2.34%. At PG level the enrolment was about 1.71% in 1991 which increased marginally in 2007 (2.6%).

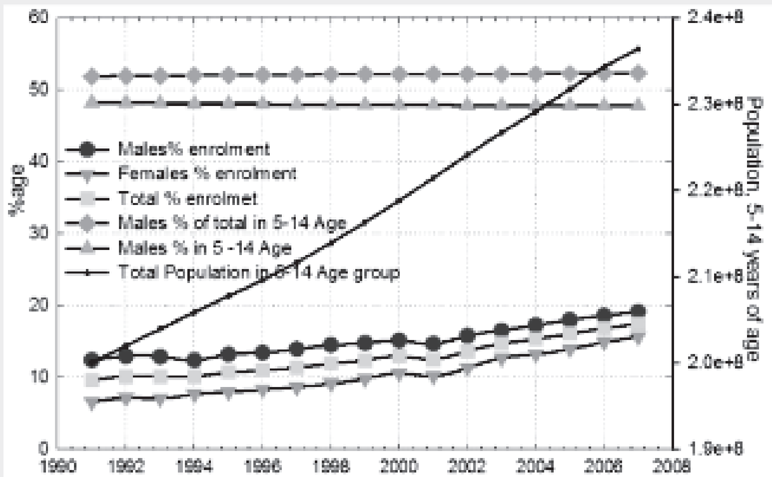


Fig 1-01.03: Break-up of Enrolment at Secondary Level in India

Source: *IAMR, Yearbook-2008, HRD Report 2005, UGC Report 2006*

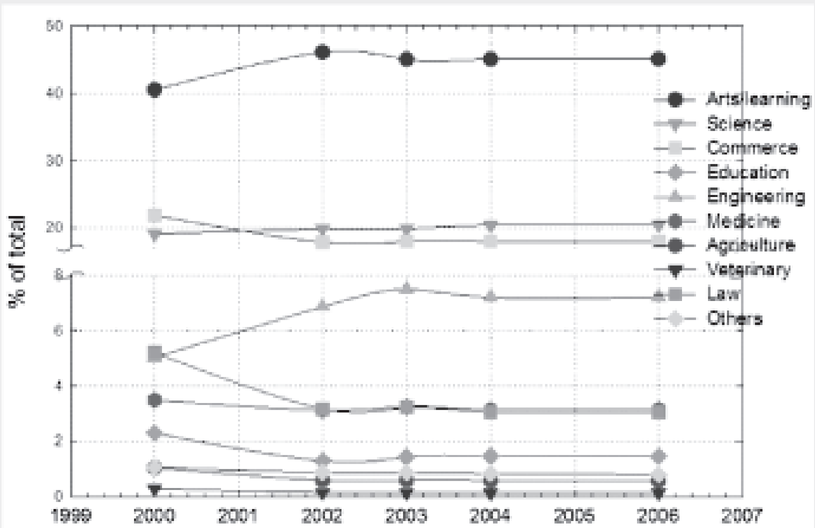


Fig 1-01.04: Break-up of Enrolment in Higher Education

Source: *Computed from UGC Yearbooks, 2001 to 2006*

Discipline wise break-up of enrolment in higher education as percentage of total enrolment is given in Figure 1-01.04. It is optimistic that science is still the second choice of the students after humanities. It is interesting to note that engineering is growing rapidly while law has declined over the years. Veterinary science is the least preferred discipline for higher-level education. The status of overall doctorate students was very low, as only 0.0186% students enrolled for Ph.D. in 2003 and 0.0339% in 2006, as percentages of total school going population. Moreover, Ph.Ds produced in natural sciences are declining while Ph.D. in agriculture discipline depicted a sharp growth after the year 2000. Ph.D. production in engineering is almost static, while it is the lowest in medicine.

The key observations from Fig 1-1.05 to Fig 1-1.08 are as follows:

B.Sc.: Almost 78% of the students fail after entering B.Sc. levels in science. Therefore 22% is the passing out population, which is eligible to go to next level of education; i.e. M.Sc. level.

M.Sc.: The second set of trend shows only 15% of UG entrants get admission into M.Sc. courses; which means 7% do not enroll. This may be attributed to the fact that most of B.Sc. pass outs eventually join the workforce thus never entering into M.Sc. level. Second trend (green hatchet line) shows the passing out population at M.Sc. level. It is approximately 5% of the total enrolment at M.Sc. level. Out of this 2.8 % are males and 2.15 % are females. This corresponds to 10% failure or dropouts at M.Sc. level.

Ph.D.: Approximately 4.0% of total at B.Sc. level get into Ph.D. level, which corresponds to a very high success rate from M.Sc. pass outs becoming Ph.D. aspirants. It also shows that 2.45 % corresponds to males and 1.54 % corresponds to females. Further, Uttar Pradesh and Maharashtra are the leading states in producing doctorates while Tripura and Sikkim are least productive. In basic sciences Osmania University, University of Calcutta and Aligarh Muslim University are the leading universities. Similarly, IIT Madras, IIT Delhi and IIT Bombay are three leading IITs, which produce maximum number of Ph.Ds.

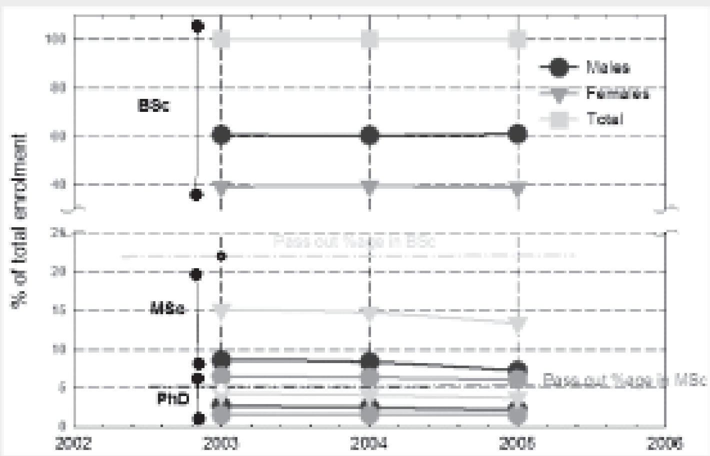


Fig 1-01.05: Percentage of Enrolment at BSc/MSc/PhD Levels

Source: *Computed from MHRD Reports, UGC reports and Edustat Data*

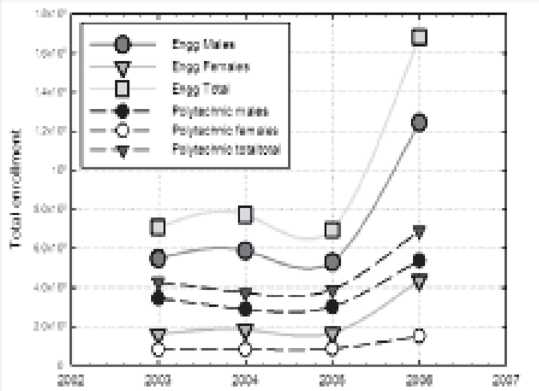


Fig 1-01.06: Enrolment at Graduate Level in Engineering Degree and Polytechnics

Source: *Edustat and MHRD 2004 –2005*

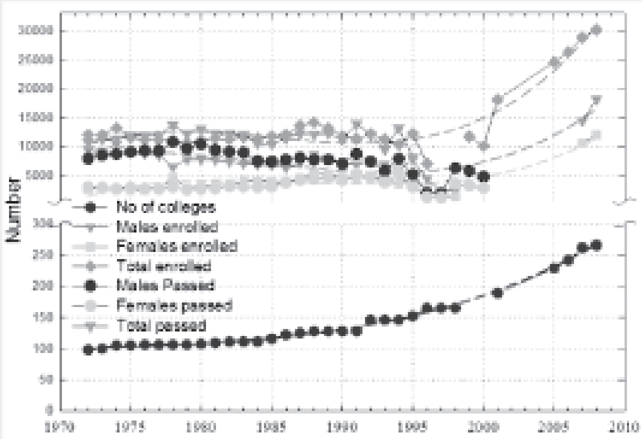


Fig 1-01.07: Break-up of Enrolment in Medical Sciences

Source: *Indiaeducationstat database*

Pattern of Enrolment in Professional Courses

Enrolment in engineering at diploma level as well as at degree level has increased very fast after the year 2005. It is also observed that female enrolment is constantly increasing at degree level, contrary to diploma level. Break-up data shows that Automobile engineering remained at the top with the highest Diploma to Degree ratio, though it has shown sharp decline after the year 1991. Metallurgical engineering remained the second most sought after branch after automobile engineering, with an increasing ratio. This shows that material science may be one of the emerging branches in the coming years. Textiles engineering remained

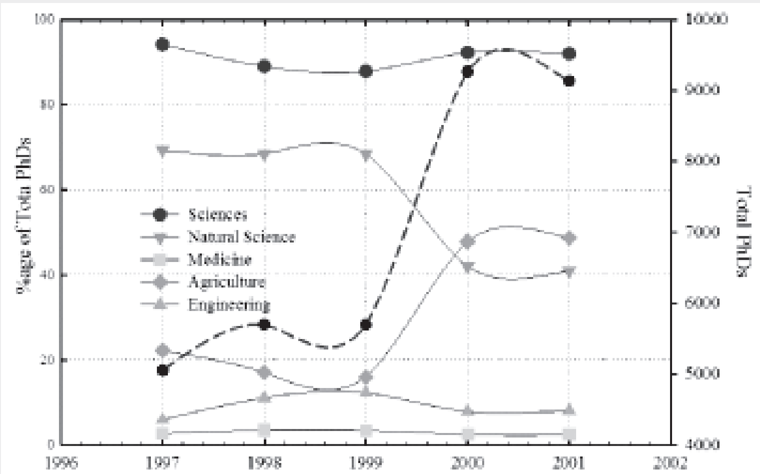


Fig 1-01.08: Break-up of PhD in Science and Engineering

Source: *Indiastat database*

at third position followed by Civil, Electrical and Mechanical engineering. Statistically, Andhra Pradesh and Tamil Nadu are top two states producing maximum number of engineers in the country followed by Maharashtra, Karnataka and Uttar Pradesh. In the Northeast, Sikkim is the least engineers producing state. In medical education Karnataka and Maharashtra are the leading states in the country, whereas Arunachal Pradesh is at the bottom. Total enrolment in medical education increased after 1990, which may be due to the entry of private players in higher education. It is also interesting to note that most of the students pass their examination in medical stream.

Vocational Education in India

Vocational education enables gaining skills and experiences directly linked to a career in future. Distributed over several tiers, vocational education gets offered at school or for drop-outs, and at post-schooling, and sometimes on-the-job. Both public and private provisioning prevails in the country. After finishing the course, students are often offered placements in jobs. Vocational trainings in a way give students some work related experiences that many employers look for. Two major gaps could be noticed: quality and mismatch. Because of poor quality or mismatch with market demands certain skill sets trained at vocational centers suffer from poor placement. According to a National Sample Survey Organization (NSSO) report (No. 517, 61st round, 2003) two types of vocational trainings are available in India: a) Formal and; b) Non-formal. Formal vocational training follows a structured training programme and leads to certificates, diplomas or degrees, recognized by State/Central Governments, Public Sector and other reputed concerns. Non-formal vocational training helps in acquiring some marketable expertise, which enables a person to carry out her/his (often ancestral) trade or occupation. In a way through such non-formal vocational training a person receives vocational training through ‘hereditary’ sources. Often ‘Non-formal’ vocational trainings are also received through ‘other sources’. In such cases trainings are received by a person to pursue a vocation which is not ancestral and is different from the trade or occupation of his/her ancestors. Data and graphs used here are all indicative and not exhaustive.

Vocational Training in India is imparted mainly by two types of bodies: Public Industrial Training Institutes (ITIs) and privately owned Industrial Training Centers (ITCs).

The main training schemes are the Craftsmen Training Scheme (CTS) and Apprenticeship Training Scheme (ATS). In addition some other training schemes are also provided by DGE&T. There are about 5,114 Industrial Training Institutes (ITIs) imparting training in 57 engineering and 50 non-engineering trades (Planning Commission). Of these, 1,896 are State Government-run ITIs while 3,218 are private. The total seating capacity in these ITIs is 7.42 lakh (4 lakh in government ITIs and 3.42 lakh in private). Figures 1-02.01 to 03 represent the detailed information on the number and capacity of ITIs/ITCs. A number of vocational training

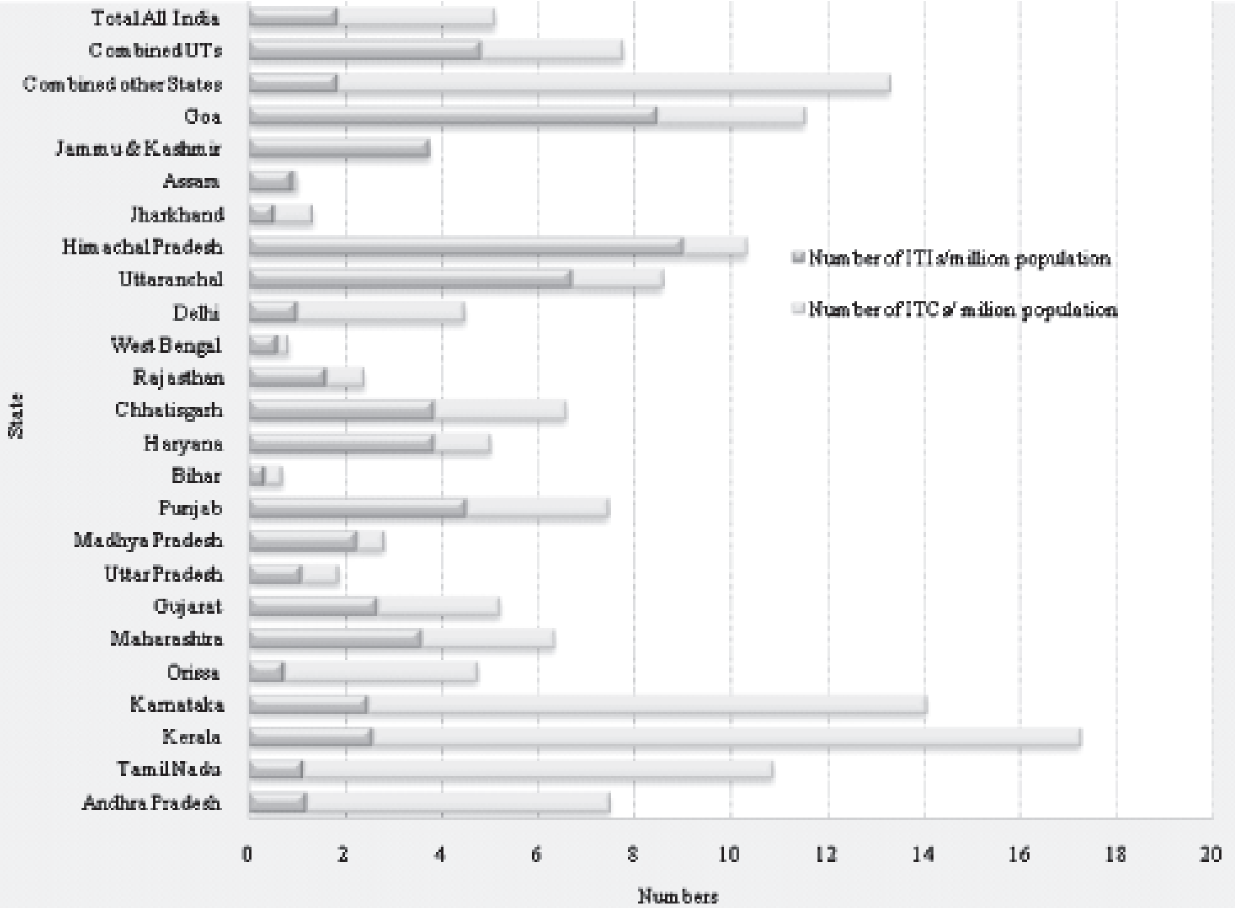


Fig 1-02.01: Number of ITIs and ITCs available per million Persons in different States in India *Source: World Bank*

institutes are being run by private training providers. The formal training system of India starts at Grade 8 and above. According to ILO, the DGE&T's skills development competes with other formal and non-formal programmes, such as higher vocational schools (10 plus 2 stream), colleges, polytechnics, etc. The share of ITI-based training seems to capture around 10-12 per cent of the total number of school graduates at Grade10.

Other Premier Organizations Providing Vocational Training (Govt. and Non-Govt.)

- Khadi and Village Industries Commission (KVIC) which provides EDP and Khadi Village Industries training
- Tool Room & Training Centres (DC, MSME)
- Provisions through the National Manufacturing Competitive Council (NMCC)
- CAPART (Council for Advancement of People's Action and Rural Technology)
- SRI, Ranchi (Society for Rural Industrialization)
- Ramakrishna Math and Ramakrishna Mission centres and many more.

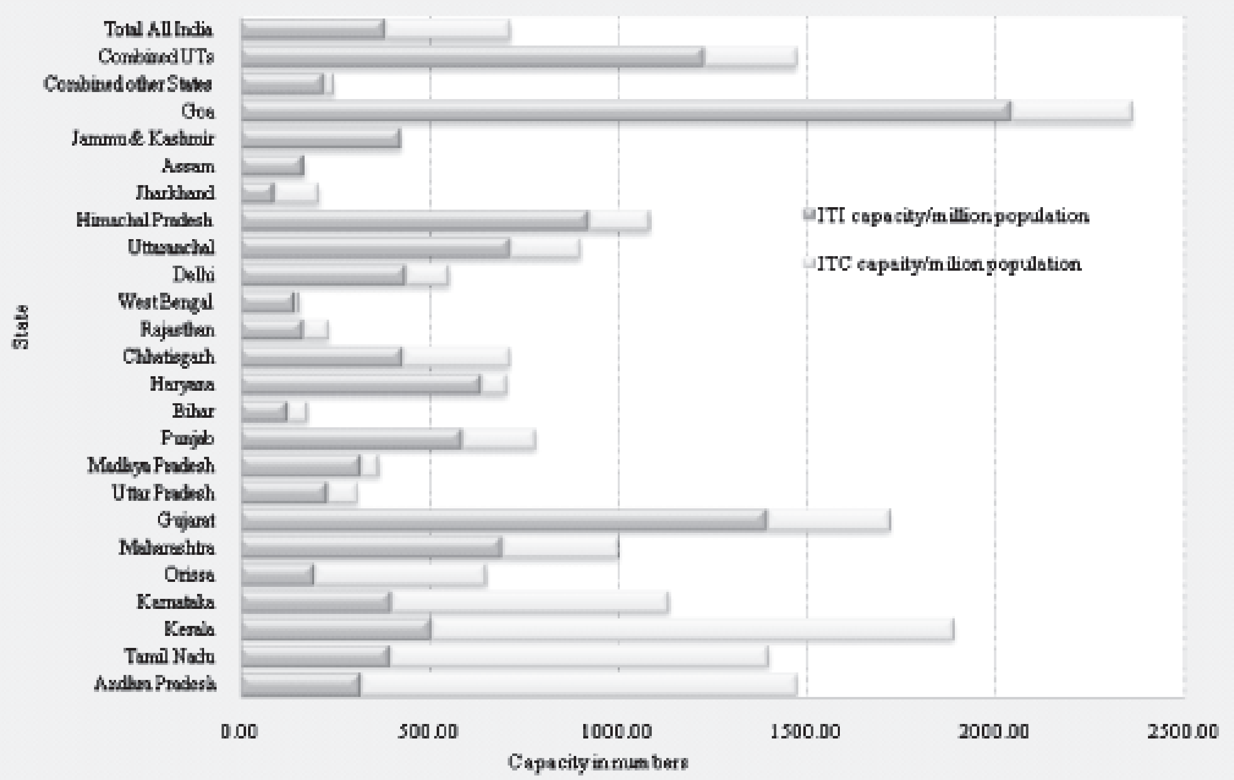


Fig 1-02.02: Intake Capacity of ITIs and ITCs per million Persons in different States in India
Source: *World Bank*

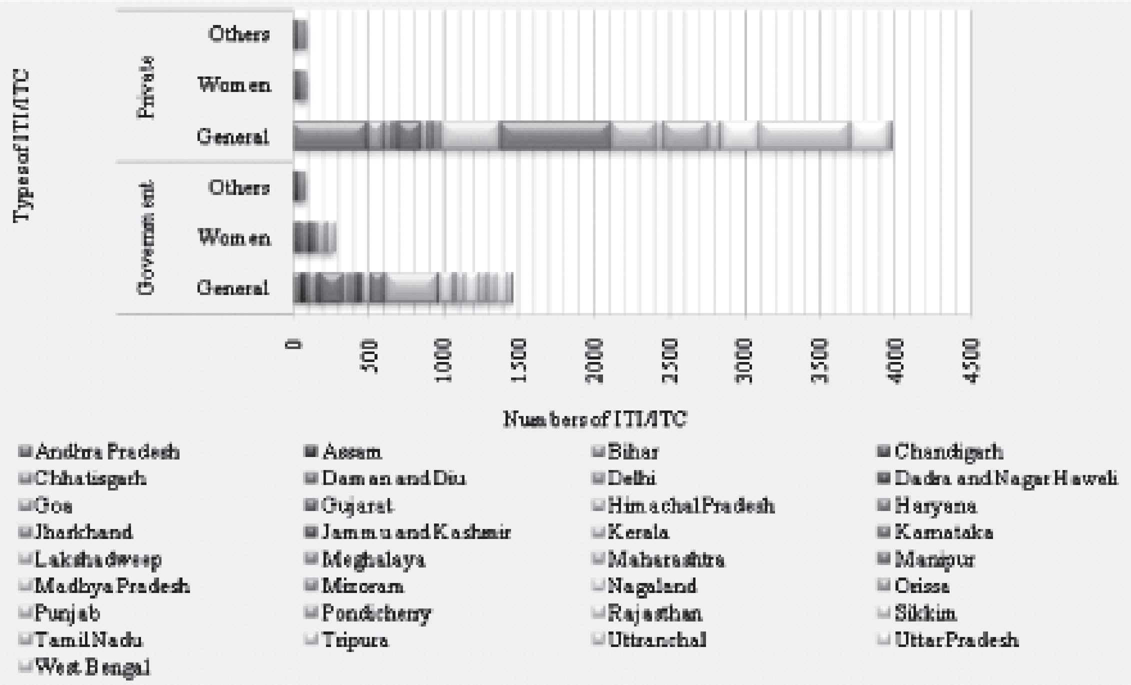


Fig 1-02.03: ITIs/ITCs under Government and Private Bodies, in Main States of India

Source: *Ministry of labour DGE&T*

From these figures it may be concluded that Tamil Nadu holds the majority stake in private owned vocational institutes and Maharashtra for Government owned vocational institutes.

Communities Trained by KVIC and its Major Activities

Rural Employment Generation Programme (REGP) is the flagship programme of KVIC. The main objective of this programme is to generate employment in rural areas by setting up of new village industries (except negative list) availing loan from the banks and margin money (middle end subsidy) from KVIC. Prime Minister's Employment Generation Programme (PMEGP) is a central sector scheme to be administered by the Ministry of Micro, Small and Medium Enterprises (MoMSME). The implemented body will be Khadi and Village Industries Commission (KVIC), a statutory organization under the administrative control of the Ministry of MSME as the single nodal agency at the National level. At the State level, the Scheme will be implemented through State KVIC Directorates, State Khadi and Village Industries Boards (KVIBs) and District Industries Centres (DICs) and banks. The Government subsidy under the Scheme is channelized through KVIC with the help of identified Banks for eventual distribution to the beneficiaries/entrepreneurs in their Bank accounts. The implementing agencies are KVIC, KVIBs and DICs will associate reputed Non Government Organization (NGOs)/reputed autonomous institutions/Self Help Groups (SHGs)/National Small Industries Corporation (NSIC)/Udyami Mitras empanelled under Rajiv Gandhi Udyami Mitra Yojana (RGUMY), Panchayati Raj institutions and other relevant bodies in the implementation of the scheme. Here training formally or informally plays a crucial role for success of the schemes.

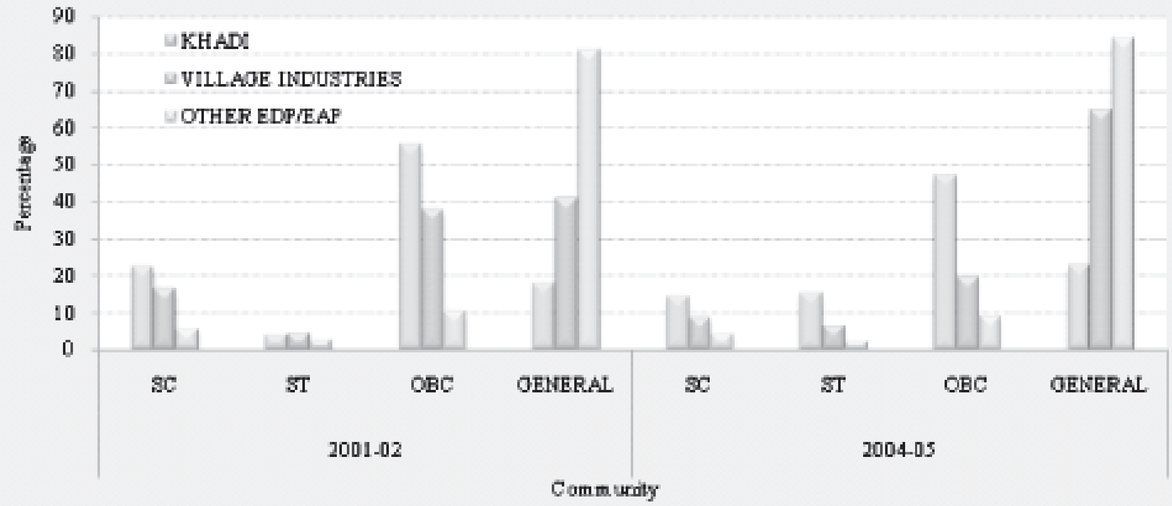


Fig1-02.04: Percentage of different Social Group Trained by KVIC in the Year 2001-02 and 2004-05

***Source:** India Year Book 2008*

School – A Part of Vocational Education – A Brief Statistics

*Other than ITI/ITC several Government and private bodies are equally important for the vocational training system in India. They are the following: S*chools also provide vocational training formally at 10 and 12th level. The following figure shows the percentage of the stake of all major states, provide vocational training in India.

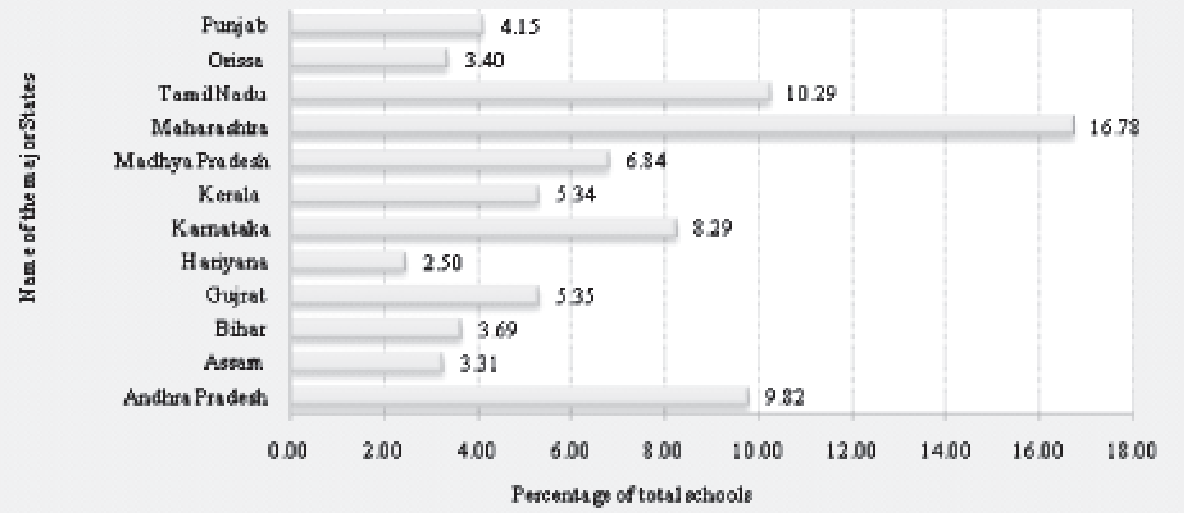


Fig 1-02.05: Percentage share of the schools imparting vocational training for some major states

Source: *MHRD, Annual Report 2002-03, India Year Book 2008, Manpower profile*

It is observed that the above states like Maharashtra, Punjab, Orissa Tamil Nadu etc. are holding most of the stake in number of schools which imparts vocational training. Schools have an important role on vocational studies because one can start it from his/her schools days. More coverage in school with proper infrastructure can create a large technical group in future which is now lagging behind.

Paramedical Practitioner Status in Rural India

From Fig 1-02.06 it is clear that out of 3,15,746 paramedical workers in rural India, 47% are female health workers. But extension workers are hardly 1%. We also need to focus on the availability of Radiographers,

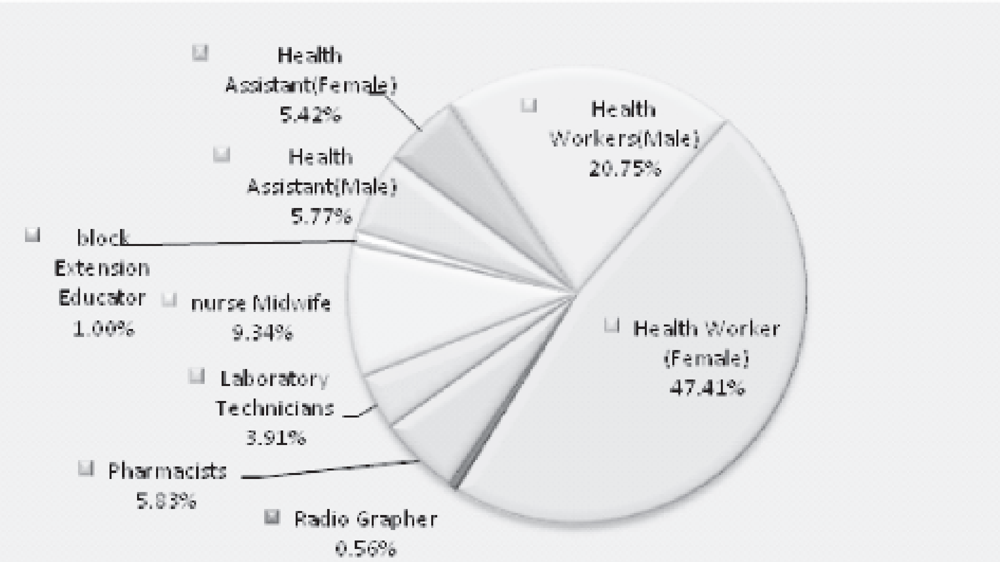


Fig 1-02.06: Trained paramedical practitioners available in rural India

Source: *MHRD, Annual Report 2002-03, India Year Book 2008, Manpower profile*

Pharmacists and Laboratory Technicians for rural India. To disseminate knowledge of basic health facilities we need to train more paramedical workers for rural India.

Major Initiatives taken in 11th Five Year Plan

The Eleventh Plan has taken the initiative to launch a National Skill Development Mission that may bring some changes in 'Skill Development' programmes. The Mission will be operative under Prime Minister's National Council on Skill Development (under the Chairmanship of Prime Minister) for apex level policy directions, a *National Skill Development Coordination Board*, and a *National Skill Development Corporation/Trust* involving many separate and service sectors. The State governments will emphasize their Departments/Agencies into a State Skill Development Mission. The chosen private sector (mainly the twenty high growth sectors) will be an important part as the private arm of the Mission with an outlay of Rs 22800 crores.

The National Skill Development Corporation will be constituted as Government Equity with a view to obtaining about Rs 15000 crore, the public and private sector, and bilateral and multilateral sources for the promotion of skill development and act as a non-profit company under the Companies Act with appropriate governance structure (board of directors being drawn from the outstanding professionals/experts).

The National Commission for Enterprises in the Unorganized Sector (NCEUS): It has been set up as an advisory body for the informal sector to bring about improvement in the productivity of these enterprises for generation of large scale employment opportunities on a sustainable basis, particularly in the rural areas. (details available at: http://nceus.gov.in).

Public Private Partnership (PPP): Major emphasis was given on the PPP mode in the Eleventh Five Year Plan. It focuses on the following:

- Private Investment in Skill Training.
- National framework for domain specific standards and common principles.
- National database for location wise availability (and shortage) of skilled personnel will be established.
- The system should provide the options of multiple entry and exit points and total mobility between vocational, general and technical streams.
- Special emphasis on economically weaker sections.
- To overcome regional disparities due to diverse socio-economic factors, VGF approach would be adopted to address regional imbalances through PPP.

Key Issues

- The structure of the job market is changing. Training courses lack focus at on-the job market. As a result, and as various reports suggest, the number of students is declining for long term vocational courses,

- The job creation should be done regionally, not centrally, otherwise it creates regional imbalance of trained manpower.
- Funding for the public ITIs in India is very low, whereas other countries like China, USA have a special fund for this purpose and part of fund can take care of restructuring vocational training systems in order to achieve international quality. In the 11th five year plan National Skill Development Mission has been introduced, which is a welcome development.
- ITI's must focus on low-literate youth and unorganised sector.
- Accountability and training supply management are also major problems for ITI's, which need to be tackled head on.
- Policy focus on the paramedical vocational studies might be important, particularly for rural areas.
- A central vocational training standardization system, accredited nationally and globally, for maintaining the quality of the vocational education would be beneficial.
- Bridge organizations linking R&D institutes with the vocational education system might help the vocational trainers and trainees to remain contemporary and act as grass root entrepreneurs.
- Vocational courses need to be made part of the school curriculum.

Educational Infrastructure in India

Education is a principal input to economic growth and investment in educational infrastructure remains a critical indicator of expansion and improvement in quality of education. India has a large school going population, therefore a strong educational infrastructure is required in order to accommodate the entire school going population, and also to keep pace with the developing economy and provide it with quality manpower. A related issue is about the institution of education and development of skill, which together constitute the institution for an economy based on increasing return, immense connectivity and mobility. Infrastructure is indicative of both physical organization and the institution.

Today Indian education requires more investment. This can lead to good quality infrastructure and education. In 1961-62, public expenditure in educational sector was 1.52% of the GDP, which increased to 3.68% by 2004-05 (Fig 1-03.01). At elementary level the expenditure was 1.78% of GDP in 1990-91, which marginally

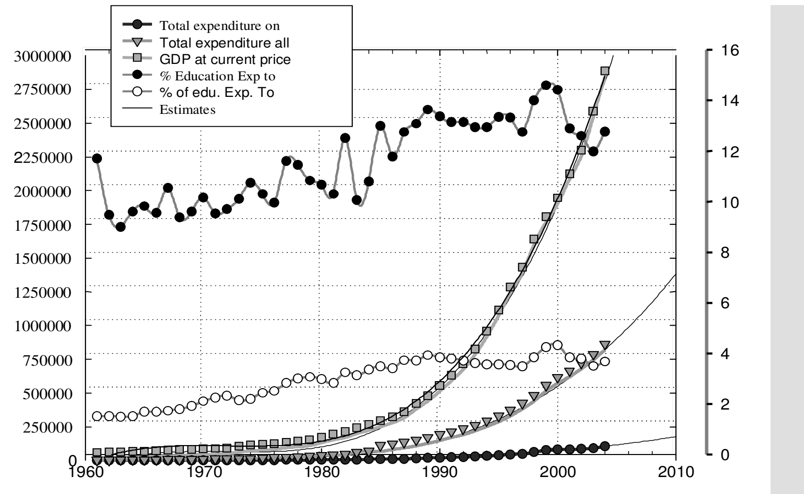


Fig 1-03.01: Break-up of total expenditure

***Source**: Author*

went up to 1.89% in 2004-05. Fluctuating trends were observed for secondary and higher secondary level education. The expenditure on secondary/higher secondary level education was in the range 1.13 to 1.11% of GDP during 1997-1998 to 2004-05. The expenditure on higher education, as percentage of GDP was 0.77% in 1990-91, which decreased to 0.62% in 1997-98 and then rose slightly to 0.66% in 2004-05. Similarly, when compared to other sectors, the share of expenditure on elementary education to total expenditure on all sectors was 6.19% in 2004-05, while on higher secondary education it was 3.85% for the same period. Maharashtra and Uttar Pradesh are at top in enrollment, whereas A&N is at the bottom. Also pupil teacher's ratio (PTR) is very low in India as compared to developed nations, which needs to be improved. PTR is pathetically poor at primary level and upper primary levels, figuring 46 and 34 respectively. However, it is comparatively comfortable for higher institutes (PTR-25).

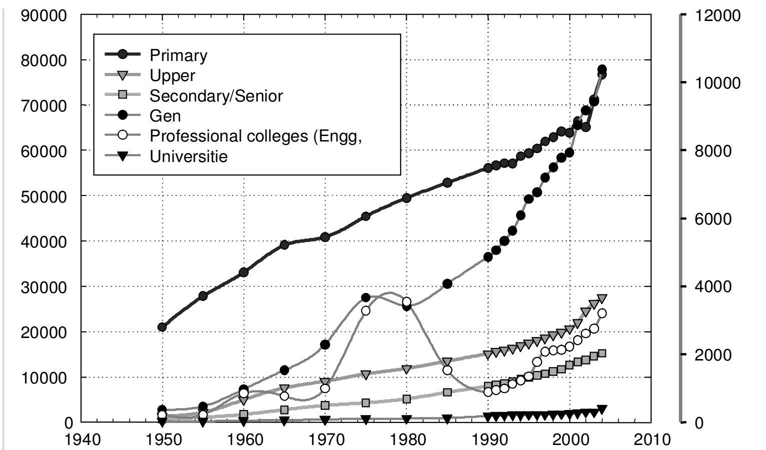


Fig1-03.02: Growth of recognized educational institution from 1950 to 2004

***Source:** Selected Education Statistics, MHRD*

Since enrolment at all educational levels is increasing, so to accommodate increasing students more educational institutes are indispensably required. Both public and private agencies manage educational institutes; however, government agencies manage more institutions than private agencies. Government and local bodies organize more than 90% primary schools, whereas private agencies owned a small fraction of total schools and their contribution was about 9.79% in 2004-05. In the case of Secondary/ Senior Secondary levels the growth of institutes under different management bodies has also increased continuously. Since 1973-74, percentage of government Secondary/Senior Secondary schools has increased from 26.5% to 33.1% in 2004-05. It is apparent from the Figure 1-03.02 that number of institutes increased very fast after 1990-91. It may be due to the new economic and education policy, which allows private partners in the educational field. According to the Department of Higher Education during the period 1950-51 and 2004-05 the number of Primary Schools increased by 3.66 times, while the Upper Primary Schools and Secondary/Hr. Schools increased by more than 2.0 times each. The major growth took place in general education and professional education, which is around 28 and 15 times respectively. Similarly, universities have also registered significant growth after private investment was permitted. It is important to note that since 2001-02, number of Universities/ Deemed Universities has increased more rapidly as compared to other educational institutions. During this period, Primary Schools increased by 1.2 times, Upper Primary Schools by 1.3 times, and Secondary/Senior Secondary Schools by 1.1 times. Consequently, in higher education, colleges for general education increased by 1.3 times, while Universities increased by 1.5 times. For higher education there were 407 universities including deemed universities and institutes of national importance.

Performance in Sciences at Secondary/ Higher Secondary Level

Post 90's witnessed a structural change in education. Private investment was allowed in the educational sector. Consequently, a number of private educational institutions were established which increased the out turn of students, although quality of education, some skeptics aver, has been declining. This may loosen up competitiveness in education, particularly in science education which may in turn be disadvantageous for Indian science and technology (S&T). To compete globally, quality and better performance in science education is imperative. Therefore, a brief picture of performance in basic sciences viz. physics, chemistry, mathematics and biology at the 10 years and 12 years schooling levels is presented in this section. Due to constraint of adequate statistics, the review is confined to Central Board of Secondary Education (CBSE) and some state boards.

Performance in CBSE (2007)

After independence, an economic development model was set up with the emphasis on science and technology. Consequently in schools, science education received special attention in order to generate science professionals and thereby better scientists in the country. However, studies show that over the last decade priority for

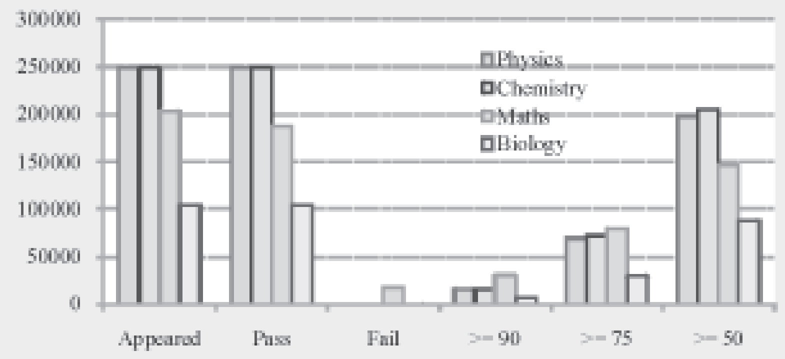


Fig 1-04.01: Performance of Science in 12th Standard

Source: *Central Board of Secondary Education, 2007*

science is declining both at school and university levels whereas enrolment in other disciplines is increasing. It is a matter of concern and if the trend continues for a long time consequences may be adverse. So, policies should encourage students to opt science at secondary level. School education is the foundation of creativity and skill development; therefore, this section deals with the performance of science students at secondary level of the Indian education system. The information is gathered from CBSE. Fig 1-04.01 shows the performance of those securing greater than 90% marks, greater than 75% marks and greater than 50% in CBSE examination. Computation indicates that Physics and Chemistry are the most preferred subjects followed by Mathematics and Biology in the science stream at 12th level, however, number of students clearing these streams are more than from streams with Physics and Chemistry. In addition, more students score above 90% and 75% score in mathematics and number of students scoring more than 50% marks was more in Chemistry followed by Physics and Mathematics.

Fig 1-04.02 represents comparative performance between science and non-science disciplines. It shows that a larger fraction of science students score more than 90% among overall pass out students. Same trend can be noticed for number of students scoring more than 75% and 50% marks. In all three categories (90%, 75% and 50%) male students dominate over female students. It is interesting to observe that in the case of non-science stream the scenario is reversed where female students dominant over male students in all three categories (90%, 75% and 50%). It was found that in CBSE board, science students prefer combination of physical education, followed by computer science and painting at 12th standard level. It was estimated that nearly 47% students opted physical education followed by computer science (24%) in the year 2007. Accountancy is the least preferred subject among science students. Data indicates that more students opt for science subjects than non-science subjects though percentage of passing out students in science subjects is less than for non-science subjects.

Also, in CBSE board it was observed that intercity performance was identical at 12th standard. However, students from Ahmedabad, Chennai, Jaipur and Kolkata and Bhopal are performing better in mathematics, whereas in physics and chemistry performance is more or less same in all cities. Conversely, students from Agra, Hyderabad, Vizag and small towns are performing better in Biology.

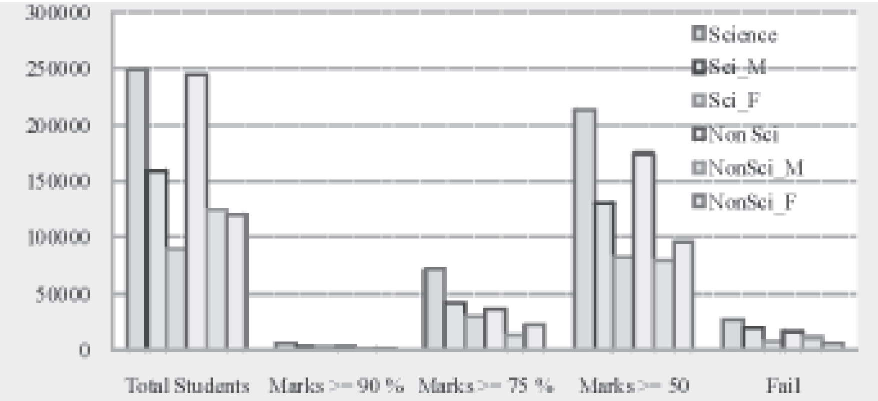


Fig 1-04.02: Performance of Science vs. Non-Science 12[th] Std.

Source: *Central Board of Secondary Education, 2007*

Performance in State Boards (2007)

Based on the information gathered from 8 states namely UP, Punjab, Bihar, Manipur, MP, Maharashtra, Tamil Nadu and Goa for secondary and higher secondary state boards following inferences regarding performance in physics, chemistry, mathematics and biology (PCMB) may be drawn (Fig 1-04.03 to 1-04.06):

- Share of students appearing in PCMB has declined over the years in UP, Goa and Manipur; the declining rate is highest in Bihar, whereas in Manipur, Tamil Nadu, Punjab and MP there is no much change.

- Percentage of students appearing in PCMB in UP, Bihar and MP is about 40% whereas in Punjab and Goa about 20% students appeared in science stream.

- In Tamil Nadu and Manipur, more than 60% students appeared in PCMB in the year 2007.

- Passing and scoring 50% marks is relatively constant except Bihar showing continuous declining trends while in Manipur it is increasing.

Further, performance in mathematics subject in UP, Bihar, Manipur, Maharashtra, and Tamil Nadu is declining. It is obvious from the figure that approximately 20% students appeared in UP, Bihar, MP and Maharashtra whereas less than 20% students opted mathematics in Goa and Punjab. Further, passing out condition is pathetic in all the 8 states except Tamil Nadu where about 20% students got pass marks while in UP the situation is worse. The performance in physics, chemistry and biology is similar to mathematics. This is a matter of great concern as it is surely to affect India's S&T capabilities in future. Therefore, appropriate measures are required to switch the problem.

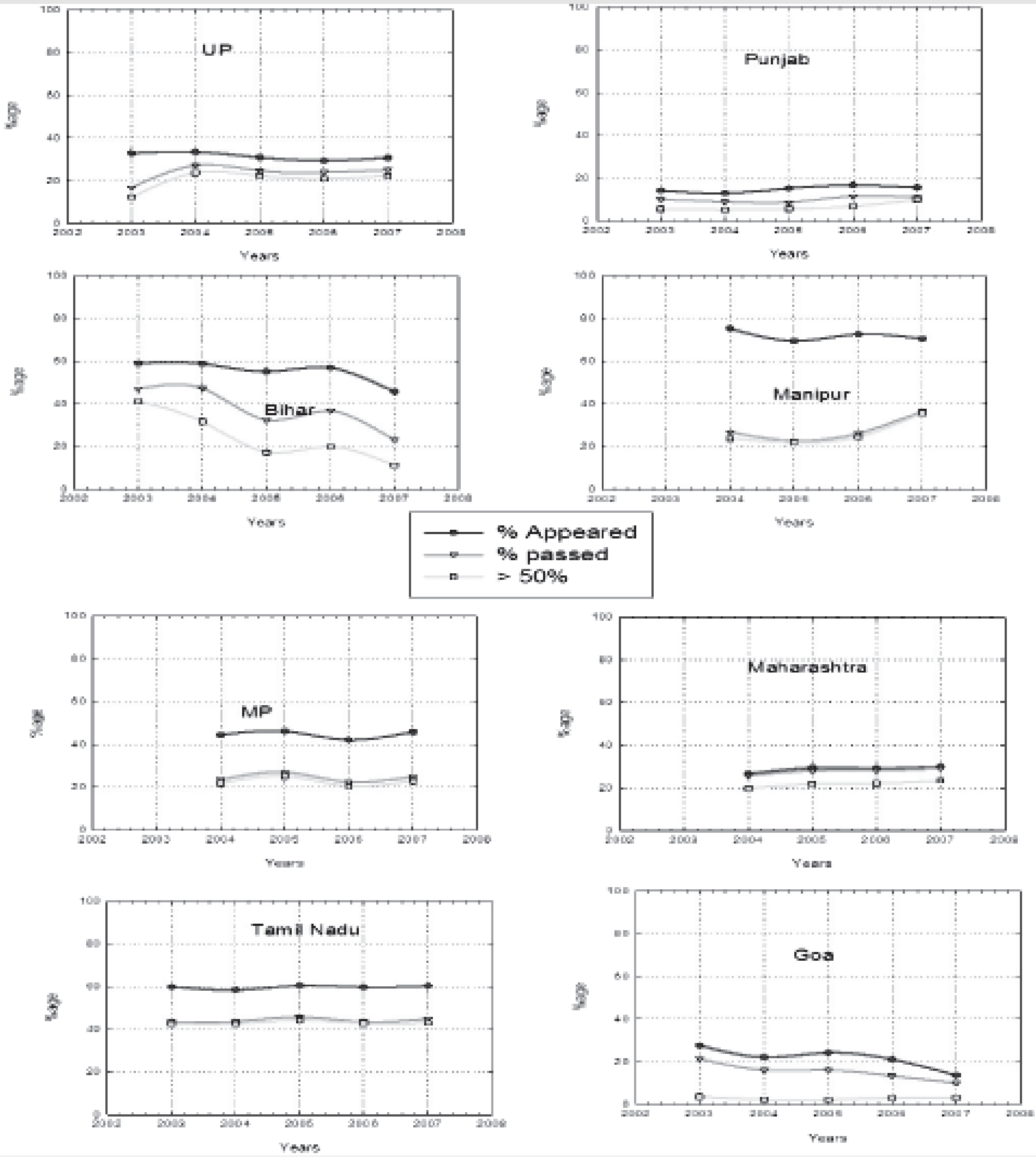


Fig 1-04.03: Performance in PCMB at 12[th] Std

Source: *Respective State Boards*

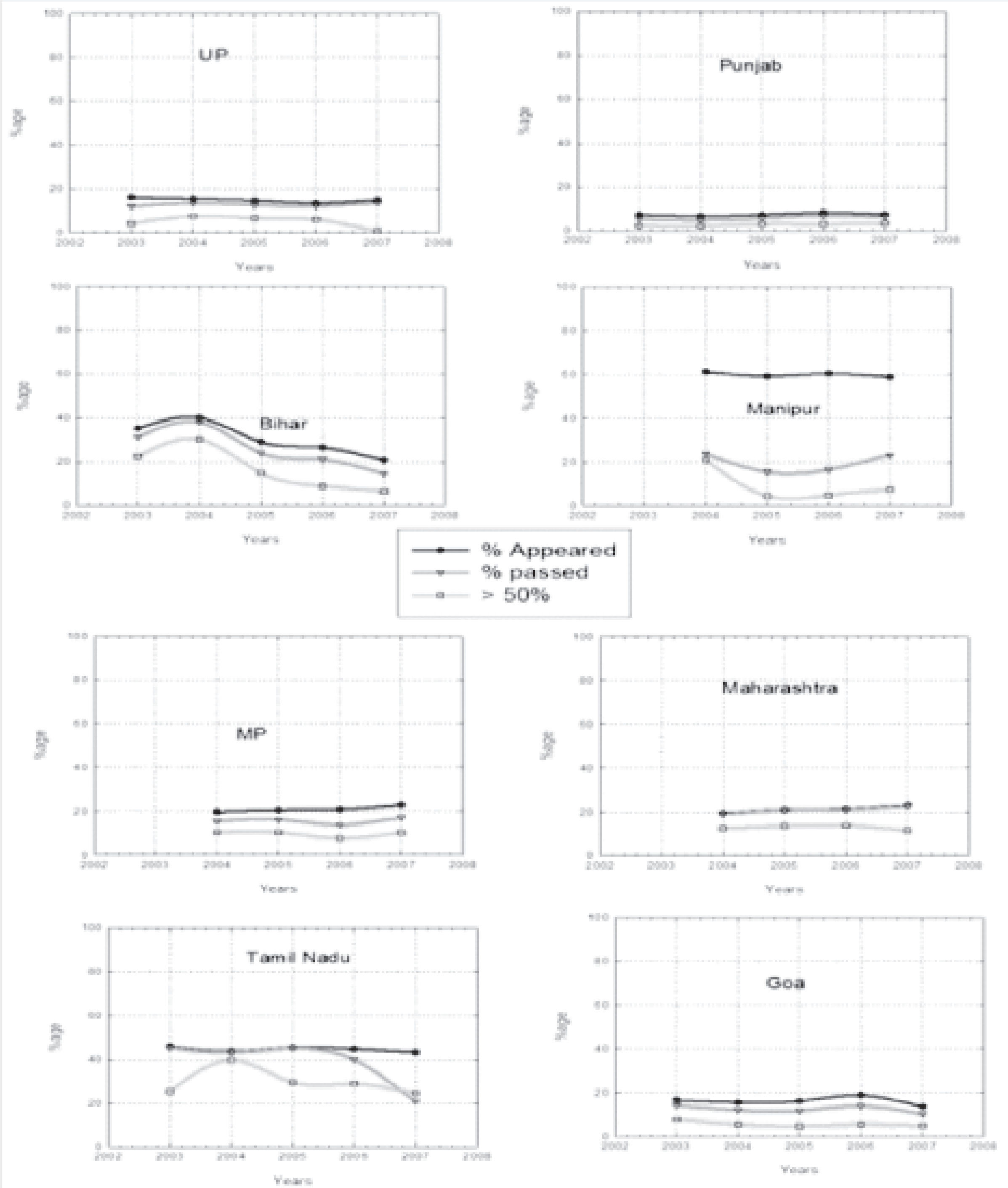


Fig 1-04.04: Performance in Mathematics at 12th Std

Source: *Respective State Boards*

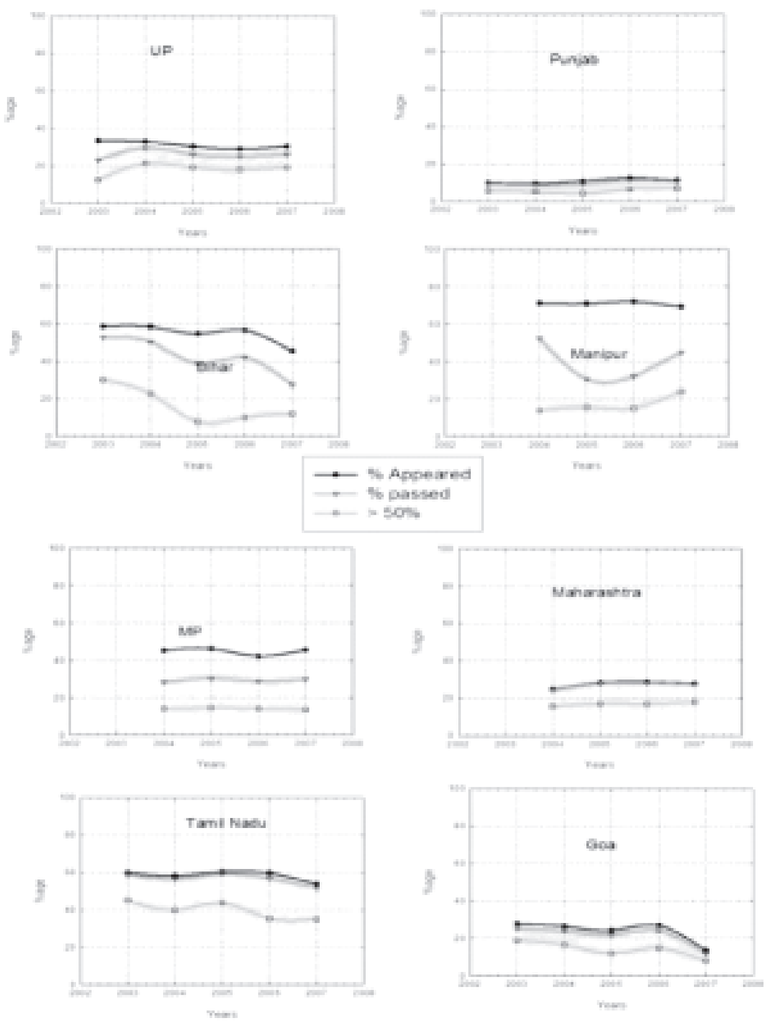


Fig 1-04.05: Performance in Physics at 12th Std.
Source: *Respective State Boards*

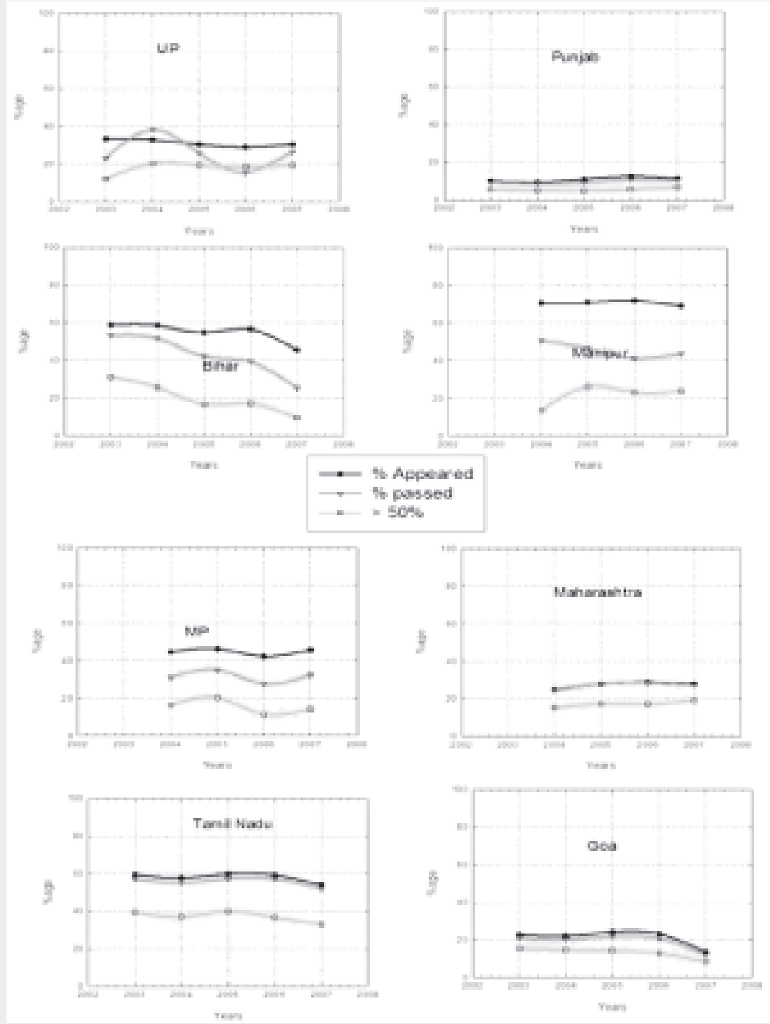


Fig 1-04.06: Performance in Chemistry at 12th Std.
Source: *Respective State Boards*

Here, an attempt is made to look at the stock of Indian manpower in Science & Technology (S&T). In general, NSF and OECD both include engineers, natural scientists, social scientists and technicians in its definition of S&T workforce, but in this section social scientists have been excluded. Following fields have been included in the calculations - agriculture & forestry, engineering, education, medicine (allopathy), dental, paramedical (nursing), apprentices, science (general) and veterinary science. It is assumed that a graduate or equivalent remains active participant in the economy for about 35 years or more on average. For graduate stock calculations, total estimated out-turns for last 35 years (e.g. 1966 to 2000 for getting stock for year 2001) were added. For getting relevant ratio, it was divided by relevant current active population (age group 20-59). For PhD stock calculations, total out-turns for last 30 years (e.g. 1971 to 2000 for getting stock for year 2001) were added. For getting relevant ratio, it was divided by relevant active population (age group 25-59) of that particular year. Fig 1-05.01 shows the ratio and stock for S&T manpower.

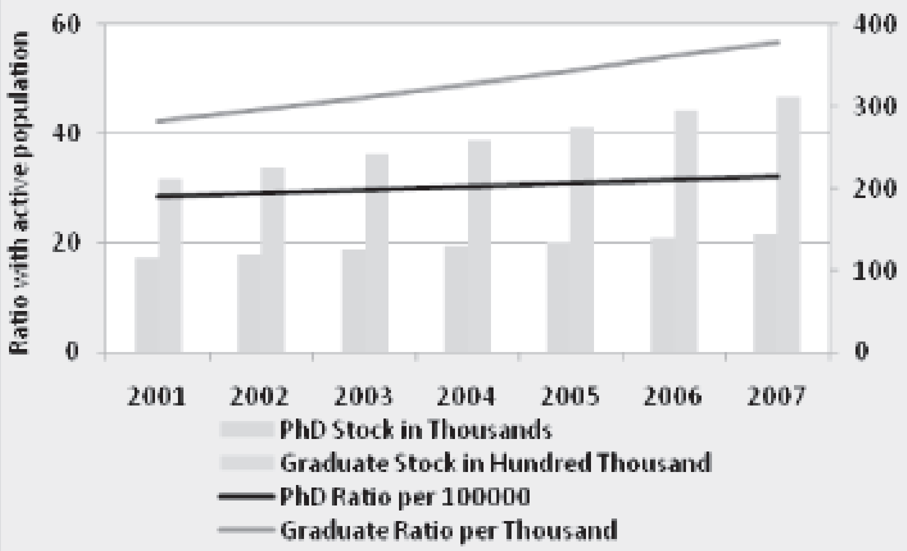


Fig 1-05.01: Indian S&T Manpower Stock and Ratio

Sources: *India Yearbook 2008 Manpower Profile, IAMR; UN Population Data; Respective governing bodies UGC, MHRD, Medical Council of India, Dental Council of India, Nursing Council of India*

Here it can be observed that over the last few years, rate of growth of highly specialized (PhD) manpower is much less than growth in graduate S&T manpower. But an added problem is the migration of this manpower to other countries. Fig 1-05.02 shows the enrolment of immigrant students from India and China in US higher education system, in absolute numbers and percentages. In this figure it can be noted that in terms of number of students going to US, a decade back there was significant difference between India and China but now they are comparable. Similar trend can be observed in case of percentage of having Indian or Chinese student as compared to all students from the world going to US. Such a share, although, is indicative more of US immigration policy than of the quality of students. In fact, 2005 onwards, India and China exhibit nearly same value in percentage.

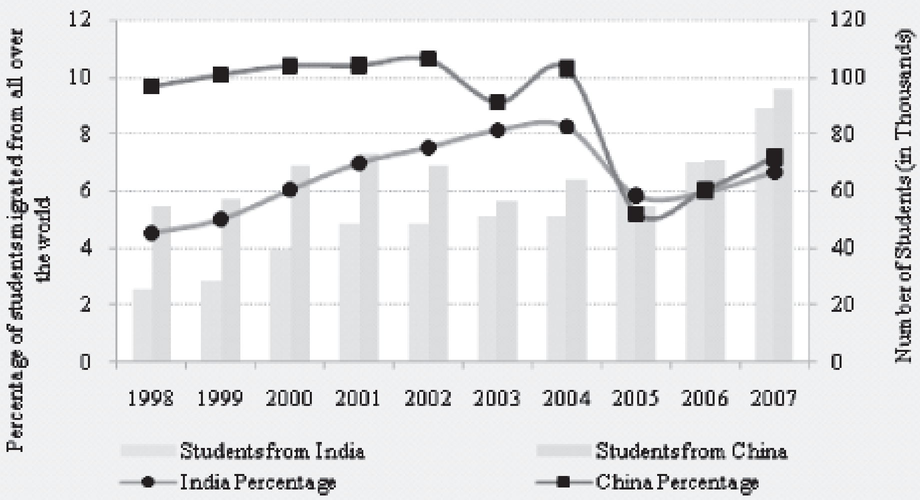


Fig 1-05.02: Migration of Indian & Chinese Students to US

Source: *Yearbook of respective years, Office of Immigration Statistics, USA*

According to NSF data of Asian recipients of U.S. S&E doctorates (1985-2005) as discussed in section on 'International Migration of Students', India was 4th in terms of its student getting doctorate degrees from US, whereas China was at the top with more than double the number of Indian doctorates. If a comparison is done according to the field between India and China, it can be seen here that in engineering, the ratio was somewhat closer (China: 12,784, India: 8,172) but in science, number of Chinese students was far ahead (China: 28,893, India: 10,540). Overall, performance and perhaps enrolment of Indian students in biology, mathematics and physical sciences were very poor; only in computer science India fared relatively better. In engineering subjects Indian position was not as bad as in biology and mathematics. Assuming that immigrant stock is a resource, Indian resource in the USA is far less than what a small country such as Taiwan or Korea could boast. Mainland China's stock is very large especially in biology. This situation should be indicative of the domestic institutions. In other words: biology and mathematics, the two generic areas, suffer from poverty in India. Engineering resources could be secured from USA.

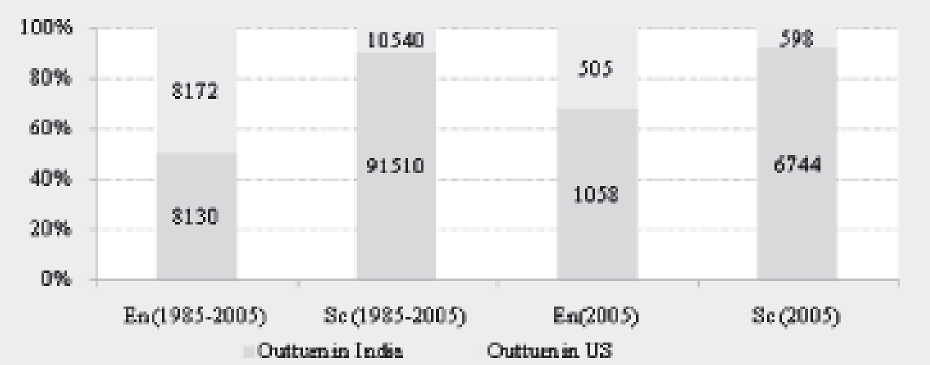


Fig 1-05.03: Outturn of Indian Students in Engineering and Science - Domestic and US

Note: *Numbers Inside Show Numbers of Doctorate Recipients*

Sources: *National Science Foundation, Survey of Earned Doctorates, special tabulations (2006); National Science*

Fig 1-05.03 shows the domestic as well as US out-turn of Indian PhD students for the period 1985-2005. It is remarkable to note that for engineering, the ratio is nearly same for out-turns in US and India. For the year 2005, it is somewhat better, but still the US generates one third of the total out-turn. This should be a matter of great concern. Even if India can manage to call back half of the doctorate degree recipients in engineering field, our S&T manpower will be increased greatly.

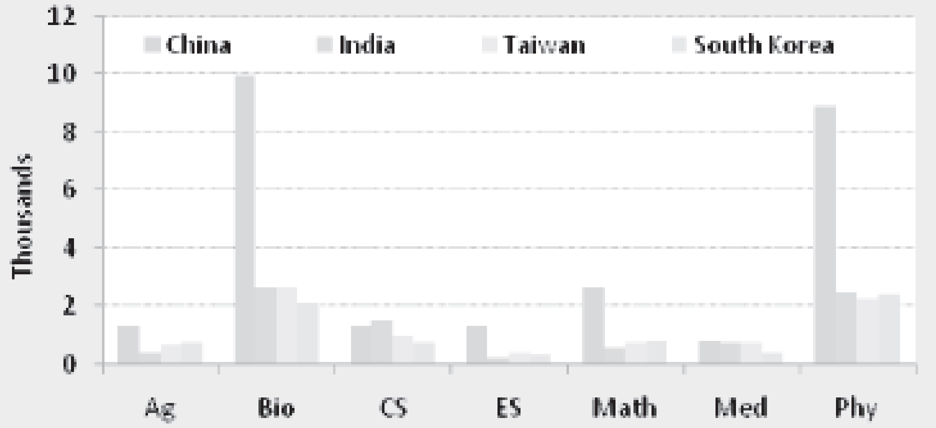


Fig 1-05.04: Immigration of Asian Students to US in Science Area

Note: Ag – Agriculture Sciences, Bio – Biological sciences, CS – Computer Sciences,

***Source:** National Science Foundation, Survey of Earned Doctorates, special tabulations (2006)*

If attention is drawn to science (Psychology and Social Science have not been included, unlike in the US; although much part of cognitive and other psychologies belong to hard core areas) subjects, comparison is shown in Fig 1-05.04. Because of the unavailability of the data of these countries on their domestic out-turn, the out-turns were compared based on number of doctorate recipients in US. Here it can be seen that, only

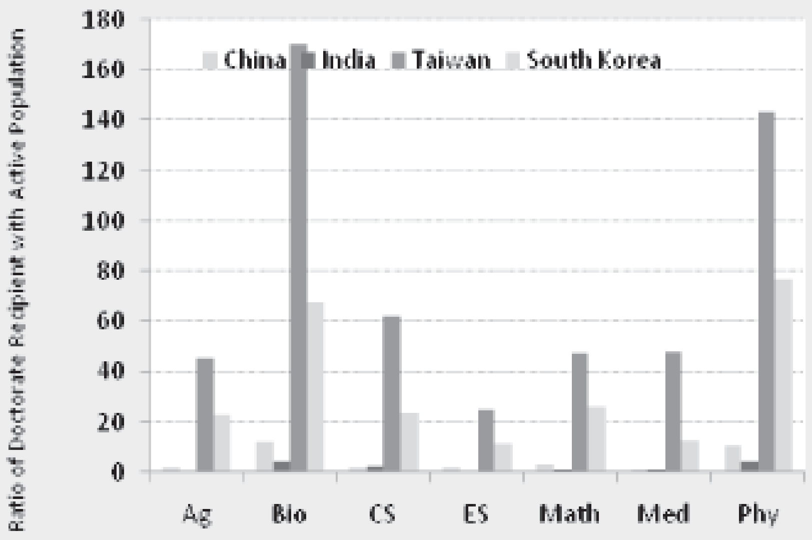


Fig 1-05.05: Recipients of U.S. Science doctorates normalized by per million active population in home country

***Source:** National Science Foundation, Survey of Earned Doctorates, special tabulations (2006); UN Population Data* in computer sciences Indian students were slightly ahead of China and other countries. Specifically, Biological Sciences, Mathematics and Physical Sciences are areas where India is trailing by a huge margin. Hence, these should be the areas of focus.

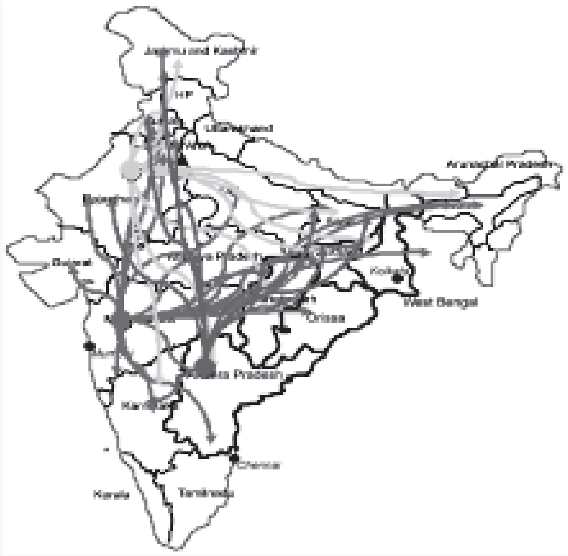
To make the comparisons more realistic, the numbers of students were normalized with their active population (age group 15-59; source: UN Population Data) for the year 2000. Fig 1-05.05 shows the number of recipients of U.S. science doctorates, normalized by per million persons in home country. Here it can be clearly seen that in terms of doctorates recipients per million persons, India is far behind Taiwan and South Korea. Basically, this focuses attention on the serious lacuna in S&T manpower generation and this should be an area of importance when designing policies for higher education.

Inter-State Migration at Secondary level

It has been observed that a few Indian states having better educational infrastructure especially in the Engineering and Medical education, attract students from the other states at secondary level. In this section an attempt has been made to find out the link between student migration and the educational infrastructure of these states. According to data and the information provided by state boards pertaining to students who appeared in 10th class in 2005 and students who appeared in 12th class in 2007, it is observed that the flow of students has taken place either into neighbouring states or to states where there is a difference in the infrastructure. From Table 1-06.01 it may be noticed that some states are more venerable for out-flux of students. Fig 1-06.01 is indicative of the migration pattern in select states of Rajasthan, Andhra Pradesh and Maharashtra.

Table 1-06.01. Inter-state flow of students

	Influx	Outflux	Outflux/Influx
Nagaland	6	777	129.5
Maharashtra	107	2451	22.9065
West Bengal	305	1615	5.2951
Karnataka	1082	5179	4.7865
Andhra Pradesh	129	465	3.6047
Haryana	216	606	2.8056
Goa	1	2	2
Chhattisgarh	53	9	0.1698
Jharkhand	468	42	0.0897
Bihar	4801	226	0.0471



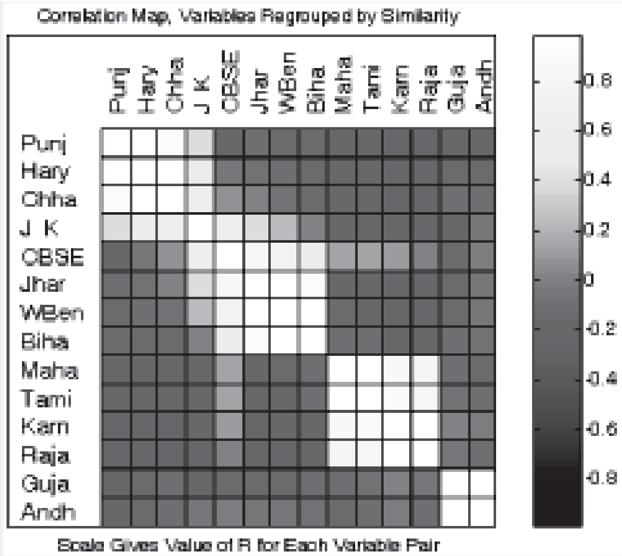


Fig 1-06.01: Qualitative depiction of Inter-State migration of students from 10[th] to 12[th] standard
Note: *Maps of India are indicative only*

Fig 1-06.02: Matrix of Pearson Correlation Coefficients for state to state migration of students from 10[th] to 12[th] Standard, 2005 to 2007

Emerging pattern of inter-state-board migration of students is given in Fig 1-06.02. It shows Pearson's correlation matrix for inter-state migration. Dark colour indicates low level of migration whereas lighter colour indicates high level of migration.

International Migration of Students

Process of globalization has accelerated international migration of students, particularly from developing and Sub-Saharan countries to developed countries. It has provided a global marketplace to the host countries. According to United Nations Educational Scientific and Cultural Organization (UNESCO), students from Sub-Saharan Africa are the most mobile; about 7% are studying in overseas universities while only 0.40% students from North America (the US, Canada and Mexico) go overseas for higher education. Major share of international flow of students is from developing countries, particularly from India, due to such push and pull factors. Consequently, many countries are trying to open up markets for foreign students by

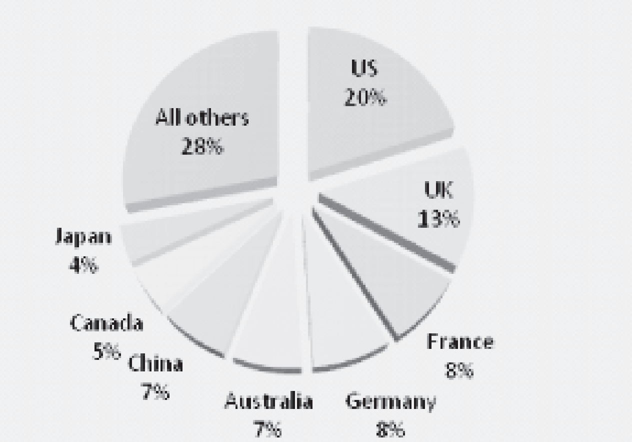


Fig1-07.01: Global Destinations for International Students at the Post-Secondary (Tertiary) Level, 2008
Source: *http://www.atlas.iienetwork.org*

laying emphasis on attracting more foreign students, and maximizing the market potential of foreign study. India, China may be a major source of education market in future for foreign study. However today, thousands of students from India are looking towards US, Europe and Australia for higher studies. Although very few students from developed country regions are coming to Asia. USA has been the favorite destination for foreign students at post secondary (tertiary) level followed by UK, France, Germany, China, Australia, and Japan, as shown in Fig 1-07.01.

However, of late, USA's share has been in decline. Despite this US, European Union and Australia host nearly 81 percent of all foreign students. India, China, Republic of South Korea, Japan and Canada are the top five countries contributing the largest share of students enrolling in USA, Australia, UK and Canada.

Flow of Students from India and China

India and China are the major sources of foreign students to overseas countries and they have been contributing significantly, in particular, to US research, which aids USA's global competitiveness. Science and engineering are the choice subjects of the students from India and China for their doctorate degrees studies abroad. A discipline-wise distribution of students who got US doctorates during 1985-2005 and flow of students from China and India is given in Tables 1-07.01 and 1-07.02, respectively.

Table 1-07.01: Asian recipients of US doctorates in various fields (1985-2005)

Field	Asia	China	India	Taiwan	S. Korea
S&E	130,426	41,677	18,712	19,187	18,872
Engineering	48,166	12,784	8,172	8,816	7,273
Science	82,260	28,893	10,540	10,371	11,599
Agricultural sciences	5,313	1,313	434	709	728
Biological sciences	20,973	9,957	2,668	2,658	2,132
Computer sciences	5,850	1,360	1,515	970	745
Earth & atmospheric Sc.	2,947	1,345	243	388	366
Mathematics	6,236	2,692	575	739	829
Medical/other life sciences	4,026	813	727	753	413
Physical sciences	19,735	8,934	2,479	2,234	2,429
Psychology	2,005	297	238	297	318
Social sciences	15,175	2,182	1,661	1,623	3,639
Non-S&E	22,691	2,668	2,911	3,727	5,267
All fields	**153,117**	**44,345**	**21,623**	**22,914**	**24,139**

Source: www.nsf.gov/statistics/seind08/c2/tt0-09.htm

Simultaneously, the flow of students and scholars into China and India has also begun. Foreigners began joining Chinese universities for education in late seventies and the number is growing steadily. It was estimated that approximately 1,40,000 international students were enrolled for higher studies in China by 2005. South Korea is the largest source of foreign students to China contributing 39.3%. The leading source countries of foreign students to China and India are listed in Table 1-07.03, India is lagging behind China in attracting foreign students (around 13,267 in 2005).

Thus, internationalization of education has created a worldwide market for higher education. Therefore, universities are building links with universities in other countries to enhance their global reach in the area of

Table 1-07.02: Flow of students from China and India to USA and vice-versa

Year	China			India		
	No. of students	% of foreign students in US	Number of US students to China	No. of students	% of foreign students in US	Number of US students to India
1994/95	39,403	8.7	1,257	33,537	7.4	409
1995/96	39,613	8.7	1,396	31,743	7.0	470
1996/97	42,503	7.8	1,627	30,641	6.7	601
1997/98	46,958	9.8	2,116	33,818	7.0	684
1998/99	51,001	10.4	2,278	37,482	7.6	707
1999/00	54,466	10.6	2,949	42,337	8.2	811
2000/01	59,939	10.9	2,942	54,664	9.9	750
2001/02	63,211	10.8	3,911	66,836	11.5	627
2002/03	64,757	11.0	2,493	74,603	12.7	692
2003/04	61,765	10.8	4,737	79,736	13.9	1,157
2004/05	62,523	11.1	n/a	80,466	14.2	n/a

Source: *http://opendoors.iienetwork.org/*

Table-1-07.03: Major source countries to China and India

Rank	China (2008)		India (2005)	
	Country	Percentage	Country	Percentage
1.	South Korea	33.0	UAE	11.30
2.	Japan	9.5	Nepal	10.19
3.	United States	7.5	Iran	8.44
4.	Vietnam	5.0	Bangladesh	7.10
5.	Thailand	3.7	Oman	4.86
6.	Russia	3.7	Sri Lanka	4.38
7.	India	3.7	Mauritius	3.97
8.	Indonesia	3.4	Saudi Arabia	3.15
9.	France	2.4	Kenya	3.15
10	Pakistan	2.3	United States	2.99

Source: *http://www.atlas.iienetwork.org/?p=53467*; http://www.atlas.iienetwork.org/

higher education. Moreover, foreign students are contributing in ample measure to the host country's economy. According to Open Doors Report (2005), foreign students contributed $13.3 billion to US economy in 2004/05. US, UK and Australia, anticipating huge market for education, are demanding further liberalization of trade in cross border education through General Agreement on Trade in Services (GATS). According to an estimate, students from India to US may get doubled as compared to that from China. China may contrarily attract more students from US than India by the year 2015 A.D. India must be ready to develop technical education in order to attract foreign students with possible economic implications.

A large number of Indians have settled abroad. Fig 1-08.01 shows the number of Indian immigrants legally admitted into the US according to their class of admissions. Others include Refugees & Asylees, Diversity and Cancellation of removal etc.

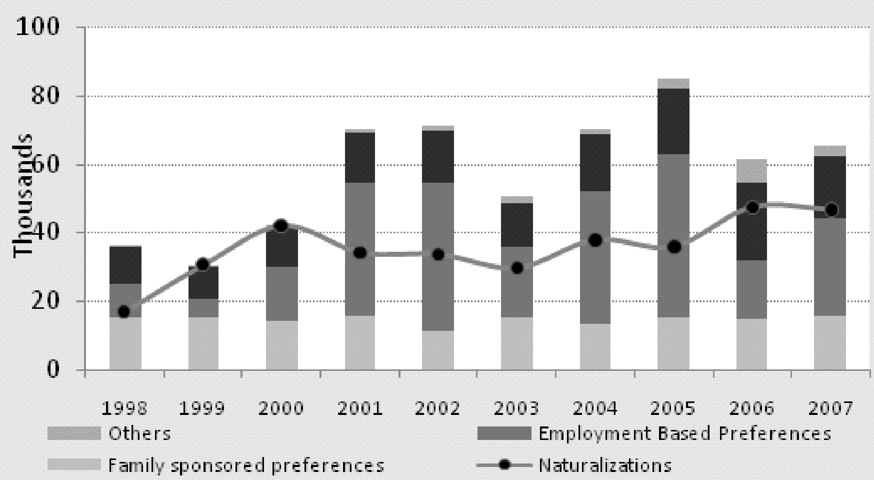


Fig 1-08.01: Immigrants Legally Admitted in US by Selected Class of Admission from India
Source: *Yearbook of respective years, Office of Immigration Statistics, USA*

As the figure suggests, largest chunk of Indians settled in the US have moved because of employment based preferences; sometimes more than half of total settlements (as in 2005). On the other hand if Indian workers who are temporarily migrating to the US are considered, their numbers range from more than double those of permanent settlements (as in 1998) to five times as many (as in 2007). Fig 1-08.02 shows the number of Indian workers who have temporarily migrated to US, along with their class of admission. 'Others' include nurses, agriculture workers, industrial trainees and exchange visitors. As can be seen in Fig 1-08.02, specialty groups and intra-company transferees form the major part of the flow. It shows that Indian workers, who migrate to US, are mainly some type of specialists.

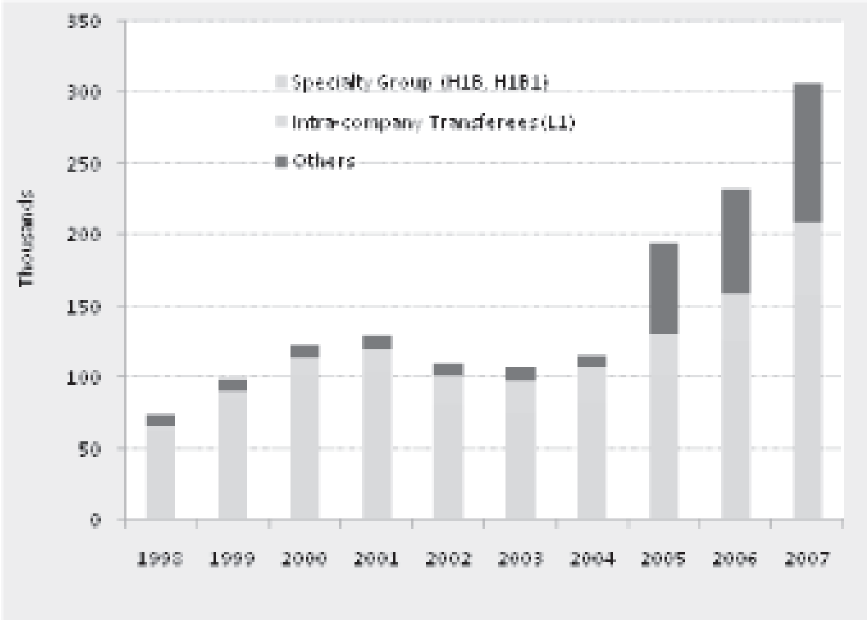


Fig 1-08.02: Indians immigrated as Temporary Workers in US
Source: *Yearbook of respective years, Office of Immigration Statistics, USA*

Another country where large numbers of Indians migrate is Australia. Fig 1-08.04 shows the arrival and stock of temporary residents and students in Australia. Here, it can be seen that in case of Australia, more students are immigrating as compared to temporary residents. Canada is another country

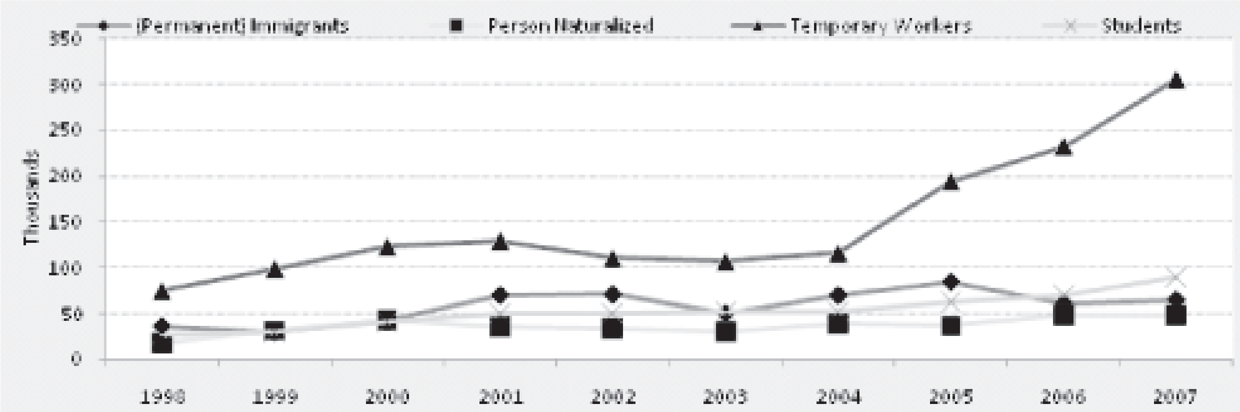


Fig 1-08.03: Various Categories of Indians Admitted into the US
Source: Yearbook of respective years, Office of Immigration Statistics, USA

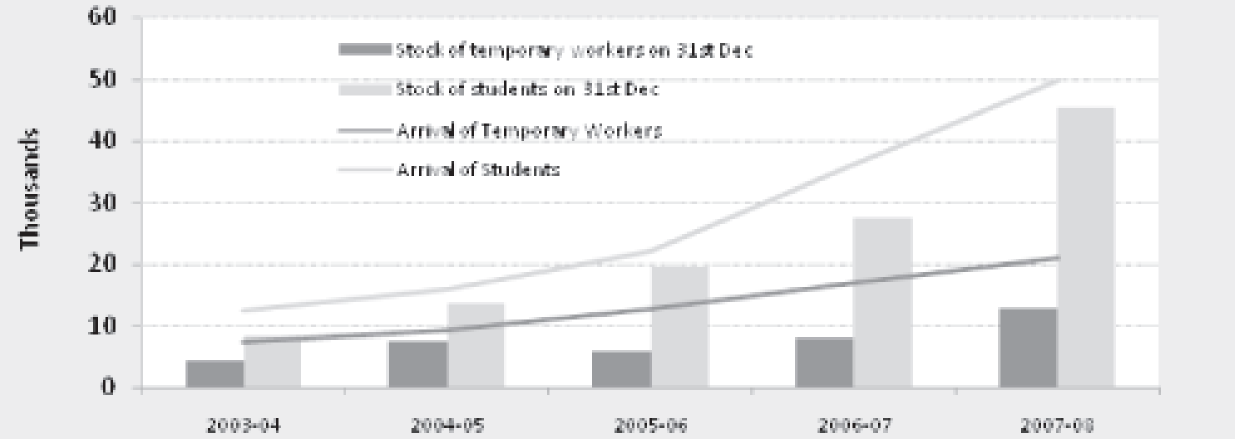


Fig 1-08.04: Temporary Residents and Students Immigration from India in Australia;
Source: Immigration Update reports of respective years, Department of Immigration and Citizenship, Australian Government

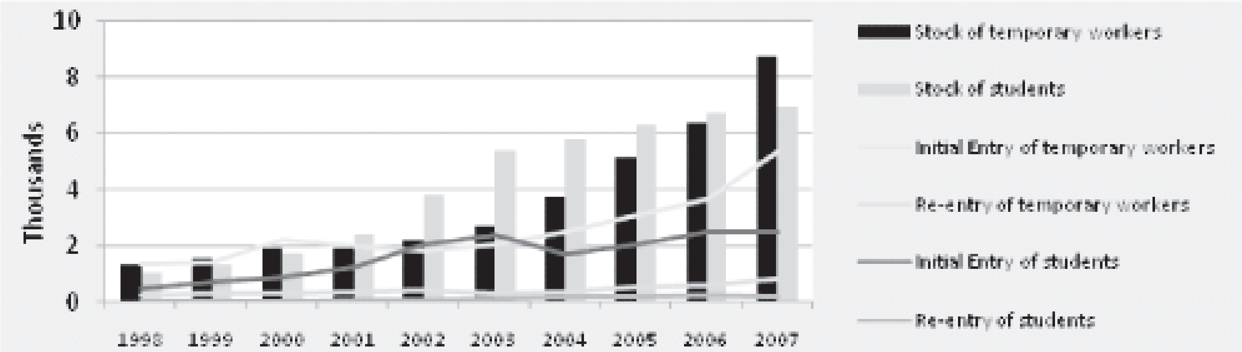


Fig 1-08.05: Temporary Workers and Students in Canada from India
Source: Immigration Overview 2007, Citizenship and Immigration Canada, http://www.cic.gc.ca/english/resources/statistics/index.asp.

which hosts large number of Indians. Fig 1-08.05 shows the entry and stock of Indian workers and students as temporary residents in Canada.

The number of students going to these countries were compared with the estimated out-turn of graduate students in S&T areas (refer section on 'Stock of Indian S&T manpower'). Fig 1-08.07 shows this comparison. Here it can be observed that percentage of students going to these countries for higher studies has increased over the years.

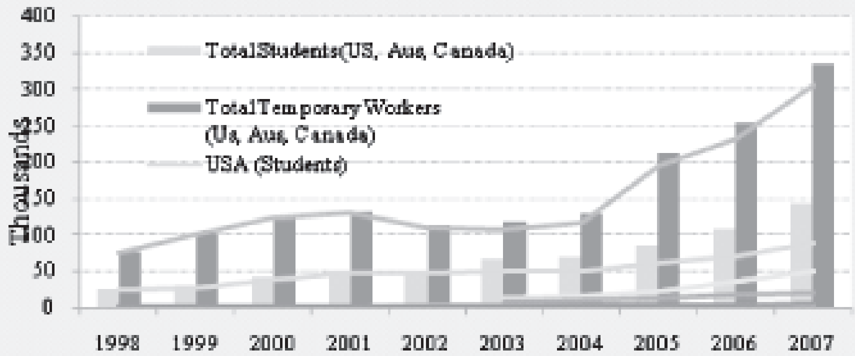


Fig 1-08.06: Comparison of Migration of Indian Temporary Workers and Students in USA, Australia and Canada

Source: *Reports of Immigration Departments of Respective Countries*

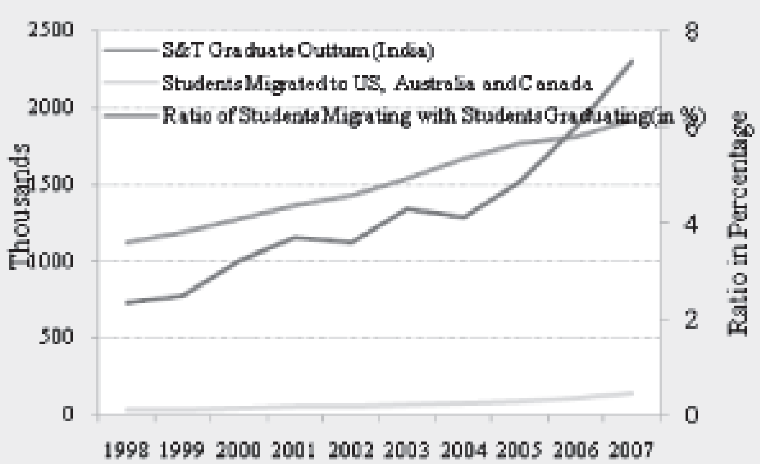


Fig 1-08.07: Out-turn and Migration for Indian Students

Measures to promote Basic Science

The major concern of the government and policy makers is the deviation of students from science stream to other disciplines at higher education level. Hence, policy measures have been taken to increase enrolment at higher education by initiating several scholarship schemes to attract students towards science. The National Talent Search Examination (NTSE), Kishore Vaigyanik Protsahan Yojana (KVPY) and Innovation in Science

Pursuit for Inspired Research (INSPIRE) are some of them. The former two schemes have been successfully implemented without significant improvement in science education. The third scheme, which has been inaugurated in 2008, has advantage over other schemes as its domain is quiet large from school level to Post Ph.D. level. The brief outline of these schemes is as follows:

National Talent Search Examination (NTSE)

NTSE introduced in the year 1963, by National Council of Education Research and Training (NCERT), is a national level scholarship program to identify and nurture talented students. Every year 750 to 1000 scholarships are offered and the scheme is open to the students of Class VIII and Class X standard. These scholarships are awarded for pursuing education up to doctoral level. The selection is based on a national level competitive examination comprising the Mental Ability Test (MAT) and the Scholastic Aptitude Test (SAT). A stipulated number of candidates qualifying these two tests are subjected to a face-to-face interview. The final awards are made on the basis of composite scores obtained in the MAT, the SAT and the interview.

Kishore Vaigyanik Protsahan Yojana (KVPY)

KVPY was started during 1999 by the Department of Science and Technology (DST), Government of India to encourage students of Basic Sciences, Engineering and Medicine up to Ph.D. levels to take up research as a career. The selection is made through national level competitive examination.

Innovation in Science Pursuit for Inspired Research (INSPIRE)

DST introduced in 2008 another ambitious scholarship scheme "Innovation in Science Pursuit for Inspired Research (INSPIRE)" to promote science education in the country. The proposed scheme INSPIRE includes three components in different age groups:

(a) to provide Science innovation scholarship of Rs 5,000 for a total of one million young learners of the age group 10-17, once in their school career, during the next five years for experiencing the joy of innovations

(b) to provide a mentorship through global icons including 60-70 Nobel prize winners and 150-200 Indian leaders in science through a summer camp for the top 1% performers in the Class X and XII examination every year for a period of five years

(c) to offer scholarship for doctoral research backed by an assured research career opportunity scheme for a total of 10,000 young people leaving plus two level, for a period of five years after their Ph.D. in sciences

This integrated approach will provide a handholding and safety net mechanism for identifying and nurturing youth with aptitude and talent for research. This scheme is based on identifying early and building the required human resource base for the country, within the absorption capacity of our current S&T system and R&D base.

A large part of the science and engineering doctorates out-turn of the country is provided by research institutions, notably CSIR, DRDO, ISRO and other institutes under Department of Atomic Energy and similar non-university bodies. Contribution of CSIR alone is quite significant and could be as high as 1,500 doctorates within next few years. Out-turn of doctorates from the university sector is skewed in nature, with a few major universities (primarily the central universities which receive larger share of financing, have larger number of faculties and lower student-teacher ratio) producing most of the doctorates. Further, there are disparities in terms of quality.

Another prevalent problem relates to the recruitments. Not only some of the lesser known universities, even the reputed institutes like IITs, TIFR and other well known national laboratories, such as the CSIR, face the competition from corporate recruiters, the global universities and the foreign R&D centers; in all such organizations including universities large number of teaching/ research positions have remained unfilled.

The country currently is planning to deploy extraordinary amount of public resources in higher education in order to build a large number of new universities and several new research establishments. Securing appropriately trained, highly educated science and engineering manpower for this expansion would therefore prove to be the most critical. It should not be ignored that the doctorate-level research and training is being undertaken in institutions other than universities as well. Identification of institutions, which are generators of knowledge and training in advanced areas of S&T, would therefore be crucial.

This section will present data and analyses on the doctorates from various universities and research institutions in Indian cities. First part deals with the data collected through case based opinion and the second part deals with data derived from the websites of various scientific institutions in India. Two broad groups of institutions could be imagined for simplicity, the 'major'

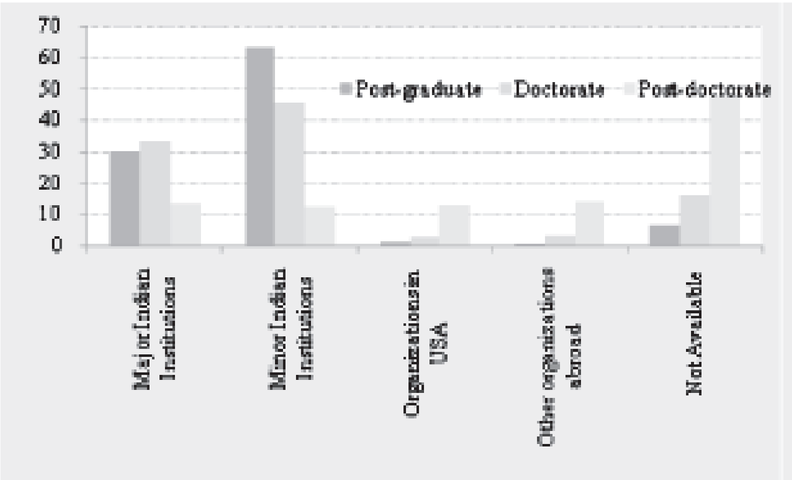


Fig 1-10.01: Organizations where case respondents studied

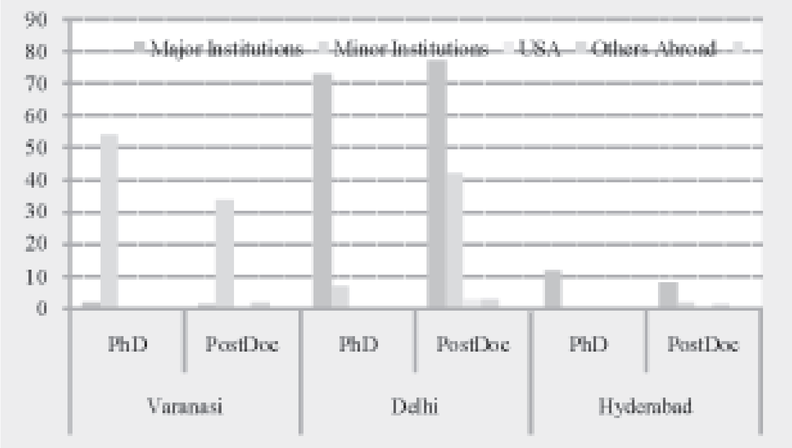


Fig 1-10.02: City-wise profiles of organizations from where case respondents received their training

institutions comprise those who receive above-average resources such as the IITs, institutes of national importance and similar, while the 'minor' institutions represent small and state universities and similar who receive below average resources. The case data provides examples of instances and might not be exemplar or cannot be used for estimation.

Fig 1-10.01 shows the employability of persons trained in domestic institutes vis-à-vis institutes in the USA (interestingly it exhibits a pattern which is quite similar to the pattern being reflected in the website data discussed in the second part). As only a few persons with doctorates from USA return for employment in domestic R&D establishments, the picture is overwhelmingly skewed towards both major and minor domestic institutions. There is also a difference in the pattern of employment.

Fig 1-10.02 describes the city-wise distribution of patterns of employment. It clearly exhibits that non-metropolitan cities, such as Varanasi, employ more of personnel trained in domestic institutes.

Table 1-10.01: Profiles of cities from where researchers/ academicians of most Indian major and few minor organizations, received their trainings

City	M Sc	Ph D	Pos-Doc
Agra	3	4	From
Allahabad	4		All
Bangalore	13	93	Over
Bombay	20	56	India
Burdwan	7		Only
Calcutta	27	68	24
Chennai	33	39	
Delhi	27	37	
Hyderabad	7	21	
Kalyani	4		
Kanpur	24	59	
Kharagpur	11	14	
Lucknow	27	18	
Mysore	5	6	
Pune	17	25	
Roorkee	5	7	
Varanasi	6	12	
USA	5	101	125
Others abroad		16	65
Others	78	50	

Source: *Websites of Various Scientific Institutions and Universities*

Now we discuss the above findings in relation to the analyses of data gathered through browsing more than thousand homepages of academicians and researchers on their organizations' websites. This data exhibits the trends of employment by major educational and research establishments having/ possessing highly educated manpower. Further, this data informs us on the employment worthiness of the manpower generated by the domestic institutions of higher learning and research. As most universities and R&D laboratories do not maintain websites that provide access to individual homepages, the data presented here too is partial and non-representative. Organizations we might describe as 'major' include all IITs, TIFR, IISc, ISI, Bose Institute, IMSc, and similar others. The minor organizations will include those with comparably much smaller funding support.

Table 1-10.01 exhibits a few distinct features, and the data, to recall, refers only to persons employed in institutes of teaching or R&D: small cities retain a significant share of masters

Table 1-10.02: Profiles of organizations from where researchers/ academicians of most Indian major and few minor organizations, received or definitely did not receive their trainings

Level	Major institutions Yes/No	University Yes/No	Abroad Yes/No
M.Sc.	164/164	229/97	24/302
Ph.D.	454/168	347/276	123/499
Post Doc	203/11		187/25

Source: *Websites of Various Scientific Institutions and Universities*

out-turn while at the doctoral studies level the metropolitan cities Bangalore, Bombay, Delhi, Calcutta, Chennai and a few small cities with IITs such as Kanpur or cities with major universities such as Pune garner the lion's share. Other universities indeed hold little prospect. Additionally, turnover from minor institutes is small in quantity. However, for both doctoral and post-doctoral, USA remains the most important geography of schooling. Few domestic institutes offer post-doctoral training. This data cannot inform us on the actual turnover. However, partial reflection on the nature of turnover in higher education along with preferences of the public employers is both exhibited.

Table 1-10.02 offers further insights into quality of research training, employability of trained personnel and the pattern of employment in most major and a few minor institutions of research and teaching. One may thus conclude that the major institutions in India appear to be at par with global institutes, if not more preferred, in turning over employable personnel at both doctoral and post-doctoral levels; however, minor institutes appear to be more effective in turning over masters' level personnel.

MEDICAL MANPOWER IN INDIA : AN OVERVIEW

Medical education occupies a crucial position as it provides the country the healers and involves a close and deep study of life itself and its vital processes. The Indian medical education sector is broadly classified into:

I. The modern system of medicine [allopathy, or Non-Indian System of Medicine (NISM)] and

II. Indian systems of medicine and homeopathy (ISMH) that include Ayurveda, Unani, Siddha and Homeopathy.

The governance of Medical Education in India is routed through various councils in respective systems. The *Medical Council of India* (*MCI*) and the *Dental Council of India (DCI*) controls the NISM system, whereas the *Central Council for Indian Medicine (CCIM*) and the *Central Council of Homeopathy (CCH)* prescribes and recognizes all standards of education in Indian Systems of Medicine viz. Ayurved, Siddha, Unani Tibb and homeopathic medicine qualifications respectively. The *Indian Nursing Council (INC)* and the *Pharmacy Council of India (PCI)* looks after the nursing education for Nurses, Midwives, Auxiliary Nurse-Midwives and the pharmacy education up to graduate level respectively. All these councils are autonomous bodies under the Ministry of Health and Family Welfare.

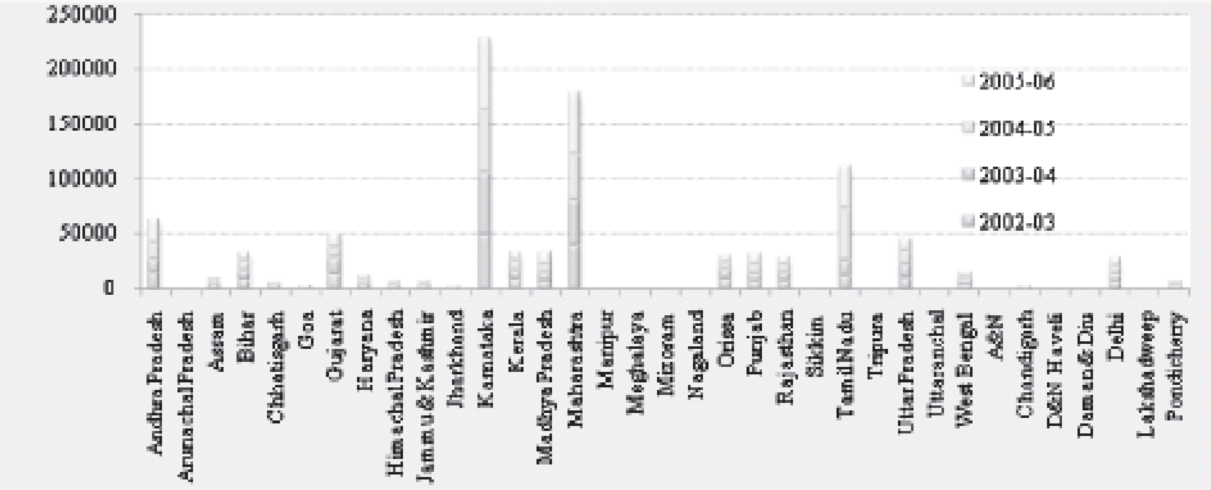


Fig 1-11.01: State-wise Enrolment (in numbers) of Students in Medical Education (Medicine, Dentistry, Nursing, Pharmacy, Ayurvedic, Unani and Homeopathy) in India over the years.

Source: Ministry of Human Resource Development, Govt of India

NISM training for doctors in India is provided at several levels. The undergraduate degree, referred to as MBBS (Bachelor of Medicine and Bachelor of Surgery) is of 5.5 years and the postgraduate degree programs,

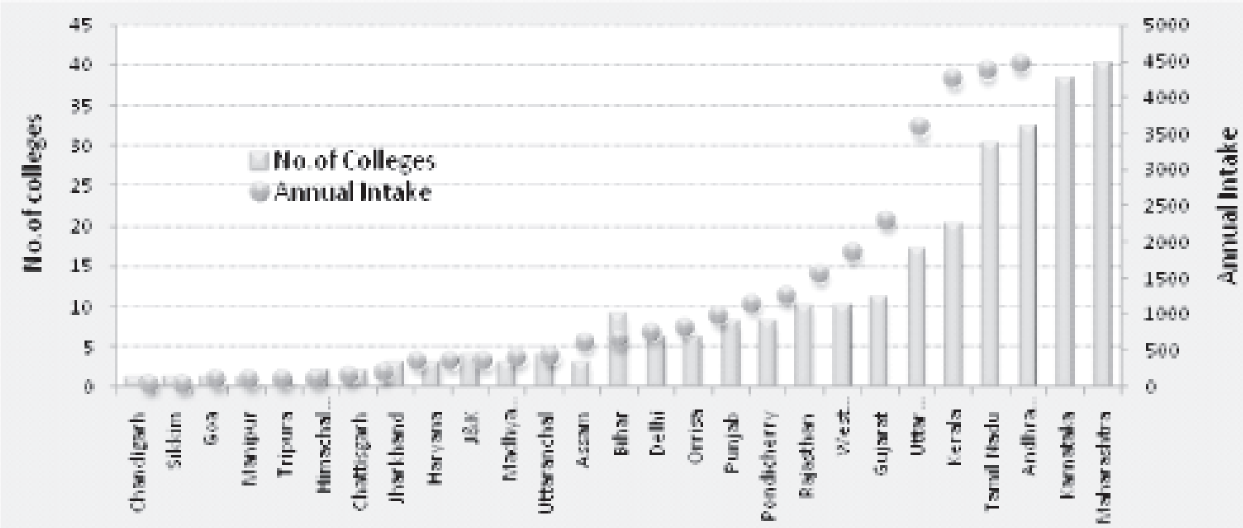


Fig 1-11.02: State-wise distribution of Medical colleges and their annual intake in 2008.

Source: http://mciindia.org/apps/search/viewMBBS.asp

M.D. (Doctor of Medicine) and M.S. (Master of Surgery), are of 3 years duration. D.M. and M.Ch are super specialty programs in medicine after postgraduate education. Similarly, Dental Education in India starts with the Bachelor of Dental Surgery (BDS) which is a four year course with one year of compulsory rotary internship. Post Graduate training includes Master of Dental Surgery (MDS). In India, there are 215 dental colleges offering BDS and 121 dental colleges offering MDS.

Indian systems of medicine and homeopathy (ISMH) that include Ayurveda, Unani, Siddha and homeopathy is provided by offering degrees like BAMS (Bachelor of Ayurvedic Medicine and Surgery) and BHMS

(Bachelor of Homoeopathic Medicine & Surgery). The course duration is 5½ years including one year of compulsory internship. Post graduate courses include M.D. in Homeopathy. There are 98 ayurvedic colleges, 8 siddha colleges and 40 unani colleges in India offering different degree and diploma courses.

Table 1-11.01: Universities of Health Sciences established in various states of India

Name of the University	State	Year of Inception
NTR University of Health Sciences	Andhra Pradesh	1986
Rajiv Gandhi University of Health Sciences	Karnataka	1994
MGR University of Health Sciences	Tamil Nadu	1997
Baba Farid University of Health Sciences	Punjab	1998
Maharashtra University of Health Sciences	Maharashtra	1998
West Bengal University of Health Sciences	West Bengal	2003
Rajasthan University of Health Sciences	Rajasthan	2005

Source: *Websites of State Governments*

Various committees of experts like the Bhore Committee (1946), Mudaliar Committee (1962), Chadha Committee (1963), Mukherjee Committee (1965 &1966), Jungalwalla Committee (1967), Kartar Singh Committee (1973), Shrivastav Committee (1975) were appointed by the Government of India from time to time to render advice on different aspects related to health and education. The reports of these committees have formed an important basis of health planning in India. There was a National debate in 1983 on standards of Health Science Education. An "Expert Committee for Health Manpower Planning, Production and Management" was constituted in 1985 under Dr. J.S. Bajaj, then professor at AIIMS. It resolved that there is a need to establish a separate Health Sciences Education Commission at National level at par with UGC and Unitary Health Sciences Universities in the States.

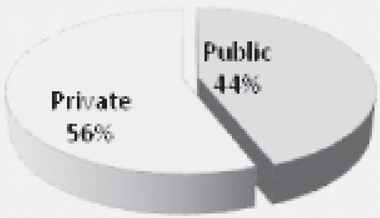


Fig 1-11.03: Percentage share of public and private medical colleges offering M.B.B.S course in India in 2008

Source: *http://mciindia.org/apps/search/viewMBBS.asp*

Accordingly, for the purposes of affiliating, teaching and ensuring proper and systematic instruction, training and research in Modern System of Medicine, Homoeopathic System of Medicine, Ayurvedic System of Medicine, Unani System of Medicine, Nursing Education, Pharmacy Education, Dental Education, Education on Laboratory Technology, Physiotherapy, Speech Therapy and Education on other paramedical courses several Universities of Health Sciences have come into existence since 1986 in different states of India. Table 1-11.01 provides a list of such Universities of Health Sciences with their year of inception. Such universities hope to foster and develop an intellectual climate conducive to the pursuit of excellence, either independently or jointly with other centres of excellence of higher learning.

In recent years, India has been through an expansion in the number of medical colleges due to the growth of private colleges. India, with a population in excess of 1.1 billion, has the largest number of medical schools within one country (274), with an admission capacity to undergraduate medical courses (MBBS) measuring 31,298 per year. In 1980, there were 112 medical schools in India, whereas in 1994-95 there were 152, admitting 12,249 students. The figures below are indicative of the fact.

Changes have been brought, though not very speedily and effectively. The main concern seems to be to make quantitative changes. There is a ten-fold increase in the number of medical colleges and the output of doctors. This has been largely unplanned and has only resulted in a marked increase in output without any thought for finding rewarding careers for them. This leads to frustration and thus the westward flood. As a result there is a shortage of health professionals in the country. As per WHO's World Health Report for 2006 the number of registered doctors in India has increased from 61,800 in 1951 to about 645,825 in 2005 - that's 0.60 doctors for 1,000 people. The Joint Learning Initiative, a global health network launched by the Rockefeller Foundation findings suggest that India has 0.59 doctors, 0.8 nurses and 0.47 midwives for 1,000 people, which adds up to 1.86 health workers for 1,000 people. The statistics for the state sector reveals a pathetic scenario. According to the Union Ministry of Health and Family Welfare's (MoHFW's) Health Information of India, 2004, the country had 67,576 government doctors: meaning one doctor was serving roughly 15,980 people. Thus, the current availability of doctors does not meet the recommendations of several past committees. The government's estimated requirement of specialist surgeons, obstetricians and gynecologists, physicians and pediatricians in 2001 for community health centers in rural areas is 12,172, but only 6,617 positions have been sanctioned and 4,124 positions have been filled. An 'Escorts Heart Institute and Research Centre' document prepared in 2005 said India would need at least one million more qualified nurses and 500,000 more doctors by 2012. Besides quantity, another criticism is that of neglect of rural and remote areas and overproduction of highly trained persons with no corresponding increase in gainful employment. There is a big gap in the distribution of health care personnel over rural and urban areas. The promotion of medical colleges in the smaller cities in the districts has not made much of an impact on the distribution of medical manpower. It is time we made a close study of this problem, which is basically a study of manpower requirements and distribution.

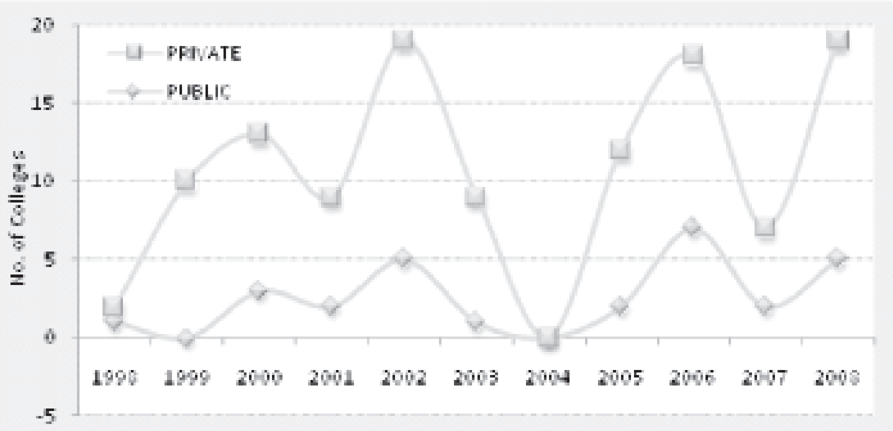


Fig 1-11.04: Trend of introduction of new medical colleges since 1998

Source: http://mciindia.org/apps/search/viewMBBS.asp

Medical needs of an individual and a community, and mental health needs, disease patterns and prevalence rates determine the plan for teaching/ practicing institutions. Changes and reorientation should be brought about to make the education relevant to the needs of the largest group of poor. Proper vocational guidance could be made available to the medical graduate, so that reliable data and rational thinking precede the choice of future career. Perhaps, we might even think of a larger share and inputs in public health so that such a career becomes attractive. To the traditional approach of how to provide clinical cure for individuals, we must provide for and add care of well defined populations so that the medical student knows how to be useful to the community at large. Excellence in medical education is not merely a vertical expansion and a set of achievements. Maximum improvement of health and relief of suffering within available resources should be our goal. There is thus a clear need to set up innovative models and bring about qualitative changes.

Gender and Science in India

Gender has figured in important ways in shaping the careers of scientists for centuries. Science and technology has been considered 'masculine' for a long time. Gender bias and discrimination in science is observed in most societies. To address these problems, changes in the society at large are absolutely essential. Science and society are closely linked and there is need for change within the social processes and the institution of science.

In the western countries, gender questions in science have been extensively raised. On the contrary, in India the status of women in science has still not drawn adequate attention. The feudal, authoritarian values and hierarchy have characterized Indian society. Are these reflected in Indian science as well? There are only a few reports and studies on gender and science in India. They touch upon issues only in a random manner; many times analyses have focused on differences, rather than on the inequalities associated with those differences. Moreover these studies are scattered and there is no systematic mapping of women in science. The question of women in science in India thus stands out. Some of the questions can be: a) What factors help women in opting for scientific careers?; b) What are the constraints faced by women in pursuing science education?; c) Do their career paths change after education?; d) Is the prevailing organizational culture of scientific research and development institutions suitable to women scientists?; e) How far are existing government policies for higher/science education gender sensitive and do they promote science education of females in the country?

This section aims to examine the role of gender as a variable in determining the science careers in India. It is divided into two sub-sections. The first sub-section deals with gender and education, analyses the available data on the enrolment of females into various courses in science and engineering. Subsequently, through a critical examination of the education and science policies, it addresses the current realities of women's participation in science education/research. The second part will discuss an empirical study.

Historical Background

Modern education for women in India began in the early years of the nineteenth century and by the 1880s universities started admitting them, Calcutta in 1877-78 and Bombay in 1883. The National Committee on Women's Education submitted a report in 1959 and expressed great dissatisfaction at the slow progress of women's education in the first decade of independence. The First to Fifth Plans (1951-79) continued to give some attention to women but, as a subject of 'welfare'. The shift in the approach from 'welfare' to 'development' of women could take place only in the Sixth Plan (1980-85). Committee on Differentiation of Curricula for Boys and Girls, was also established in 1964. Subjects in which women's enrolment increased significantly during the decade of 1970-1980 are commerce (3% to 16%); Science (18% to 28%) and Education ('36% to 48%).

Incongruities and oppositions can, however, be seen in case of women scientists in India both historically and currently. Women were, for example, denied entry to C.V. Raman's laboratory. Women's participation has been limited and confined to junior positions. Only a few women could make it to senior decision-making positions. Organizational hurdles outweigh so called family constraints; unequal treatment and subtle discrimination against women scientist and engineers in the behavioral and interpersonal relations also prevail;

Table 1-12.01: Enrolment of Girls as percent of Total Enrolment in University Education by Faculty

Year	Arts	Science	Commerce	Education	Engg/Tech	Medicine***
1960-61	18.6	--	1.1	32.5	0.8	20.4
1970-71	33.5	18.5	2.8	37.3	1.0	21.3
1980-81	37.5	27.9	15.2	46.7	4.6	23.8
1990-91	39.8	36.8	24.0	44.2*	10.9*	34.3*
1995-96	41.5	35.5	29.0	41.2*	14.2*	34.5*
1999-2000	44.9	37.4	34.0	42.6*	16.2*	37.8*
2001-02	43.8	39.1	38.7	43.5	24.9	40.6
2003-04**	45.5	39.8	36.7	52.1	23.1	46.3

Source: *Manpower Profile India Yearbook 2000-2001, and 2005, Institute of Applied Manpower Research, New Delhi, India.*
Only for degree level, not post graduate, **estimated, * Excludes dentistry, public health, nursing, midwifery and pharmacy*

and the cultural and social context in which science is learned and practiced contributes to the gendering of science and; discrimination component is much higher in scientific and technical fields in India than among social sciences and other fields. The prevailing socio-cultural systems in India result in a 'triple burden' for women in academic and scientific careers. Women in all professions perform a double role of managing job and domestic responsibilities, which has been commonly referred to as a 'dual burden'. In science, the dual burden is combined with various problems that are specific to scientific profession. Recently, Indian National Science Academy commissioned a study to the Research Centre for Women's Studies, SNDT Women's University, Mumbai to examine the socio-economic and institutional factors that limit women's participation in science.

Contemporary Data

The participation of girls at all stages of education has been increasing steadily through the years. Table 1 shows the enrolment pattern of women in higher education by faculty/discipline in India over the last few decades. It is observed that the highest representation of women is in education. Education, to a larger extent, is considered to be most apt subject for women as it is compatible with other responsibilities of women as mother and wife. This is followed by disciplines like arts and medicine. Lesser percent of women seem to opt for fields like engineering. In the field of science, and engineering however it is good to note that, the women's enrolment is on rise over the years as seen from Table 1-12.02. The participation of women in engineering has remained negligible till the early 1980s. It is only in the past 15 years that their enrolment has shown an increase.

Table 1-12.02: Enrolment of Women in Engineering

Year	1974-75	1979-80	1985-86	1989-90	1994-95	1999-2000
No. of women enrolled	1300	4400	12200	15800	24900	63100
Women as percentage of total enrolment	1.5	3.7	6.9	7.6	8.3	16.2

Source: *University Grants Commission (1999)*

Indian S&T Systems: the Place of Females

In India, a rapid expansion of science and technology has taken place in the post-Independence era. Unfortunately, very few women have been part of these structures. The latest available data reveals that in all, there are 41,198 women employed in R&D establishments, which is 13.9% of the total employed in such establishments. By the nature of activity, 12% women are primarily engaged in R&D activities, 11.5% in auxiliary activities and 17.4% in administrative activities. 84% of the total women were employed in the institutional sector. The majority of them were engaged in administrative activities (Research and Development Statistics, 2007). Are women equally represented at top-tier institutions? Indian National Science Academy (2004) reports that the proportion of women in national laboratories and prestigious universities is less than 15%, except in the case of DBT and ICMR where the percentage exceeds 25%.

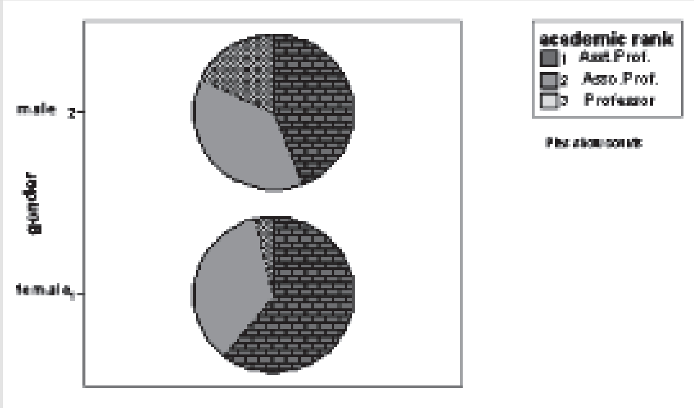


Fig 1-12.01: Proportion of women and men at different hierarchical positions

Fig 1-12.01 shows that the number of females becomes lesser at higher positions in the academic hierarchy. It reflects the gendered nature of the prevailing organizational culture of scientific research and development institutions.

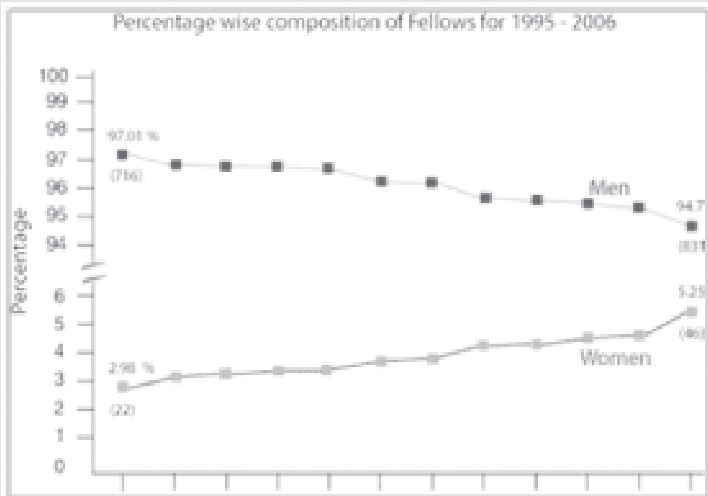


Fig 1-12.02: Gender status of Fellows
Source: *Indian Academy of Sciences*

Not only the poor statistical prevalence of women scientists of concern, but also females still do not get equal recognition in the field of science as illustrated in Fig 1-12.02.

Government of India, however, has recently taken many initiatives for women's education and for imparting high level skills to them. Special scholarships and awards have been instituted to attract students in general and women in particular to the science and technology streams, yet more needs to be done. But certain things are clear. The extant data does indicate that there exist high wastage ratio of women S&T personnel and wide gap exists between percentage of women studying science and percentage of women doing science. We may thus conclude that gender plays an important role in the shaping of scientific careers in India. Major attitudinal and institutional changes in the structure and procedures are probably required in Indian science.

S&T Financing

Overview

Innovation, the introduction of new goods, services, or processes contributes to national competitiveness as well as social welfare. To achieve that goal, S&T is undoubtedly the key driver. In such a context, S&T financing is the most important factor which plays a major role because the organizations that fund S&T work, decide how it is done and what kinds of innovations the nation will ultimately produce. This *theme* focuses on financial inputs and flows into S&T in the country at the government level (across several ministries and departments) with special emphasis on some hidden expenditures on S&T which generally remain untraced. Financing across some select sectors like health and environment has been looked into. The *theme* also captures the trend of the private investment in Research & Development and in the area of high technology trade over several sectors.

Beginning with a detailed examination of the various sources of S&T financing, the schemes and programs under which financing of S&T takes place and the trends in financing of S&T, this *theme* then looks into how financing takes place specifically for two important sectors: 'health' and 'environment'. Subsequently, investments in S&T and innovation get captured through analyses of multiple forms of expenditures on S&T. Finally, this *theme* looks at the trends in high technology trade over several sectors like armament, scientific instruments, pharmacy and computer office equipments. Between the years 1995 and 2006, India's share in global high technology trade has increased marginally from 0.14 percentage points to 0.23 percentage points. The analysis indicates that India has performed relatively well in the knowledge intensive service industries.

The full text of these extended summaries is available at *http://www.nistads.res.in*

Financing of S&T in India

Here we describe the pattern of changes experienced in the allocation of financial resources to science and technology (S&T) at the national and state levels since the beginning of the last decade. Changes taking place at the national and state levels are delineated in respect of the scope and rationale, objectives and targets, potential and instruments of allocation of financial resources to S&T in the public and private sector in India. Changes in the sources, performers and targets of extramural R&D funding are analyzed. The scope of analysis is confined to understanding the patterns of changes that have especially occurred in the allocation and utilization of public finance made available for research and development (R&D) and technology development by the Indian state. The period beginning with nineties has a special significance on account of the changes occurring on account of the economic reforms in the macro economic situation in India. During this period, the policymakers expected the sector of S&T to benefit quite significantly from the shift to the model of market governance being erected for the management of economy, innovation, technology and science in India.

Financial Resources for S&T

Analysis of the progress of plan expenditure on science and technology allocated to Central Scientific Departments indicates that most recently an improvement has been experienced in the gross budgetary support for S&T expenditure *vis-à-vis* other activities. S&T and Environment activities could receive a higher priority in comparison with the allocations made to the activities to be undertaken by the Central Socio-Economic Departments. Table 2-01.01 provides a synoptic view of the comparative trend of increased percentage of plan expenditure on S&T and Environment, Education, Art & Culture and Health and Family Welfare when computed in relation to total outlay made available from gross budgetary resources for Central Plan. But it is also a matter of concern that the plan expenditure on agriculture, rural development and industry and minerals as a percentage of total outlay on Central Plan has shown a steady trend of decline.

Public Funding of S&T by Scientific Departments in Central Plan: Funds for R&D and S&T in India flow from three sources: from Central government allocation made through the Planning Commission; from State governments and the private and business sector. The main performers of research in publicly funded research organizations are controlled by the six Central Scientific Departments, namely Department of Atomic Energy; Department of Space; Department of Science and Technology; Council of Scientific & Industrial Research/Department of Scientific and Industrial Research; Department of Biotechnology and Department of Ocean Development. The other important performers of research in publicly funded research organizations are controlled by the Socio-Economic Ministries, namely Ministry of Defence/Defence Research and Development Organization; Department of Agricultural Research/Indian Council of Agricultural Research;

Table 2-01.01: Sectoral Composition of Expenditure against Gross Budgetary Support of Central Plan (1998-2008)

Year/Sector	S&T Environment	Education, Art and Culture	Health & Family Welfare	Agriculture & Allied Activities	Rural Development	Industry & Minerals
1998-99	4.37	11.43	8.61	7.10	15.66	7.65
1999-00	4.48	11.25	9.85	6.91	12.41	4.59
2000-01	4.42	10.89	9.10	6.13	9.34	6.17
2001-02	5.03	9.93	8.43	5.01	10.37	7.37
2002-03	4.85	10.23	8.06	4.69	17.79	4.30
2003-04	5.30	10.83	8.15	5.25	16.84	4.07
2004-05	6.41	13.38	8.71	5.98	11.79	3.66
2005-06	5.16	14.43	7.80	6.15	14.91	4.23
2006-07	5.17	16.98	7.88	6.13	13.3	4.72
2007-08*	5.21	16.23	8.10	5.69	11.78	4.51
2008-09**	5.16	18.22	8.27	5.57	10.54	4.09

Note*: Revised & **: Budgeted

Source: Author

Department of Health Research/Indian Council of Medical Research; Ministry of Human Resource Development; Ministry of Information and Communication Technology; Department of Non-Conventional Sources of Energy and Ministry of Environment and Forests.

Allocations from Central Scientific & Socio-Economic Ministries to Strategic and Civilian S&T. Fig 2-01.01 and Fig 2-01.02 provide an overall picture of the changing pattern of allocation and utilization of plan resources made available to the Central Scientific and Socio-Economic Departments from Central Plan since the start of Seventh Five Year Plan in 1985. This analysis of the progress of plan expenditure on science and technology allocated to Central Scientific and Socio-Economic Departments indicates that while the rate of growth of plan

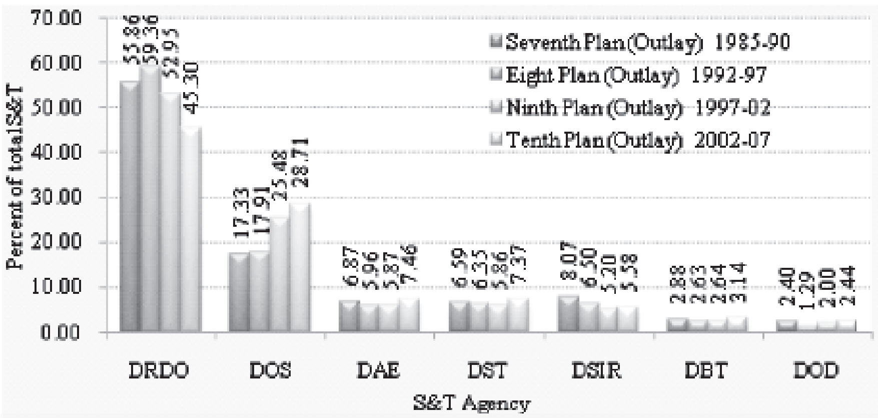


Fig 2-01.01: Sectoral Composition of Expenditure against Gross Budgetary Support of Central Plan for Science &Technology (Seventh to Tenth Plan)

***Note:** In case of DRDO the figures pertain to R&D expenditure and these figures have been compiled from the information as provided in the Report of Standing Committee of Parliament for Ministry of Defence.*

***Source:** Compiled on the basis of information obtained from Planning Commission http://planningcommission.nic* expenditure of Central Scientific Departments has almost doubled with each plan period since the start of Seventh Five Year Plan, a predominant proportion of additional resources have however, gone to the three strategic sectors, namely Defence Research and Development Organization, Department of Atomic Energy and Department of Space.

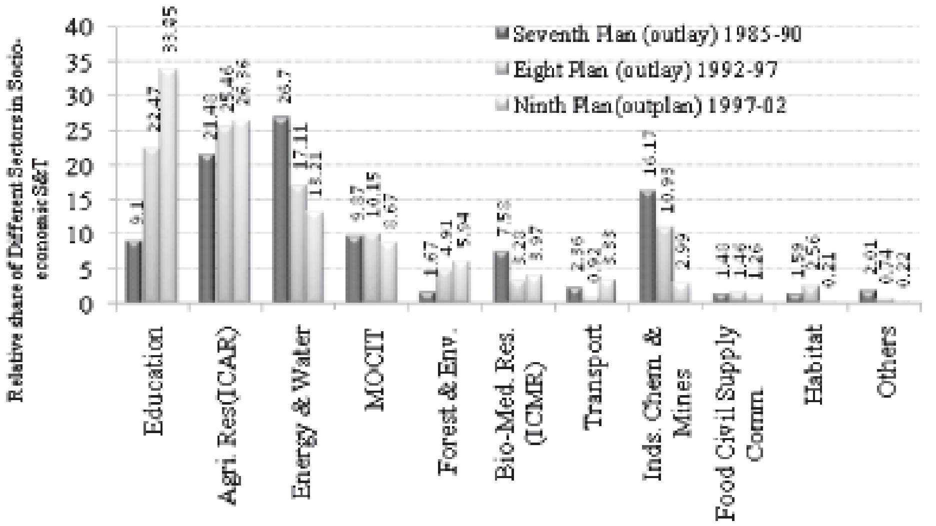


Fig 2-01.02: S&T Plan Outlays under Socio-Economic Ministries/Departments;

***Note:** In Eighth Plan: @: Excluding Khadi and Village Industries, *: Figures estimated on the basis of 1992-93 Outlay, **: Excluding Nutrition; In Ninth plan: *: It is estimated on the basis of 9th plan anticipated expenditure. & in Tenth plan *: Budget Estimate*

***Source:** Compiled on the basis of information obtained from Planning Commission http://planningcommission.nic.in*

It is also clear from the assessment of shares of civilian and strategic S&T in the most recent allocations that India's predominant proportion of R&D expenditure to the tune of 63.8% by the government is consumed by strategic sectors namely, Defence Research and Development Organization (30.3%), Department of Atomic Energy (12.2%) and Department of Space (21.3%). The civilian S&T agencies which draw priority in terms of R&D funding concern Council of Scientific and Industrial Research (9.3%) and Indian Council of Agricultural Research (13.5%) which adds up to 22.8%. The remaining around 15% of the total central government expenditure is accounted for by biotechnology, information and communication technology (ICT), ocean development, non-conventional and renewable energy sources, medical research and environment and forests. It may be mentioned that the least funded research council continues to be the Indian Council of Medical Research.

Further, this analysis of the progress of plan outlays allocated to different socio-economic objectives indicates a decline for the sectors of energy and water, information and communication technology, habitat, industry, mines and chemicals. Furthermore, when we characterize the Gross Expenditure on R&D (GERD) by objectives, the broad socio-economic objectives constitutes around 32%. The remaining objectives can be said to be closer to the goals of advancement of science and technology areas and related fields. See Table 2-01.02 for the patterns of changes experienced in respect of R&D objectives during the last decade of the nineties.

Table 2-01.02: Changing Patterns of Objectives of National R&D Expenditure

R&D Objectives	R&D exp by objectives in 92-95 average % terms	R&D exp by objectives in 2002-03 in % terms
Defence	17.24	18.3
Exploration & assessment of earth, seas, atmosphere & space	12.87	12.1
Development of Agriculture, Forestry & Fishing	18.07	17.7
Promotion of Industrial Development	14.27	12.1
Development of Energy, Transportation & communication	9.63	11.3
Development of health services & environment	10.73	11.7
R&D expenditure by objectives	1992-95 average in % terms	2002-03 in % terms
General Advancement of Knowledge & Educational Services	6.74	11.6
Others	10.45	5.2

Source: *Compiled on the basis of information obtained from Planning Commission http://planningcommission.nic.in*

Figure 2-01.03 outlines the trend of allocation of outlay and actual expenditure incurred by the State S&T departments. In the leading states of Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, Himachal Pradesh, Haryana, Rajasthan and Punjab, allocations made to the state S&T

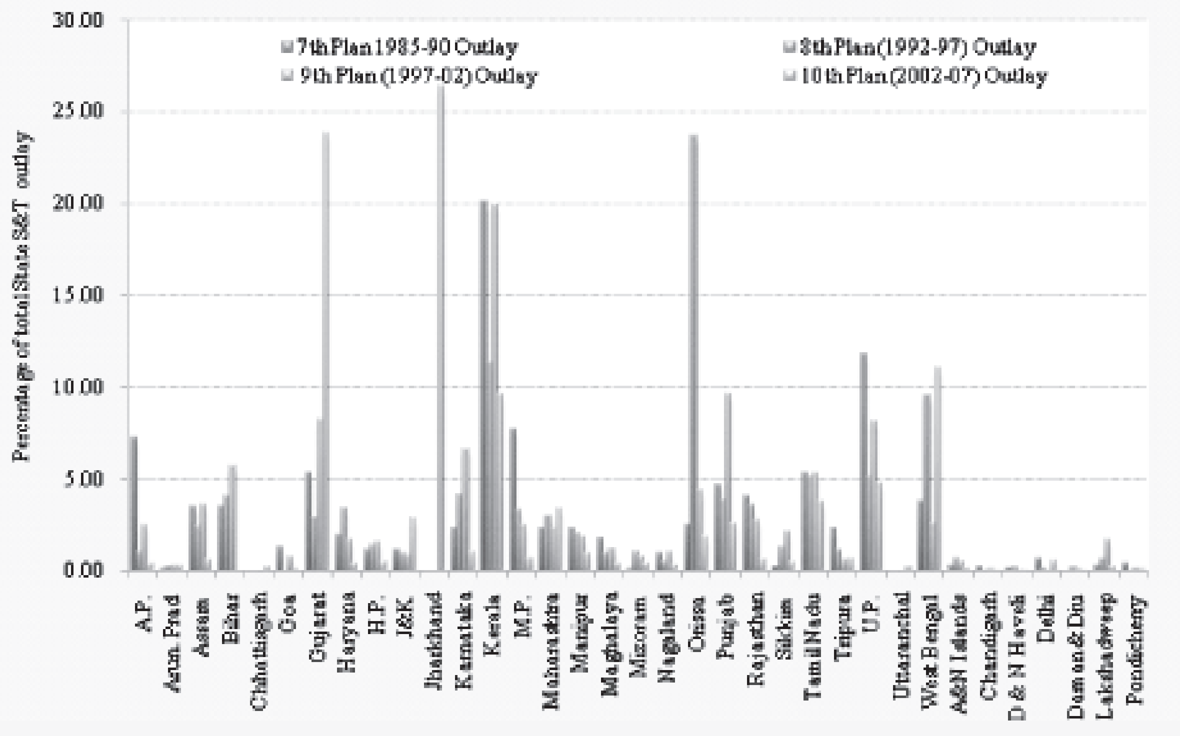


Fig 2-01.03: State Plan Outlays under S&T Sector

Source: *Compiled on the basis of information obtained from Planning Commission http://planningcommission.nic.in* sector have declined in the Tenth Five Year Plan. The states that have picked up are Gujarat, West Bengal and Maharashtra.

Financial Resources for R&D

The National Expenditure on R&D increased from 18,088.16 crores in 2002-03 to Rs. 28776.65 crores in 2005-06. The projected R&D expenditure would attain a level of Rs. 32,941.64 crores in 2006-07 and Rs. 37,777.90 crores in 2007-08.

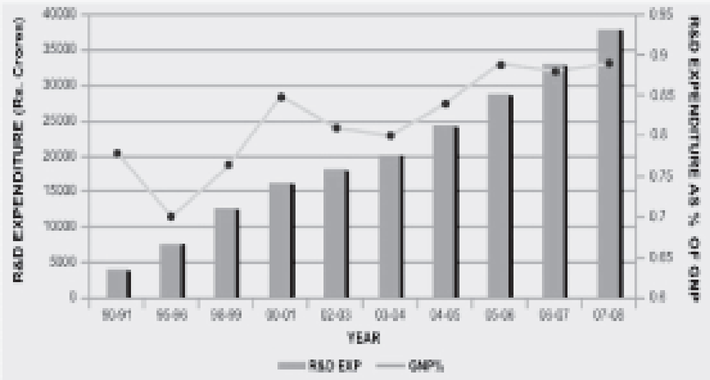


Fig 2-01.04: National R&D expenditure and its percentage to GNP

Source: R&D Statistics at glance 2007-08, www.dst.gov.in

R&D Expenditure as percentage of Gross National Product (GNP) in 2005-06 was 0.89% as compared to 0.81% in 2002-03, which is an improvement over the trend witnessed earlier during the period of nineties. See Fig 2-01.04 for the pattern of changes in the national expenditure on R&D as a percentage of Gross National Product (GNP).

However, when compared with rest of the world, India still lags behind the emerging economies of Brazil, China and Russia in respect of the R&D expenditure as a percentage of GDP. We have given in Table 2-01.03 a comparative assessment of the current level of per capita national R&D expenditure in the case of BRIC group of countries which also shows that the country is spending far less than others on R&D. Further, even when we compare the evolution of national R&D expenditure as a percentage of GDP over time in the case of developed and developing countries, it is obvious that the momentum is still not encouraging enough to allow the country to catch up with rest of the world. See Table 2-01.04 for a relative assessment of the pattern of change in the level of national expenditure on R&D over time in the case of both developed and developing countries. See also Fig 2-01.05 for the latest available figures providing a comparison of resources allocated to R&D in developed and developing countries.

Table 2-01.03: National Expenditure on R&D: A Comparative Assessment

Name of the Country	Per capita R&D Expenditure in US $
Brazil	22.55
Russia	24.91
India	3.53
China	12.15

Source: UNESCO 2005

Pattern of Changes in the Annual Rates of Change of R&D Expenditure: Though in absolute terms the R&D expenditure has shown an increasing trend, the R&D expenditure as percentage of GNP is failing to keep pace with the growth of gross national product. The annual rate of change of R&D expenditure suffered a persistent decline. It declined in nominal as well as real terms. The annual rate of change of R&D expenditure at constant prices declined from 20% in 84-85 to 1% in 94-95 and from 10.96 % in 96-97 to

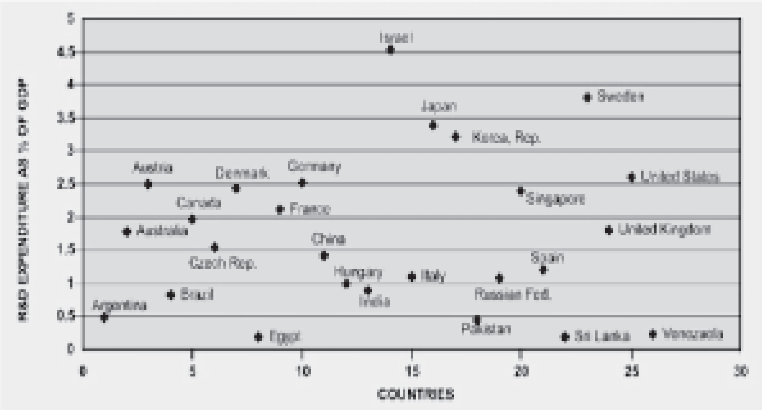


Fig 2-01.05: R&D Expenditure as percent of GDP for selected countries 2004-07

Note: *The year of information available for different countries varies between 2004-05 and 2006-07.*

Source: *R&D Statistics at glance 2007-08, www.dst.gov.in*

Table 2-01.04: Pattern of Change in R&D as a % of GDP over Time: A Relative Assessment

Name of Country	1991	1995	2000	2003
USA	2.72	2.51	2.76	2.62
Germany	2.52	2.25	2.49	2.5
France	2.37	2.31	2.18	2.2
Japan	2.93	2.89	2.99	3.12
Korea	1.92	2.5	2.65	2.96
Taiwan	-	1.78	2.05	2.16
China	0.74	0.6	1.0	1.23
Brazil	0.46	0.69	1.05	1.04
India	0.78	0.76	0.86	0.81

Source: *National Bureau of Statistics/Ministry of Science & Technology, 2004, China, Beijing China Statistics Press, p 385*

6.43% in 2003-04. While the annual rate of change grew somewhat in the latter period of nineties, but the increases obtained in the rate of growth were not momentous enough to allow the country to catch up in respect of R&D expenditure with the other emerging economies.

Sectoral Contributions: Although the share of Central Government itself declined from 79% to 71% in percentage terms, it remains even today a major source of funds for the conduct of R&D activities in India. Of course, the private sector is certainly a bigger contributor to national R&D expenditure than it was ever in the past. See Fig 2-01.06 for the details of sectoral contribution of private sector to R&D expenditure over time.

In 1985-86, the private sector accounted for 12.8% of GERD. It increased to 20.3% in 2002-03 and witnessed a decline to 19.00 % of GERD in 2004-05. See Table 2-01.05 and 2-01.06 for the evidence of changes in the pattern of growth of R&D expenditure during the decade of nineties. The share of private

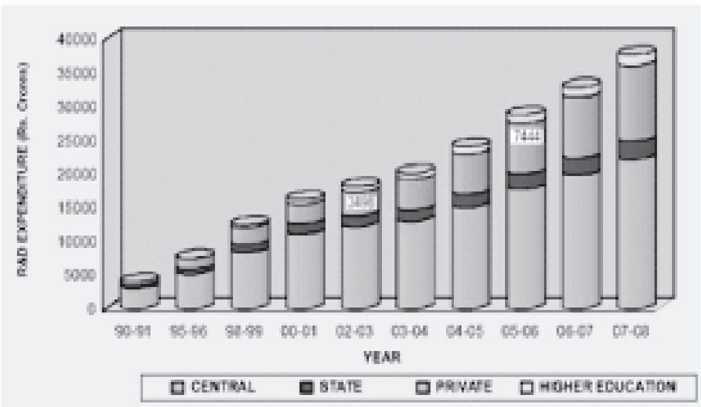


Fig 2-01.06: Sector-wise Growth of R&D Expenditure

Source: *R&D Statistics at glance 2007-08, www.dst.gov.in*

Table 2-01.05: Decline in National R&D Intensity 1985/86-2003/04 (Post-Reform Period)

Period	R&D expenditure as a % of GNP / GDP
85-86	0.89 /0.88
90-91	0.79/0.78
91-92	0.78/0.77
96-97	0.72/0.72
97-98	0.77/0.76
2003 /04	0.79/0.78

Source: *R&D Statistics, MOST*

sector is however still fluctuating. Furthermore, the contribution of private sector industry approximately works out to only 0.15% of GDP. In terms of the significance of increase in the contribution of private sector R&D expenditure, it may also be kept in mind that today the share of private sector industrial units accounts for 81.9%.

During the period of reforms, the observed increase in the share of financial support to R&D by private sector industry is linked to the declining share of financial support to R&D by public sector. There was a major decrease in the proportion of national R&D expenditure incurred by the public sector. This share was close to 10% between 85-86 & 94-95, which in 2002-03 was down to the meagre figure of 4.5%. Only 0.26% of Sales Turnover (STO) was spent on R&D in 2002-03 for public sector. Industrial sector as a whole accounted for 21.8 % of total investment in 85-86, 26.4% of total investment on R&D in 94-95 & 24.8% of total investment on R&D in the country during 2002-03. However, when we assess the trend in relation to GNP, it turns out that while the industrial sector spent 0.38% of GNP on R&D during 1985-86, its current expenditure on R&D by industrial sector is down to 0.20% of GNP.

This is in spite of the fact that during the decade of nineties the agencies such as Council of Scientific and Industrial Research, which houses over 37 laboratories, DST, DSIR, Department of Electronics and Department of Biotechnology among others, promoted science and industry links far more vigorously compared to academic sector of research system. DSIR has initiated several research programmes to forge science and industry links. Trained manpower for in-house R&D at the leadership level was also provided in many cases to private sector from these institutions only. Even it also does not augur well for the growth of public-private sector partnerships for R&D. But there is no systematic data available on the private extramural research expenditure. There are two types of private extramural R&D funds being given to the public research systems. One type is the mode of funding from Indian private business enterprises and industry to the S&T agencies such as CSIR and universities. For instance, in the case of CSIR, external industrial funding to CSIR increased from 60.7 crores in 1997-98 to 255 crores in 2003-04.

Table 2-01.06: Changes in the Sectoral Contribution of National Expenditure on R&D (In Percent)

Year	Central Govt. including Public Sector & Higher Education	State Sector	Private Sector
1985-86	79.95	7.87	12.18
1994-95	74.96	8.63	16.41
2002-03	71.20	8.50	20.3%
2004-05 (estimated)	72.00	9.00	19.00

Source: DST

Fig 2-01.07 outlines the shares of different states to scientific and agricultural research. The contribution of expenditure incurred on state sector research institutions is concerned.

Financial Resources for Project Funding

Extra-mural project funding is the second most important allocation mechanism for public research funding alongside intra-mural institutional funds allocated to research organizations and universities. Its share in the overall funding is only four percent in India. In most European countries, it covers between a quarter and a third of total public research funds. In 2007, the total budget for this source of project funding was about 350 crore rupees. In terms of focus, during the year 2007 much of the SERC funding was to go to nano science

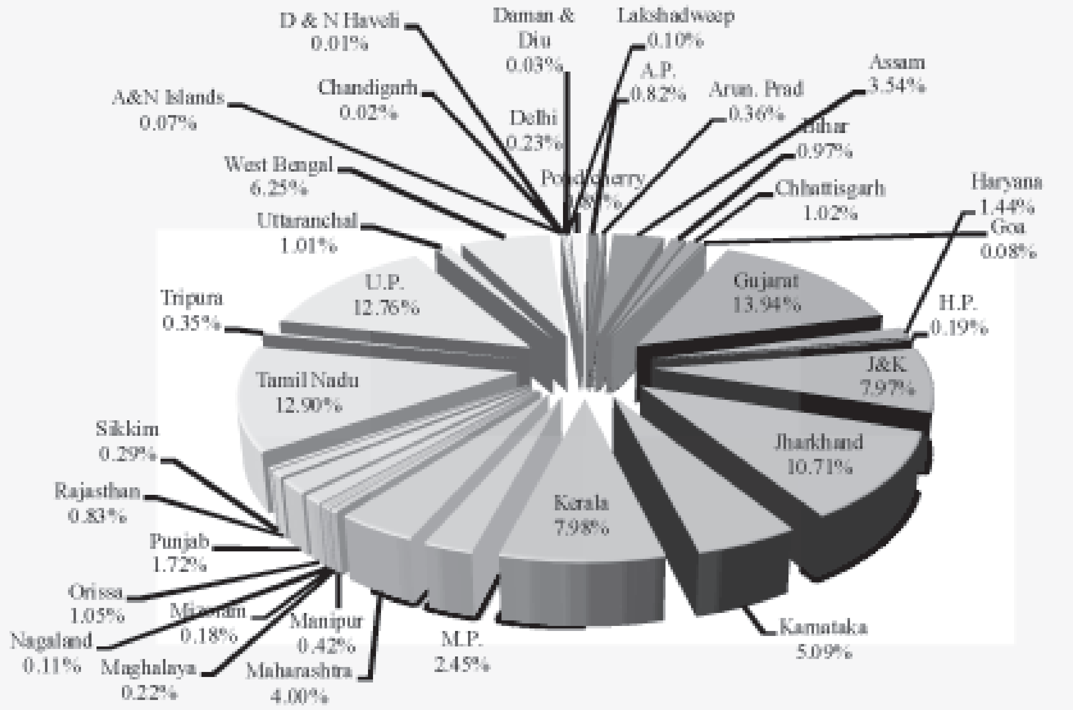


Fig 2-01.07: State-wise Total Research Investment in Tenth Plan Outlay (2002-07)

Note: Total *Research Investment = Agriculture & Research Education + Scientific Research*

Source: *Compiled on the basis of information obtained from Planning Commission http://planningcommission.nic.in*

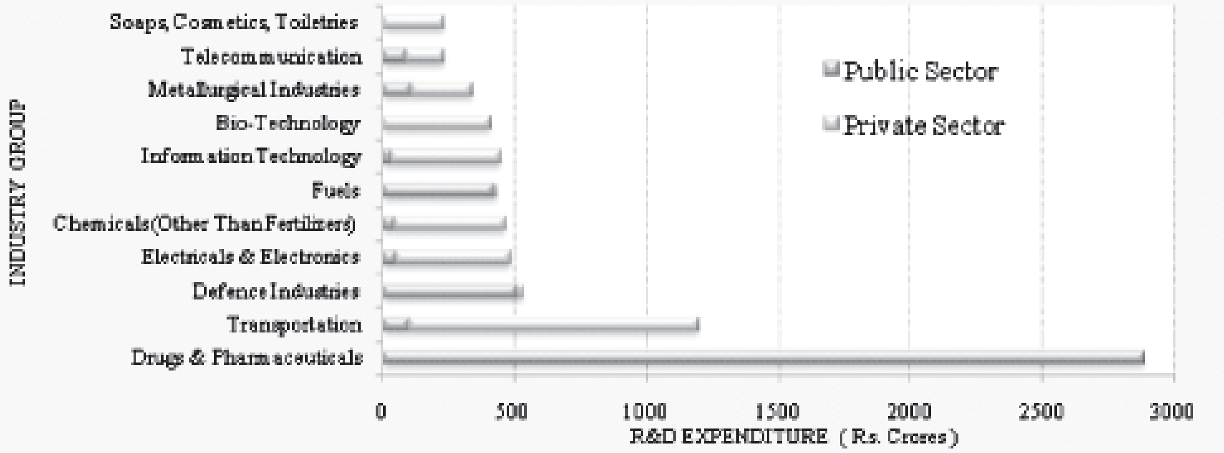


Fig 2-01.08: R&D Expenditure by Leading Industry Groups, 2005-06

Source: *R&D Statistics at glance 2007-08, www.dst.gov.in*

and technology field of studies. Below we analyze in detail the portfolio of managing agencies, the funding instruments, the categories of beneficiaries and the disciplines benefiting from extramural funding. For the managing agencies, we used a simple classification between national government administration offering support to strategic and generic S&T through ministries, intermediary agencies including agencies with higher level of autonomy from the state (research councils) and councils/commissions with the mandate for providing support to higher and technical education and user departments.

The number of extramural R&D projects supported by scientific agencies increased from 2,718 in 2002-03 to 3,569 in 2005-06. The extramural R&D support by scientific agencies increased from Rs. 448.69 crores in 2002-03 to Rs. 1,163.80 crores in 2005-06. The maximum extramural support for R&D of Rs. 572.11 crores (49.2%) was given by DST. This was followed by DBT with extramural R&D support of Rs. 174.73 crores. The Department of Science and Technology, Ministry of Communications & Information Technology (MCIT) and Department of Bio-technology (DBT) were the three agencies which provided 80% of the total extramural R&D support during 2005-06. In India, the share of extramural funding in the overall funding is

Table 2-01.07: Department/Agency–wise Support to Extramural Projects during 1990-2006

Department/ Agency	1990-95		1995-2000		2001-2006	
	Number of Projects	Total Approved Cost (Rs. crore)	No. of Projects	Total Approved Cost (Rs. crore)	No. of Projects	Total Approved Cost (Rs. crore)
Scientific	3104	339.34	3948	556.44	6783	1894.27
%	45.71	61.96	43.23	41.48	48.17	61.59
Socio-economic	3063	169.07	4348	693.01	6106	942.43
%	45.11	30.89	47.61	51.63	43.36	30.66
Strategic	624	39.23	838	92.52	1194	238.86
%	9.19	7.17	9.18	6.89	8.48	7.77
Total	6791	547.64	9134	1341.97	14083	3075.56

Note: *: Department of Education (DOED), **: Department of Electronics (DOE), @: Ministry of Information Technology (MIT), @@: Department of Ayurveda, Yoga & Naturopathy, Unani, Siddha & Homeopathy (AYUSH)

Source: Compiled from the annual reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI

at the moment just seven percent of expenditure on S&T by Central Scientific Departments. In fact, it has only decreased from the earlier level of nine percent of total public research funds. In most European countries, it covers between a quarter and a third of total public research funds. Further, it can be seen from Table 2-01.07 that the strategic departments receiving close to 63.8% of the S&T outlays provide only 7.77% of the total EMR funds and this share has only marginally improved in the latest period of 2001-2006. Similarly, even in the case of Socio-Economic Ministries the share of EMR funds is also small and decreasing.

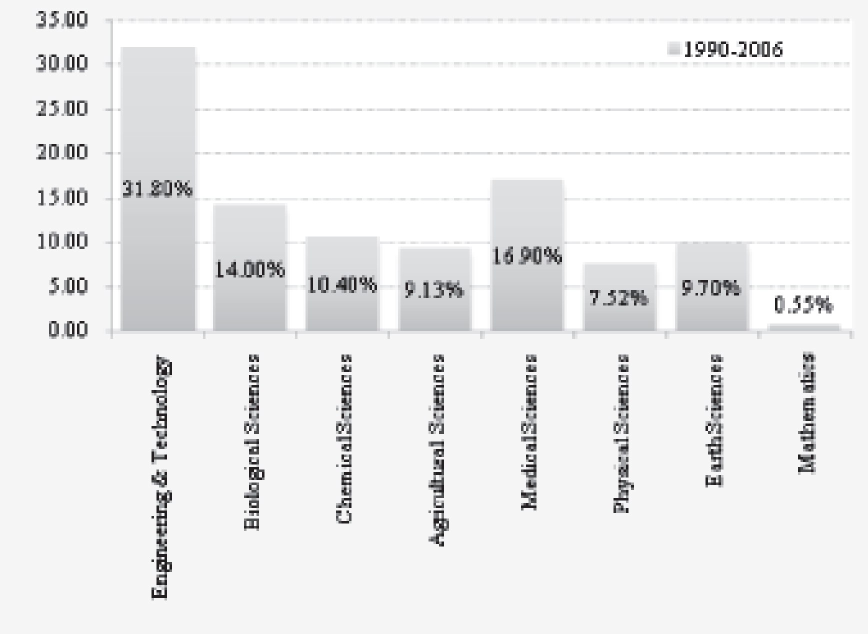


Figure 2-01.09: Total Approved cost Rs. 4964.99 crores

Source: Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI

An important aspect of the extramural funding is the issue of changing relative shares of funds received by the different types of disciplines. See Table 2-01.08 and Fig 2-01.09 for the progress regarding the changing relative shares in respect of different disciplines. The relative shares have been stable for most of the fields of natural sciences in the nineties. The fields of engineering and technology received maximum support during the period of 1990-2006. Medical Sciences had the next highest share of 16.90% during the period of 1990-2006. Biological Sciences received the next highest share of 14% during the period of 1990-2006. Chemical Sciences received a share of over 10% during the period of 1990-2006. Agricultural and Earth Sciences received the next highest level of share of over 9%. Physical Sciences took a share of about 7.50% during the period of 1990-2006. Mathematical Sciences received the lowest relative share of 0.55% during the period of 1990-2006.

Table 2-01.08: Subject Area-Wise Distribution of Extramural R&D Projects and their Approved Cost during the Year 1990-91 to 2005-2006

Subject	1990-91 to 1994-95		1995-96 to 1999-00		2001-02 to 2005-06	
	No. of Projects	Total Approved Cost (Rs. In crores)	No. of Projects	Total Approved Cost (Rs. In crores)	No. of Projects	Total Approved Cost (Rs. In crores)
Agricultural Sciences	799 (11.8%)	64.06 (11.7%)	882 (9.6%)	125.63 (9.4%)	1273 (9.0%)	263.76 (8.6%)
Engineering & Technology	1433 (21.1%)	156.44 (28.6%)	2779 (30.5%)	504.04 (37.5%)	2985 (21.2%)	918.39 (29.9%)
Medical Sciences	865 (12.8%)	40.64 (7.4%)	881 (9.6%)	90.20 (6.7%)	2037 (14.5%)	708.79 (23.0%)
Natural Sciences						
Biological Sciences	1660 (24.4%)	155.67 (28.4%)	1820 (20.0%)	206.70 (15.4%)	2625 (18.6%)	332.47 (10.8%)
Chemical Sciences	789 (11.6%)	34.52 (6.3%)	1141 (12.5%)	138.52 (10.3%)	2173 (15.4%)	343.37 (11.1%)
Earth Sciences	532 (7.8%)	45.70 (8.3%)	688 (7.5%)	180.68 (13.5%)	1322 (9.4%)	254.97 (8.3%)
Mathematics	97 (1.4%)	3.80 (0.7%)	149 (1.6%)	5.33 (0.4%)	365 (2.6%)	17.92 (0.6%)
Physical Sciences	616 (9.1%)	46.81 (8.6%)	794 (8.7%)	90.69 (6.8%)	1303 (9.3%)	235.89 (7.7%)
Total	**6791 (100%)**	**547.64 (100%)**	**9134 (100%)**	**1341.97 (100%)**	**14083 (100%)**	**3075.56 (100%)**

Source : *Compiled from the reports obtaining for the relevant period an extramural R&D funded projects,NSTMIS, DST, GOI*

The relative shares of different sciences are stable; the only area showing spurt is medical sciences. The share of medical sciences jumped from 6.7% during 1995-2000 to 23 % during 2001-2006. In terms of number of projects being supported through extramural funding, the trend of rapid growth in biological and medical sciences is also a noteworthy feature. The average cost of projects is on the rise in all fields. In the fields of engineering and medical sciences, it is in the range of about 30 lakhs. See Fig 2-01.10 for the details of changing relative cost of projects in different scientific disciplines.

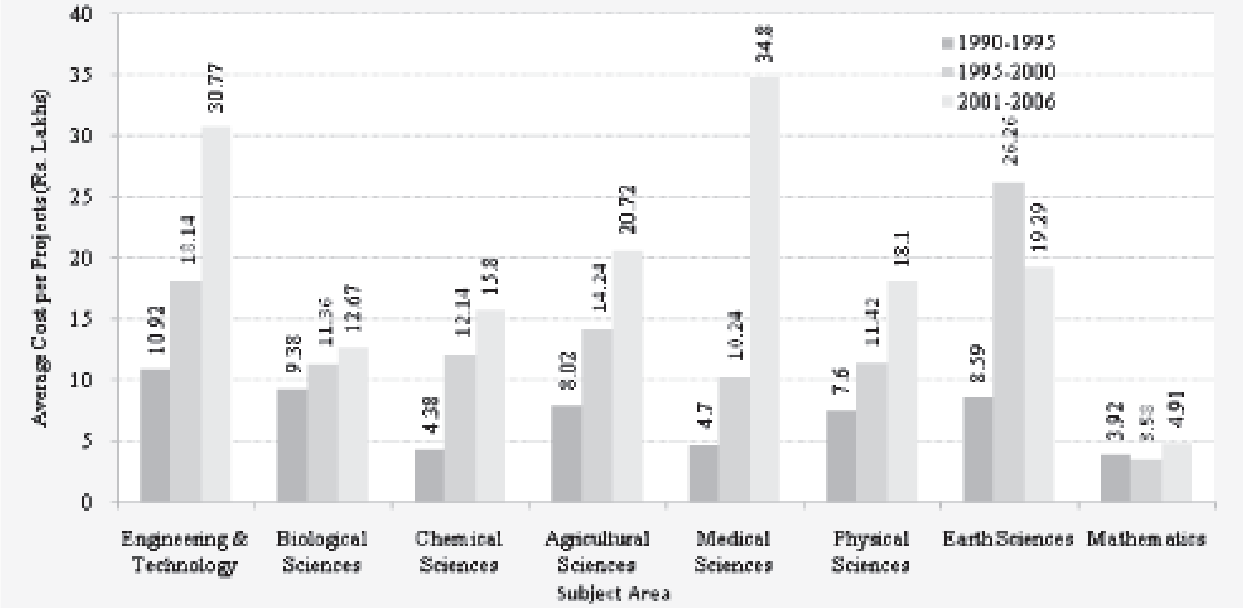


Figure 2-01.10 Changing relative Cost of Projects in different Scientific Disciplines

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

Table 2-01.09: Distribution of Extramural R&D Projects by types of Institutes and their Approved Cost during the Year 1990-91 to 2005-2006

Types of Institutes	1990-95		1995-2000		2001-2006	
	Number of Institutes	Total Approved Cost (Rs. crores)	Number of Institutes	Total Approved Cost (Rs. crores)	Number of Institutes	Total Approved Cost (Rs. crores)
Universities/Colleges	576 (52.6%)	195.09 (35.6%)	836 (56.1%)	426.07 (31.7%)	2046 (53.4%)	1012.73 (32.9%)
Deemed Universities	16 (1.5%)	45.92 (8.4%)	24 (1.6%)	84.39 (6.3%)	127 (3.3%)	225.92 (7.3%)
Institutes of National Importance	9 (0.8%)	66.69 (12.2%)	11 (0.7%)	131.26 (9.8%)	56 (1.5%)	371.26 (12.1%)
National Laboratories	233 (21.3%)	184.94 (33.8%)	274 (18.4%)	569.71 (42.5%)	680 (17.7%)	842.02 (27.4%)
Others	261 (23.8%)	55.00 (10.0%)	346 (23.2%)	130.35 (9.7%)	923 (24.1%)	623.64 (20.03%)
Total	**1095 (100%)**	**547.64 (100%)**	**1491 (100%)**	**1341.79 (100%)**	**3832 (100%)**	**3075.57 (100%)**

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

Another very important dimension of the extramural funding is the issue of changing relative shares of funds received by the different types of performing institutions with different kinds of research cultures. See Table 2-01.09 and Fig 2-01.11 for the pattern of distribution of extramural R&D in terms of number of projects & approved cost by types of research performing institutions during the Year 1990-91 to 2005-2006. In respect

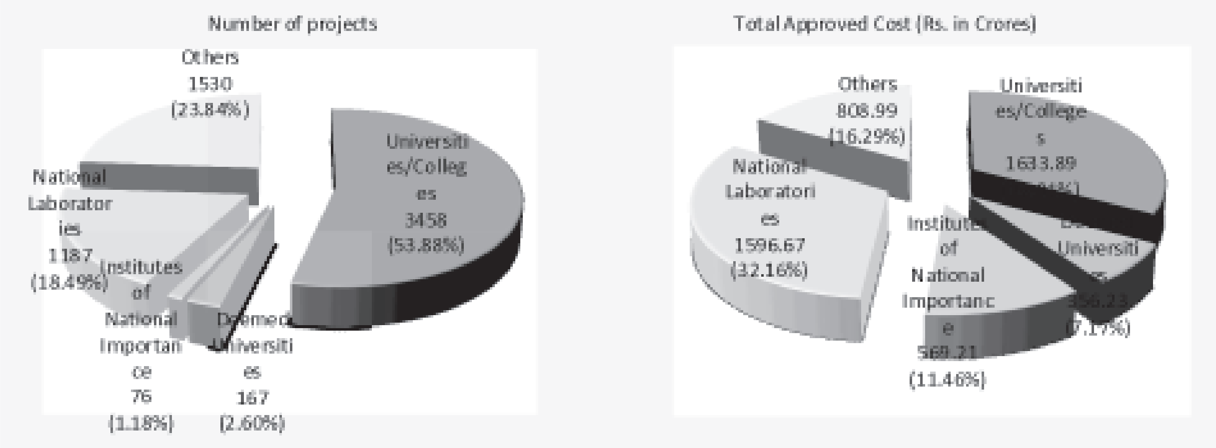


Figure 2-01.11: Distribution of Extramural R&D Number of Projects & Approved Cost by types of Institutes during the Year 1990-91 to 2005-2006

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

Table 2-01.10: Distribution in Subject & Institute-wise Investment in Extramural R&D projects during the Year 2001-02 to 2005-06. Cost (Rs. in Lakh)

Subject/ Institution	University/ College	Deemed University	Inst. Natnl. Importance	Natnl. Laboratories	Others	Total
Agricultural Science	14456.86	2277.33	493.50	7642.80	1802.40	**26672.89**
%	**54.20**	**8.54**	**1.85**	**28.65**	**6.76**	**100.00**
Biological Science	15519.99	4981.23	1614.69	9204.84	1918.89	**33239.64**
%	**46.69**	**14.99**	**4.86**	**27.69**	**5.77**	**100.00**
Chemical Science	10687.43	3793.17	7550.25	9144.25	2164.60	**33339.70**
%	**32.06**	**11.38**	**22.65**	**27.43**	**6.49**	**100.00**
Earth Science	8225.28	954.45	2032.46	9553.26	4689.64	**25455.09**
%	**32.31**	**3.75**	**7.98**	**37.53**	**18.42**	**100.00**
Engineering &Technology	14374.06	14601.97	23763.16	26598.04	12528.28	**91865.51**
%	**15.65**	**15.89**	**25.87**	**28.95**	**13.64**	**100.00**
Medical Science	14999.34	4497.39	9914.96	24638.87	15907.04	**69957.60**
%	**21.44**	**6.43**	**14.17**	**35.22**	**22.74**	**100.00**
Mathematical Science	998.93	269.79	436.20	67.45	19.35	**1791.72**
%	**55.75**	**15.06**	**24.35**	**3.76**	**1.08**	**100.00**
Physical Science	9565.24	3544.87	5366.78	5202.52	656.39	**24335.80**
%	**39.31**	**14.57**	**22.05**	**21.38**	**2.70**	**100.00**

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

of the magnitude of total approved costs during the period of 1990-2006, while the share of project funds received by universities and colleges is highest it is the institutes of national importance that top the highly skewed pattern of project funds being made available through extra-funds to the institutions with different kinds of research cultures. The institutions belonging to the category of national laboratories receives the next highest share.

The share of category of others which includes industry and NGOs is increasing. In the latest period of 2001-06, the share of others in project funds was close to 20%. See Table 2-01.10 for the details of the pattern of changing relative shares of different kinds of research performing institutions. See also Table 2-01.11 for the pattern of distribution of extramural funding in the issue of changing relative shares of funds received in different disciplines by the different types of R&D performing institutions.

The share of national government administration offering support to strategic and generic S&T through ministries in extramural funding increased from 55.08% during 20% 1995-2000 to 64.26% during 2001-2006. The share of intermediary agencies with higher level of autonomy from the state (research councils) and councils/commissions with mandate for providing support to higher and technical education declined from 24.40 % during 1995-2000 to 15.30 % during 2001-2006. The share of user departments too declined but by a smaller margin. It decreased from 20.82% during 1995-2000 to 19.40% during 2001-2006.

Table 2-01.11: Distribution in Subject & Source-wise Investment in Extramural R&D projects during the Year 2001-02 to 2005-06. Cost (Rs. in Lakh)

Subject/ Institution	Among S&T Agencies	Higher Educational Department	Among User Departments	Total
Agricultural Science	13304.17	287.53	781.27	**14372.97**
%	**92.56**	**2.00**	**5.44**	**100.00**
Biological Science	28160.52	2940.77	2138.35	**33239.64**
%	**84.72**	**8.85**	**6.43**	**100.00**
Chemical Science	**30375.14**	**1793.72**	**2170.84**	**34339.70**
%	**88.45**	**5.22**	**6.32**	**100.00**
Earth Science	20752.65	613.00	4089.44	**25455.09**
%	**81.53**	**2.41**	**16.07**	**100.00**
Engineering &Technology	42581.36	9292.23	39991.92	**91865.51**
%	**46.35**	**10.12**	**43.53**	**100.00**
Medical Science	64557.11	1595.83	3804.66	**69957.60**
%	**92.28**	**2.28**	**5.44**	**100.00**
Mathematical Science	1032.66	759.06	0.00	**1791.72**
%	**57.64**	**42.36**	**0.00**	**100.00**
Physical Science	22720.41	1539.63	75.76	**24335.80**
%	**93.36**	**6.33**	**0.31**	**100.00**

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

The mapping and classification of instrument types proved to be more difficult and (because a number of instruments are, at the level of aggregation considered with extramural R&D funding) rather heterogeneous. We resort to a classification distinguishing three types of specific cases: academic oriented, theme oriented (where themes are defined from the beginning) and innovation oriented. See Table 2-01.12 for the pattern of evolution of extra mural research supported under different instrument types during the period 2001-2006. While considering the quantitative importance of the instrument types, the share of academic-oriented instruments is over 42%. Theme-oriented instruments account for 47% of the total. Innovation-oriented instruments account for only 1% of the total. In European countries, the share of academic-oriented instruments varies from more than 40% for Switzerland to little more than 20% for Austria, Italy and Norway. Innovation-oriented instruments account for 40% of the total in Austria, 20% in Italy, 17% in Norway, but less than 10% in France and Switzerland.

Declining share in project funds in respect of the contribution of CSIR system, a research council to the system of Universities and Colleges is an emerging feature. Intermediary organizations are now far less important to universities and colleges in respect of project funds. Since the research councils have been overtaken by the ministries and departments in project funds as well as total approved costs, the pattern of links of national laboratories with research institutes can be expected to undergo some changes. Further, although the spread of distribution of project funds in respect of universities and colleges is far more now, the pattern of distribution of project funds is still highly skewed in favor of selected Central Universities and Institutes of National Importance. Among the Central Scientific Departments, the share of departments giving support to generic fields in the contribution to universities and colleges is on the rise. There has been little improvement in the share of strategic science and technology departments in the contribution to universities and colleges in project funds.

Table 2-01.12: Scope & Objective-wise Support to Extramural R & D Projects Approved during 2001-02 to 2005-06.

Schemes	No. of Projects	Total Approved Cost (Rs. crores)
2001-02		
Thematic	1080 (46.9%)	294.17 (66.1%)
Academic	1200 (52.1%)	142.91 (32.1%)
Innovation	24 (1.0%)	7.88 (1.8%)
Total	***2304 (100%)***	***444.96 (100%)***
2002-03		
Thematic	1300 (47.8%)	306.15 (68.2%)
Academic	1391 (51.2%)	134.19 (29.9%)
Innovation	27 (1.0%)	8.35 (1.9%)
Total	***2718 (100%)***	***448.69 (100%)***
2003-04		
Thematic	1314 (47.9%)	325.62 (72.7%)
Academic	1400 (51.0%)	109.26 (24.4%)
Innovation	29 (1.1%)	12.74 (2.9%)
Total	***2743 (100%)***	***447.62 (100%)***
2004-05		
Thematic	1355 (49.3%)	431.77 (75.7%)
Academic	1376 (50.0%)	133.18 (23.3%)
Innovation	18 (0.7%)	5.54 (1.0%)
Total	***2749***	***570.49***
2005-06		
Thematic	1613 (45.2%)	913.49 (78.5%)
Academic	1916 (53.7%)	220.34 (18.9%)
Innovation	40 (1.1%)	29.97 (2.6%)
Total	***3569 (100%)***	***1163.80 (100%)***
2001-02 to 2005-06		
Thematic	6662 (47.3%)	2271.19 (73.8%)
Academic	7283 (51.7%)	739.88 (24.1%)
Innovation	138 (1.0%)	64.49 (2.1%)
Total	**14083 (100%)**	**3075.56 (100%)**

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

Across the fields and different scientific disciplines, the contribution of strategic science and technology departments to universities and colleges is lower than even the research councils. Only in the field of physical sciences their contribution to universities and colleges in the project funds is significant.

But what is equally of concern is that the share of top ten institutions from EMR funds is itself about 23% and there has been only one new entrant into the league of top ten institutions over the period of last fifteen years (Table 2-01.13).

Table 2-01.13: Top 10 Institutions by Number of Projects during 1990-91 to 94-95, 1995-96 to1999-00 & 2001-02 to 2005-06

Institutions	1990-91 to 94-95		Institutions	1995-96 to1999-00		Institutions	2001-02 to 2005-06	
	No. of Projects	Total Approved Cost (Rs crores)		No. of Projects	Total Approved Cost (Rs crores)		No. of Projects	Total Approved Cost (Rs crores)
IISc, Bangalore	260 (3.8%)	29.37 (5.4%)	IISc, Bangalore	335 (3.7%)	57.19 (4.3%)	IISc, Bangalore	449 (3.2%)	202.15 (6.6%)
IIT, Bombay	183 (2.7%)	13.40 (2.4%)	IIT, Bombay	230 (2.5%)	29.78 (2.2%)	IIT, Kharagpur	346 (2.5%)	70.50 (2.3%)
BHU	176 (2.6%)	9.29 (1.7%)	IIT, Kanpur	197 (2.2%)	19.95 (1.5%)	IIT, Kanpur	287 (2.0%)	104.10 (3.4%)
IIT, Delhi	148 (2.2%)	14.43 (2.6%)	IIT, Delhi	191 (2.1%)	21.18 (1.8%)	IIT, Bombay	268 (1.9%)	95.79 (3.1%)
AIIMS	147 (2.2%)	9.55 (1.7%)	Jadavpur Univ.	171 (1.9%)	13.00 (1.0%)	IIT, Delhi	226 (1.6%)	51.97 (1.7%)
IIT, Kanpur	132 (1.9%)	9.38 (1.7%)	BHU	153 (1.7%)	11.79 (0.9%)	Jadavpur Univ.	211 (1.5%)	30.03 (1.0%)
Delhi Univ.	109 (1.6%)	8.72 (1.6%)	AIIMS	160 (1.7%)	16.49 (1.2%)	AIIMS	206 (1.5%)	42.06 (1.4%)
IIT, Madras	104 (1.5%)	8.57 (1.6%)	IIT, Kharagpur	150 (1.6%)	16.74 (1.2%)	Delhi Univ.	206 (1.5%)	52.94 (1.7%)
IIT, Kharagpur	97 (1.4%)	7.04 (1.3%)	Roorkee Univ.	143 (1.5%)	17.61 (1.3%)	IIT, Madras	195 (1.4%)	45.35 (1.5%)
Osmania Univ.	91 (1.3%)	5.15 (0.9%)	IIT, Madras	126 (1.4%)	14.72 (1.1%)	BHU	188 (1.3%)	34.39 (1.1%)
Total	1447 (21.3%)	114.90 (21.3%)	Total	1856 (20.3%)	218.45 (16.3%)	Total	2582 (18.3%)	729.28 (23.7%)

Source: *Compiled from the reports obtaining for the relevant period on extramural R&D funded projects, NSTMIS, DST, GOI*

Technology Funding by TDB

The Government of India, in 1996, enabled the placing of the proceeds of the R&D Cess Act 1985, i.e. 5% cess amount on the import of technology, into a fund called "The Fund for Technology Development and Application", in a dynamic economic environment. The R&D cess collected was Rs. 1,092.60 crores during 1996-2006, out of which Government has made available Rs. 501.42 crores to the TDB (1996-2008). To administer the funds, the Government has constituted a statutory body, called Technology Development Board (TDB), under the Department of Science and Technology. The Board has so far funded about 200 projects having a total cost of about Rs. 2,949.13 crores. It has disbursed Rs.753.81 crores as on 31 March 2008. It has provided a real opportunity to new entrepreneurs/ technopreneurs at the start up and early stages. Twenty Seven new enterprises were provided financial assistance by the Board during 2007-08. The Board plays a pro-active role encouraging commercial enterprises to take up technology-oriented projects (Table 2-01.14).

Table 2-01.14: Subject-wise Projects Funded by TDB, 1997-2008

Category	No. of Agreements	Total cost	Sanctioned
Health Medical	55	773.07	238.50
Engineering	40	328.77	108.67
Chemicals	17	127.65	41.08
Agriculture	16	90.98	29.02
Energy & Waste utilization	7	105.34	45.98
Telecommunication	10	79-79	29.35
Defence & Civil Aviation	1	8	2.20
Road Transport	10	527.04	81.20
Air Transport	2	142.10	67.80
Information Technology	26	172.56	80.50
Others	16	593.83	170.50
Total	200	2949.13	894.80

Source: *Technology Development Board, DST, 2008*

Technology Financing System in India

Technology Financing and the Innovation Support System in India is being operated by -

- The Department of Scientific & Industrial Research (DSIR), Govt. of India, for the up-scaling technologies, under its TePP and TDDP schemes, besides providing Tax-Incentives to the industry and granting of recognition to their In-house R&D Units, etc.
- The Technology Development Board (TDB), under the Department of Science and Technology, DST, for manufacturing and commercializing of all technology-based products,
- The Department of Science and Technology (DST) and Technology Information, Forecasting Assessment Council (TIFAC), as a R&D support fund for undertaking Special Projects on: Development of Instruments, and Drug and Pharmaceutical products, as well as Technology missions' projects for Sugar, Fly-ash, Advanced Composites and Bamboo.
- Indian Renewable Energy Development Agency (IREDA), under the Ministry of New and Renewable Energy, (MNRE), for the development of non-conventional sources of energy, besides energy efficiency and conservation strategies.
- Department of Bio-Technology (DBT), under SBIRI, and BIPP programmes for the development of bio-tech related products, etc, and
- Council of Scientific and Industrial Research (CSIR), New Delhi for the development and production of products and processes in the new and emerging fields, under the New Millennium India Technology Leadership Initiatives (NMITILI).

Results of TDB's Assistance: TDB's assistance has resulted in the commercialization of Hepatitis–B vaccine (Hepatitis vaccine), Interferon Alpha (Cancer Drug), Anti-infectives, Cardio-vascular drugs, Beta Carotene, Vitiligo ointment, Oncology products, Pentavalent vaccine, Handheld computer (Simputer), Ointment for diabetic ulcers, Irradiated power cable, Plasma display system, Drinking water purifiers, Industrial enzymes, Automobile diesel engine, Light transport aircraft, Battery operated car, Sedan car, Growth enhancer for crops, Automatic meter reader, Automatic automobile tracking system, etc.

Impact of TDB Funding and Societal Benefit: The impact of development and commercialization of Hepatitis-B vaccine by a new firm in Hyderabad has been dramatic. While the country was importing 2 lakh doses at a prohibitive cost of over Rs. 780 per dose during the early 1990s, today this firm alone is selling annually over 7 million doses at a price less than Rs. 50 per dose. Clearly, the society has benefited enormously from this success. It also emerges that such successes generate invaluable confidence for developing therapeutic drugs.

The country's first indigenously-built civilian aircraft, 'SARAS' recorded its maiden test flight at the HAL airport, Bangalore on 29th May 2004. TDB has provided significant financial assistance for this project.

The Reva electric car project at Bangalore and the generation of electricity using municipal garbage in Andhra Pradesh deserve special mention as these relate to environment friendly technologies.

Technology Development and Innovation Programme

This programme of the Department of Scientific and Industrial Research (DSIR), Govt. of India has two new sub-components:

Technopreneur Promotion Programme (TePP) to nurture the innovative spirits of the individual, and Technology Development and Demonstration Programme (TDDP) to support the technology development efforts of the industry – R&D System.

The efforts of the industry in technology development and demonstration of the indigenous technologies, as well as of the absorption of the imported technologies, are promoted by the Department of Scientific and Industrial Research (DSIR) under its Plan Scheme "Technology Promotion, Development and Utilization" (TPDU). The distinctive feature of the funding here is that it addresses innovations in SME's. Technology Development & Demonstration Programme (erstwhile PATSER Scheme) (TDDP) under "Technology Promotion Development & Utilization Scheme (TPDU)" gives more thrust on technology development. A distinctive feature of the Programme is that many of the projects also involve government research laboratories, IITs, IISc or Universities. Under the TDDP about 200 projects with considerable commercial potential have received support. The Scheme has been found successful in synergizing the R&D efforts of industry and national research organizations. TDDP projects have strengthened the linkages with more than 44 national research laboratories/institutions such as NAL, Bangalore; RRL, Trivandrum; IICT, Hyderabad; CMRI, Dhanbad; IIP, Dehradun; C-DAC, Pune; NML, Jamshedpur; Institute of Plasma Research, Ahmedabad; ER&DC, Trivandrum; Dalmia Centre for Biotechnology, Coimbatore; CMTI, Bangalore; etc. DSIR has also been interacting with other ministries for identification of technology development projects and, in this direction, task forces with Railways for networking and technology development in the areas of signaling/communications and electrical equipment/ power electronics have been formed. More such interactions with other economic ministries are being planned. The scheme has been successful in synergizing the R&D efforts of the industry. Fortyfive have been completed and over 35 technologies developed under the scheme have been commercialized or are under commercialization, besides, over 20 patents have been field, under filing/being scaled up which would lead to their significant commercialization in the future.

Special Technological Projects Funded by DST

The Department of Science and Technology, DST, Govt. of India, New Delhi, with a view to promoting the development and demonstration of technology, provides financial support for Instrument Development Programme, and Drug and Pharmaceutical Research.

Instrumentation Development Programme (IDP): The Department of Science and Technology (DST) initiated the IDP in 1975 with a view to indigenize the development and production of instruments, continuous updating of the technology for the instruments developed earlier; designing and development of modern advanced and novel instruments, besides establishing an S&T base and the production techniques and extend support to the developmental projects focusing on creative ways of addressing the needs of R&D labs and industrial sectors. The IDP programme has identified the following priority areas:

- Analytical Instrumentation
- Medical Instrumentation & Health Care Systems
- Industrial Instrumentation, and
- Sensors and Allied Instrumentation

So far, around 500 projects have been funded under the IDP programme, out of which 30 technologies have been transferred for commercialization by the industry. The latest technology that has been brought out to the market relates to soil testing. Around 30,000 kits have been sold in the market.

Drugs and Pharmaceuticals Research Programme (DPRP): The DST, recognizing the profound influence of undertaking R&D on the future prospects and opportunities for the growth of the Indian drug industry, initiated a programme on drug development in 1994-95 for promoting industry — R&D labs collaborative programme in drugs and pharmaceutical sectors, with the following specific objectives -

- Synergizing the strengths of publicly funded R&D institutions and Indian pharmaceutical industry, to generate the collaborative R&D projects (Public – Private Partnership)
- Creating an enabling infrastructure, mechanisms and linkages to facilitate the new drug development
- Stimulating skill development of human resource in R&D for drugs and pharmaceuticals, and
- Enhancing the national self-reliance in drugs and pharmaceuticals, especially in areas critical to national health requirements

Enterprises engaged in drug development manufacturing with national R&D labs/academic institutions can be provided with 50% cost of the project (other 50% should be borne by the industry). The DPRP supports both human and veterinary drug development for all types of medical systems – be it traditional Indian medicinal system or the modern one.

Grant-in-aid to Industry: The drug development process is highly risky, cost intensive and involves a long span of 10-15 years of continuous efforts. The major funding for the project is required at the human clinical trial plan (Phase-1 to Phase-3). Recognizing the need for the drugs that are required by the poor segment of the society, the Government of India in June 2008, approved providing Grant-in-aid to industries for the development of drugs for rejected diseases – malaria, filaria, kala-azar, TB etc. Rs.45 crores have been allocated for the 11th Five Year Plan within the existing provision of Rs. 500 crores. The budget allocation for the DPRP scheme is Rs.100 crores for 2007-08.

TIFAC's Mission-Mode Programmes: TIFAC (Technology Information, Forecasting and Assessment Council), New Delhi set up under the Union Department of Science and Technology, provides financial support to the projects, coming under the preview of the:

- Sugar Technology Mission (STM)
- Advance Composites Mission and Fly Ash Mission

The Sugar Technology Mission is a joint project of TIFAC/DST and Department of Sugar and Edible oils (Ministry of Food) Government of India, for the technology upgradation of the sugar industry; with a focus on reducing sugar loses, energy conservation, superior product quality, minimization of pollution and value addition to by-products. This is being done by the identification of technology gaps in the existing sugar factories, as well as forging strong linkages between the research institutes and the industry, etc.

The Government of India, for this purpose has identified a special scheme of concessional finance through the Sugar Development Fund of the Ministry of Food, New Delhi. The scheme provides soft loans of up to 60% of the project cost, at a simple rate of interest at 6% per annum, payable in the next 5 years with interest from the date of the first disbursement of the loan amount.

The STM has made technical appraisal/evaluation of the level of technologies already available in many sugar factories and has identified the gap areas. Modifications and value additions in plants and machinery of a few factories have been made leading to their better efficiency/performance. Technologies developed under the scheme STM are:

- Film Type Sulphur Burner
- PLC system for juice floor stabilization and control of Juice Lining and Sulphitation
- Separate clarification of vacuum filtrate.
- Syrup clarification process for the production of superior qualities sugar
- Decanter centrifuges for de-sweetening of clarifier under-flame.

These new technologies are now being replicated in 15-20 sugar factories. A dozen new promising technologies is on trial, which aim to improve the overall productivity of the sugar factories in the country.

Fly-Ash Mission is a joint activity of the Department of Science and Technology, Ministry of Power and the Ministry of Environment and Forests, New Delhi - it is being implemented by TIFAC, since 1994 with the close cooperation of thermal power plants, R&D agencies, industry, academia, government departments and ministries. It has so far financially supported 55 projects towards confidence building in fly-ash disposal and utilization technology, spread over 21 geographical sites in the country.

Gainful utilization of fly-ash has occurred in new areas like construction of roads, embankments, ash dykes reclamative of low lying areas, uses in agriculture, manufacture of bricks, blocks, pavements, tiles, wood structure, cement substitutes etc. Preparation of standards and protocols for the use of fly ash, are underway with the Bureau of Indian Standards, New Delhi.

Facilitating the Patenting System: Under the new and emerging elements in the system of technology financing and innovation support, for the management of Intellectual Property related activities under the jurisdiction of Indian Patent Act-1970 (modified in 2002, under the guidelines of Global Agreement of Trade and Traffic GATT) Patent Facilitating Centers have been set-up by the Council of Scientific and Industrial Research (CSIR) and Technology Information Forecasting Assessment Council (TIFAC), New Delhi. Fourteen Patents were granted, out of the 128 applications filed during the year 2007-08.

Development of Bio-tech Products

Small Business Innovative Research Initiative (SBIRI): The Department of Biotechnology (DBT) Government of India, with a view to realize the full potential of bio-technology launched this scheme (SBIRI) in 2005-06 for promoting the commercialization of new technologies and high-tech products in various bio-tech industries. The scheme provides early stage funding for high risk, innovative commercial product proposals. The model of a public-private partnership between industry and public funded institutes is being encouraged. The distinctive features of the scheme are to:

- Boost public–private partnership efforts and
- Support high risk, pre-proof of concept of research and late stage development of small and medium scale companies led by innovators, in lead areas of biotechnology and/or commercialization of biotech products.

The SBIRI aims to:

- Strengthen existing private industrial units where product development is based on in-house innovative R&D,
- Create opportunities for starting new technology based on knowledge-based business in biotechnology by science entrepreneurs,
- Stimulate technological innovations and product commercialization,
- Use private industry as a source of innovation and enhance greater public–private partnerships, and

- Increase product development, and commercialization in the public–private sector from government funded R&D projects.

The Department of Biotechnology has so far supported 48 projects with budget allocations of about Rs. 57 crores (2006-08), on tissue culture, aquaculture, hybrid seeds, vaccine development, bio-fertilizers and bio-pesticides. DBT has also set up a Biotech Consortium India Ltd (BCIL) – a SBIRI management agency, for promoting, transfer and commercialization of biotechnologies in India.

Renewable Energy Projects

The Ministry of New and Renewable Energy's (MNRE) policy for promotion of renewable energy broadly considers development and demonstration of technologies, facilitating institutional finance from various financial institutions, providing budgetary support for research and promoting private investment through fiscal incentives, tax holidays, depreciation allowance and remunerative returns for power fed into the grid.

The Indian Renewable Energy Development Agency (IREDA), New Delhi, set up under the Ministry of New and Renewable Energy (MNRE) provides financial assistance for the development of renewable energy sources, such as Hydro-Energy, Wind Energy, Bio-Energy, Solar Energy, New and emerging Technologies, Bio-fuel, Alternate fuels Develop-ments/activities/new initiatives, Energy efficiency and conservation.

Table 2-01.15: Sector-wise Sanctions by IREDA, 2003-08

Sectors	2003-04	2004-05	2005-06	2006-07	2007-08	Cumulative since 1987
Wind Power	121.05	204.25	261.41	266.19	426.97	3241.23
Hydro Power	122.00	176.73	17.30	160.87	226.23	2095.16
Cogeneration	58.56	77.46	0.00	116.28	68.30	1319.57
Biomass Power	58.29	32.20	89.30	0.00	0.00	706.64
Energy Efficiency & Conservation	45.03	96.73	123.32	21.30	53.73	533.21
Solar Photovoltaic's	2.96	0.00	0.00	0.00	0.00	585.95
Solar Thermal	11.43	12.36	7.00	13.00	50.92	188.03
Waste to Energy	0.00	0.00	0.00	9.19	0.00	58.33
Biomass Briquetting	0.00	0.00	0.00	0.00	0.00	12.43
Biomass Gasification	0.00	0.00	0.00	1.68	0.00	12.43
Biomethanation from Industrial Effluents	0.00	0.00	0.00	0.00	0.00	72.47
Miscellaneous	4.25	0.00	7.50	0.00	0.00	33.16
TOTAL	**423.57**	**599.73**	**505.83**	**588.51**	**826.15**	**8865.65**

Source: *IREDA, Ministry of Non-Conventional Energy Resources, 2008*

As per the Government's policy, the Ministry of New and Renewable Energy (MNRE) is providing interest subsidies. It provides thrust and importance to the renewable energy sector, and IREDA implements the various schemes entrusted to it by the MNRE. Moreover MNRE made IREDA the "fund manager" for its Interest Subsidy Scheme on 'Accelerated Development and Deployment of Solar Water Heating Systems' in Domestic Industrial and Commercial Sectors by Banks and other Financial Institutions and 'Grid Interactive Solar PV Power Generation Projects'.

The interest subsidy is released to programmes like co-generation, Small Hydro, Briquetting, Biomass and waste to energy on NPV basis, and for solar and SPV programmes on actual basis. The interest subsidy is to be passed on to the borrowers on quarterly basis subject to the borrowers complying with the terms and conditions of the loan sanction.

The total installed power generation capacity of India reached 1,43,000 MW as on 31 March 2008. The share of renewable energy generation capacity at 12,403 MW is close to 9%. There is a new vigor and vitality in this sector as a whole with the launching of new initiatives for the promotion of renewable energy, which is emerging as an effective option for ensuring Green House Gases (G-H-G) abatement and to provide a degree of National Energy Security. The financial assistance provided by IREDA to the various projects coming within the umbrella of Renewable energy is given in Table 2-01.15.

New Initiatives

Recently, the Government of India has also taken the following initiatives to enable the Indian industry to excel in the global market:

NMITLI: The Government of India, through the budget year 2000, announced a new scheme, called the "New Millennium India Technology Leadership Initiatives" (NMITLI). The scheme envisages support to innovation centered scientific and technological developments.

The Council of Scientific and Industrial Research (CSIR) has been assigned the responsibility of operationalising and implementing the scheme. It therefore, supports synergic networking of public funded research labs, academia and the industry. Areas involving cutting edge technologies have been identified for the technical, managerial and financial support to the related project research organizations.

Strategically, NMITLI supports two categories of projects namely, Nationally Evolved Projects (NEP) which are in push mode; and Industry Originated Projects (IOP) which are in pull mode. Each of the categories follows a systematic methodology to build the projects. The project building under NMITLI programme is a unique exercise which encompasses diverse efforts drawing wisdom of the best in the country.

The brand NMITLI has encouraged many S&T departments to put in place their own R&D support programmes in public-private partnership mode. In the eight years of its existence, the NMITLI programme has covered diverse areas which include: Biotechnology, Drugs & Pharmaceuticals, Chemicals, Materials, Information Technology, Bioinformatics, Energy, Weather Forecasting, Leather Technology, etc. Projects 57 in number developed over the years range from liquid crystals to decentralized power packs; mesoscale modeling to nano-material catalysts; microbiological conversions to biotech molecules; functionalisation of alkanes to defunctionalisation of carbohydrates; advanced nano-materials and composites to biodegradable plastics; and novel office computing platform to low-cost horizontal axis wind turbine. These projects seamlessly involve 80 industry partners and 270 R&D groups from different institutions with an estimated outlay of Rs.500 crore. About 2000 S&T personnel are engaged in NMITLI projects spread all over the country.

The launch of NMITLI has indeed given a boost to innovation led product oriented R&D in partnership with industry. Today, NMITLI is India's largest R&D programme in public-private-partnership mode. The NMITLI has proved beyond doubt that success of a publicly run R&D support programme depends not only upon flawless conceptualization and operationalization but also upon pro-active (R&D) management. The NMITLI experience has brought forth that Indians too can work in large teams to deliver the goods.

Further, NMITLI is able to bring a paradigm shift in thinking with emphasis on innovation, performance and time bound delivery. Early success of the programme has encouraged other funding agencies to replicate the model. The experiment has thus proved to be a successful one. Efforts are underway to expand NMITLI and bring in newer approaches and mechanisms so as to sharpen its delivery base. The expansion of NMITLI will put India further on a higher pedestal. The country needs more such programmes to give a fillip to innovation led R&D in the country.

The CSIR has also instituted a "CSIR Diamond Jubilee Technology Award" to be awarded every year to the scientists involved in the development of new innovative technology-based product in India.

Erstwhile Technology Financing Schemes

The following three TF schemes were in operation for about a decade or so but have been recently discontinued. These schemes played a remarkable role in sensitizing the industry about the importance of undertaking technology development towards its commercialization purposes. Their contributions towards this end are worth recording here to complete the picture. These were:

Programme Aimed at attaining Technological Self–Reliance (PATSER): The PATSER scheme since 1988 supported more than 100 projects for semi-commercialization purposes. With the following objectives, the PATSER supported the industry, preferably as a joint project with any of the national R&D labs for:

- Technology absorption, development and demonstration,
- Building indigenous capabilities and commercialization of contemporary products and process of high impact

Towards achieving these objectives, the DSIR provided, on a selective basis, partial financial support for RDD (Research, Design and Development) projects of the industry in the:

- Development and demonstration of new/or improved products or process technologies, including those for specialized capital goods, for both the domestic and export markets,
- Absorption and upgrading of imported technology.

The financial support was mainly for procurement of raw materials, prototype development, fees for testing & evaluation and field trials etc in the field of metallurgical, electrical & electronics, instrumentations, chemical and mechanical engineering, etc.

The PATSER projects strengthened the linkages with more than 25 R&D labs. Out of 110 projects, 20 patents were filed/granted, 45 projects were successfully developed, leading to the significant commercial production of new technology-based products.

Home Grown Technology (HGT): The TIFAC managed the HGT scheme during 1993-2006 with a view to support the Indian industry for achieving competitive strength through technological innovation. It offered financial-cum-techno-managerial assistance for scaling up of lab/bench scale technology to the pilot plant, prototype, and semi-commercial level. About 100 projects were supported by TIFAC, under its HGT scheme: the important ones were in the field of CFC substitutes, detonation spray gun coating, and safe disposal of hospital waste by plasma; and also in aerations technology, coir pith blocks, ceramic crucibles and catalytic converters, titanium scrap recycling, bio-fertilizers, etc.

Funding of R&D in Electronics Industry (F R&D, FRIEND): To respond to the R&D needs of the electronics industry, the then Department of Electronics operated the FRIEND scheme for making the electronic industry globally competitive. The financial assistance was provided to forge a strategic alliance between government and industry to share R&D risks with academic and national R&D laboratories. The technology financing support was catalytic in nature and the projects have led to the development of commercial/sellable technology-based new products or processes, elevating thereby the confidence level of the Indian industry, in the wake of meeting the challenge of the MNCs, in the emerging regime of globalization.

All said and done, it may be noted that the technical products developed under the above mentioned schemes, have found great acceptance in the domestic and world market.

Conclusion

This is a first cut exercise in the analysis of the progress of public funding of science and technology efforts. It is indicating many areas of concern which would need to be addressed suitably by the government. Socio-Economic Ministries and state level S&T councils need to be supported in a big way to give a boost to T&D for civilian areas. Technology development and innovation related research efforts would also need a similar increase in funding to make full use of the R&D investments being already undertaken in the country at the level of directed and blue sky research. Detailed impact assessment expenditures as related to state level and central level budgetary projections are evidently required for which institutional mechanisms for monitoring on a real-time basis may be set up.

Financing of Health S&T

India has continually articulated its commitment to universal health care for all its citizens through the conceptualization of several programmes and schemes since the dawn of independence. In this context, it becomes essential to undertake an assessment of the available resources through which the state has attempted to mould these policies and schemes into universal health outcomes, in order to understand the fit between the stated objectives and prioritization of these resources. This section specifically attempts to provide an insight into such prioritization of resources in terms of outlining some broad trends in the financing of Health S&T schemes. The schematic outline of the section is as follows. At the outset, the section provides an account of the organizational structure of health systems in India and some general trends in relation to health expenditure in India. Subsequently it provides a framework for capturing Health S&T financing trends in terms of key actors (principal sources and users of funds), objectives of these actors and some analysis pertaining to impact assessment. The discussion of these trends, however, essentially focuses on the dimensions of Health R&D, education and training and health services, with particular emphasis on Central government funding sources including programmes and schemes for medical education, research, training and services, State government funding sources including programmes and schemes for services and funding patterns of medical research by departments located under different ministries in the government.

Organizational Structure of Health Systems in India

Health S&T schemes are implemented by the state under the aegis of the Health Ministry. Within the ministry, there is a bifurcation in terms of the Secretariat (Health Services) and the Technical Wing (Directorate of Health Services). At the level of the Central government, there are four departments: Department of Health, Department of Family Welfare, Department of Indian Systems of Medicine and the Directorate General of Health Services. The Directorate General provides technical support for the various health programmes. Within each department, there are functionaries such as Secretary, Joint Secretaries, Deputy Secretaries and Under-Secretaries to oversee different programmes in the department. In the case of certain programmes, in addition to the above-mentioned functionaries, there are directors, advisors, commissioners and their deputies to supervise these schemes and programmes. The same administrative structure is replicated at the state level to a large extent. The interaction between the Central and State machineries for Health is facilitated through the Central Council of Health and Family Welfare. This council also fulfills advisory and policy level functions in the context of health care in the country. In addition, the Planning Commission of India has a health cell which supports the above mentioned council and provides crucial inputs towards health care efforts.

The section also discusses some broad findings in relation to the aforementioned dimensions. The section, in a nutshell, examines the broad status of health financing in India in addition to outlining some suitable measures to realize the goal of affordable health for the Indian population.

Table 2-02.01: Some measured levels of expenditure on health in India (1997-2003)

Selected Indicators	1997	1998	1999	2000	2001	2002	2003
Total expenditure on health as percentage of GDP	5.3	5.0	5.1	5.0	5.0	4.9	4.8
Private expenditure on health as percentage of total expenditure on health	84.3	81.6	75.4	75.4	75.8	76.3	75.2
External resources on health as percentage of total expenditure on health	2.3	2.4	1.2	2.2	2.0	1.3	1.6
Government expenditure on health as percentage of total government expenditure	3.2	3.5	4.5	4.3	4.2	3.9	3.9
Social security expenditure on health as percentage of general government expenditure on health	N.A.	N.A.	4.4	4.4	4.4	4.4	4.2
Expenditure on medical research, training and education as proportion of total health expenditure	N.A	N.A.	N.A.	N.A.	N.A.	N.A	31.12

Sources: World Health Report 2006, National Health Accounts 2007

These indicators provide a significant pointer to the patterns of investments, expenditure, sources of funding and proportion of allocation for health schemes and programmes in relation to the total allocation. These indicators also provide an understanding of health outcomes in relation to the expenditure. Investment on health, family welfare & AYUSH for the Tenth plan (2002-07) was Rs.31,020.3, Rs.27,125 & Rs. 775 crores respectively while total budgetary allocation under health sector was Rs.21,767.34 crores. The government expenditure on health as a percentage of total expenditure on health was 24.8% while that of the private sector was 75.2%. Public spending on health increased from 0.22% of GDP in 1950-51 to 1.05% of GDP during the mid-eighties and stagnated around 0.9% of the GDP during the later years.

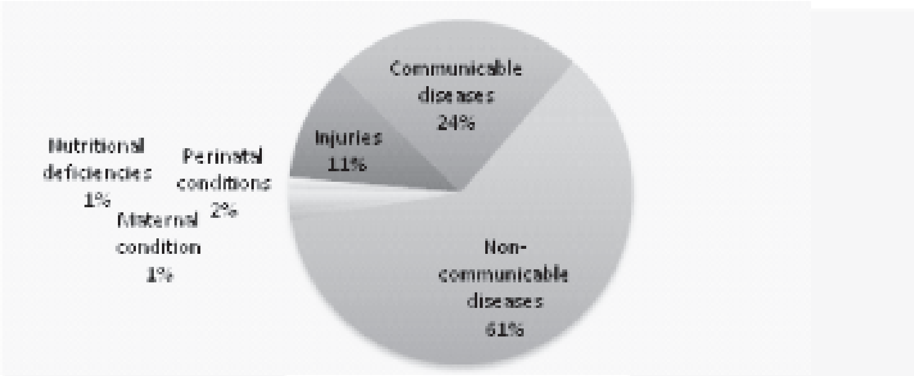


Fig 2-02.01: Projected deaths in India 2010

Note: *The above figure clearly indicates the rising burden of non- communicable diseases (61%) by the year 2010. The data however does not refer to the percentage of projected deaths due to HIV/AIDS infection.*

Source: *ICMR Tenth Plan documents*

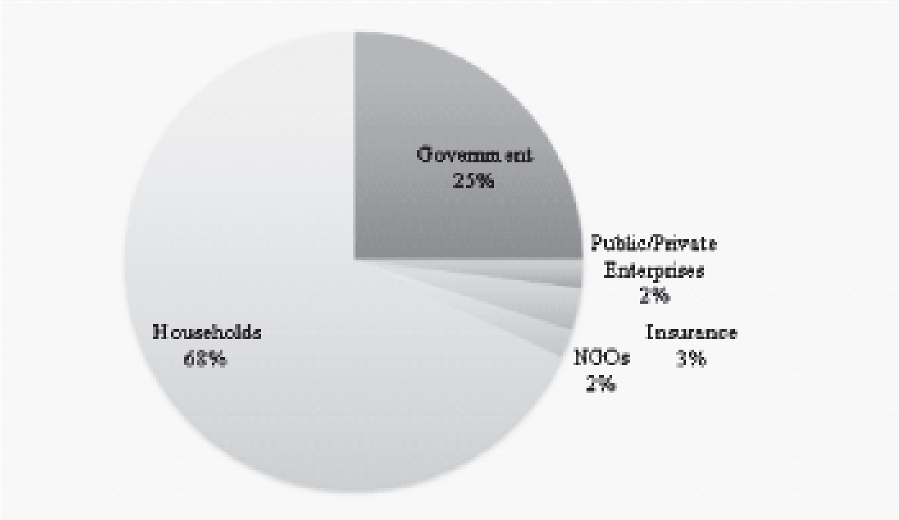


Fig 2-02.02: Share in health care spending among the different sectors.

Note: *In terms of the sources and determinants of healthcare financing, the burden of healthcare expenditure in India largely falls on individual households, indicating relatively less involvement and inadequate support structures generated by the government in this regard.*

Source: *National Health Accounts 2007*

Public Health Expenditure

The link between equitable access to health care and better outcome indicators and increased involvement of the State in health financing related activities is well disseminated. The following tables and diagrams provide us with an understanding of sector-wise allocations and details of expenditures on health education, training, research and services by central sector, state sector and departments of different ministries. They also provide us with a bird's eye-view on trends in public expenditure on health care in India and also capture the spatial distribution and flow of healthcare related expenditure.

Central Sector

Table 2-02.03 utilizing data from the Ministry of Health & Family Welfare reports, outlines the scheme-wise plan outlay and expenditure for Health during the Tenth Plan period. It may be noted that the approval outlay in the eleventh plan is provisional in nature. Also during the Tenth Plan, the Central Schemes of Control/ Containment of non-communicable diseases such as for Cancer and Mental Health have been converted to centrally sponsored schemes. The table clearly highlights the greater emphasis given to vertical programmes.

Table 2-02.02: Health Financing in India: Key Agencies (Sources & Users/Performers)

	Sources	Users/Performers
Public Sector	Central sector budget State sector budget Departments/Agencies of different ministries	Ministry of Health (State and Central health sector) Academic research institutions
Private Sector	Foundations Bilateral/ Multilateral Agencies	Pharmaceutical Firms NGOs

Source: *Authors' Compilation*

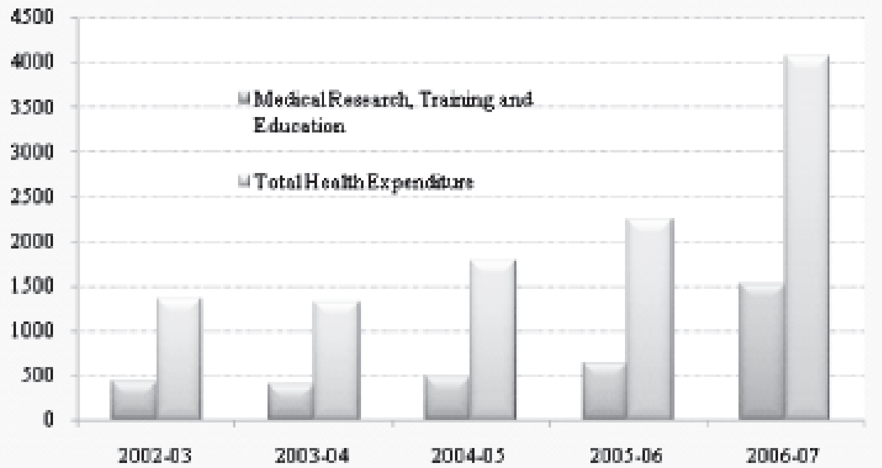


Fig 2-02.03: Medical Research, Training and Education Expenditure as Proportion of Total Health Expenditure (in crores)

Source: *ICMR reports & MHFW*

Table 2-02.03: Scheme-wise Plan Outlay and Actual Expenditure for Health during Tenth Plan Period

S. No.	Name of the Schemes / Institutions Programmes	10th Plan Approved Outlay	2002-03 Actual Exp.	2003-04 Actual Exp.	2004-2005 Actual Exp.	2005-06 Actual Exp[1].	2006-07 Approved Outlay
	1	2	3	4	5	6	7
I.	**CENTRALLY SPONSORED**	**4815.80**	**793.81**	**753.06**	**1051.39**	**1291.66**	**1919.02**
1	National Vector Borne Disease Control	1349.00	206.56	198.88	212.17	256.61	371.58
2	National Leprosy Eradication Programme	236.00	74.96	50.11	42.26	23.09	42.25
3	National Tuberculosis Control Programme	662.00	96.75	117.83	133.63	188.12	202.17
4	National Programme for Control of Blindness	445.00	84.63	85.51	86.64	92.94	90.00
5	National AIDS Control Programme	1392.80	241.35	231.88	404.50	520.82	905.67
6	National Cancer Control Programme	266.00	48.34	25.19	62.85	63.03	87.00
7	National Mental Health Programme	139.00	0.09	4.92	19.39	46.17	50.00
8	Drug De-Addiction Programme	33.00	10.72	6.13	6.14		
9	National Iodine Deficiency Disorder Control Programme	35.00	8.73	10.53	4.13	8.44	15.00
10	Other Programmes	258.00	21.68	22.08	79.68	92.44	155.35
II.	**PURELY CENTRAL SCHEMES:**	**5436.20**	**566.01**	**572.75**	**720.97**	**953.10**	**1408.98**
11	Control of Communicable Diseases:	459.80	27.71	31.30	54.09	81.75	141.45
12	Hospitals & Dispensaries:	567.00	84.76	94.65	100.36	150.03	186.64
13	Medical Education, Training & Research:	2953.60	423.18	391.93	479.61	637.19	811.31
14	Other Programmes	1455.80	30.36	54.87	86.91	84.13	269.58
	Grand Total	**10252.00**	**1359.82**	**1325.81**	**1772.36**	**2244.76**	**3328.00**

Source: *ICMR Tenth Plan documents*

Health R&D, Medical Education & Training (Central Sector): In India, the R&D investment in health is about 2% of the total health budget. However, for this investment to become meaningful, the trend of under-investing in health care must cease. The proportion of R&D allocations for health in the country is about 2% of the R&D efforts in all other sectors. In the current context, the epidemiological transition in terms of a rise in chronic diseases, continuing dominance of infectious diseases and rising burden of non-communicable diseases, has necessitated an increasing emphasis on a focused research strategy to combat challenges in infectious diseases, non-communicable diseases, nutrition and reproductive health. The instituting of the Department of Health Research under the Ministry of Health in 2007 is a step in this direction.

Funding by Different Ministries and Departments (Central Sector): The departments under different ministries in the government of India, particularly the Ministry of Science and Technology, do not only engage in research within their departments but fund research projects in both academic and industrial organizations as well. With respect to such funding patterns of extramural research and development projects by agencies like Department of Science and Technology, Department of Biotechnology, Council of Scientific and Industrial Research, Indian Council of Medical Research etc, available statistics reveal a significant increase in percentage of funding for medical research during the Tenth Plan period, especially in comparison with other areas like engineering and technology, agriculture sciences, biological sciences, chemical sciences, earth sciences, mathematics and physical sciences.

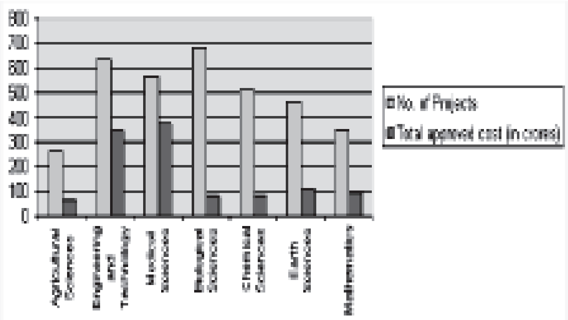


Fig 2-02.04: Area-wise Distribution of Extramural R&D Projects and their Approved Cost for 2005-06
Source: *Department of Science & Technology (DST)*

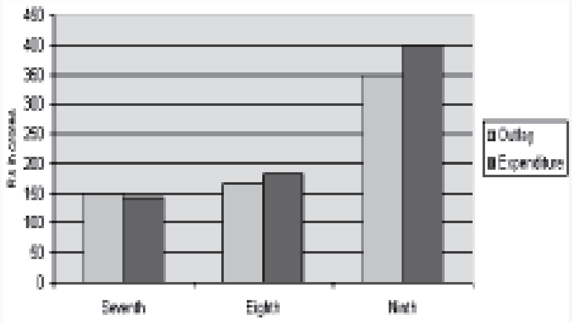


Fig 2-02.05: Plan Outlay & Expenditure of ICMR for Seventh, Eighth and Ninth Plan Period
Source: *Indian Council of Medical Research (ICMR)*

State Sector

Expenditure in the state sector related to health schemes and programmes is essentially related to services. The instituting of the National Rural Health Mission (NHRM) in 2005 is a significant development in this regard. The government of India had launched the National Rural Health Mission in order to carry out some essential architectural corrections in basic health care delivery systems. As far as the services sector is concerned, the proportion of expenditure by the state governments (85%) far exceeds the central government allocation (15%) on health services.

Budget allocations for Assam are the highest while the lowest allocations are for Haryana, Goa and Sikkim in comparison to other states. The spatial patterns of these budget allocations also signify expenditure on services rather than health research as the main determinant. States like Assam, Tripura, Meghalaya, Mizoram etc, which have been allocated a significant percentage of budgetary resources for health do not have too many health related S&T institutions

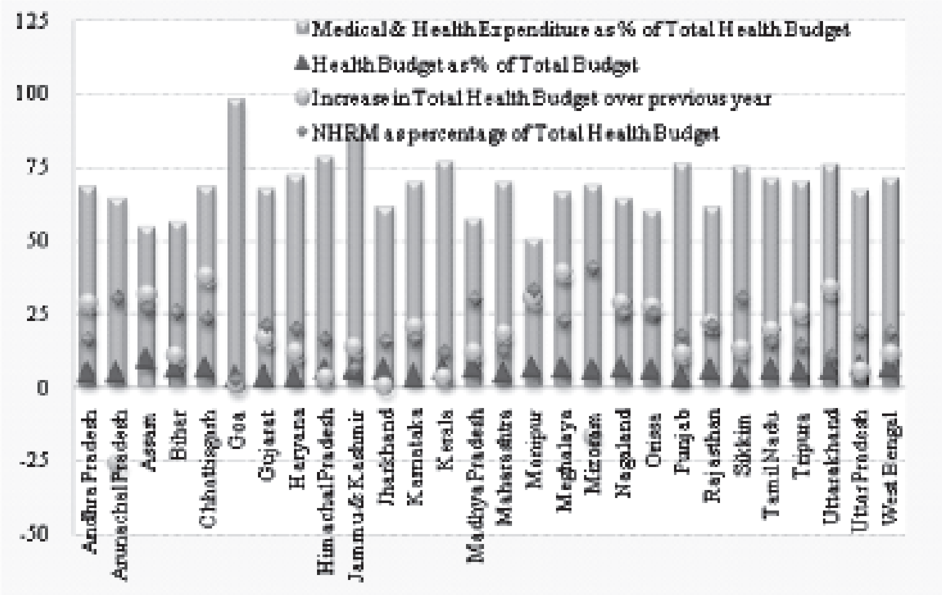


Fig 2-02.06: Health Expenditure at State Level (2006-07)

Source: NSSO 60th round

Future Initiatives

There is a need to carry out independent evidence based assessments of Central and State expenditure on health research, education and services in addition to setting up of institutional mechanisms to monitor these developments and analyze health R&D inputs and their utilization for health policy and programmes that benefit the Indian population.

Financing of Environmental S&T

The Tenth Plan had recognized that environmental sustainability is not an option but an imperative. In India, the funding of Environmental S&T comes from various departments and ministries like the MoE&F, DST (CSIR, DBT, ICAR), UGC, UNICEF and DAE. The Ministry of Environment & Forests is the nodal agency in the administrative structure of the central government for planning, promotion, co-ordination and overseeing the implementation of environmental and forestry programmes. Thus, the MoE&F contributes the bulk of funds for Environmental S&T activities, and due to constraints in availability of data, the main focus of this section is on MoEF & its funding schemes. The data for the past 10 years is collected by visiting websites of Govt. of India pertaining to the project and extracting annual reports, demands for grants, performance budget etc.

Financing of Environmental S&T in the MoE&F takes place under two major heads; *"Forestry and Wildlife"* and *"Prevention and Control of Pollution"*. Minor heads of "*Education and Training*" and "*Research*" come under Forestry and Wildlife whereas "*Research and Ecological Regeneration*" and "*Environment Education, Training/ Extension*" come under Prevention and Control of Pollution. Fig 2-03.01 shows the trend of financing of Environmental S&T taking into consideration the minor heads which contributed to S&T in the last 10 years.

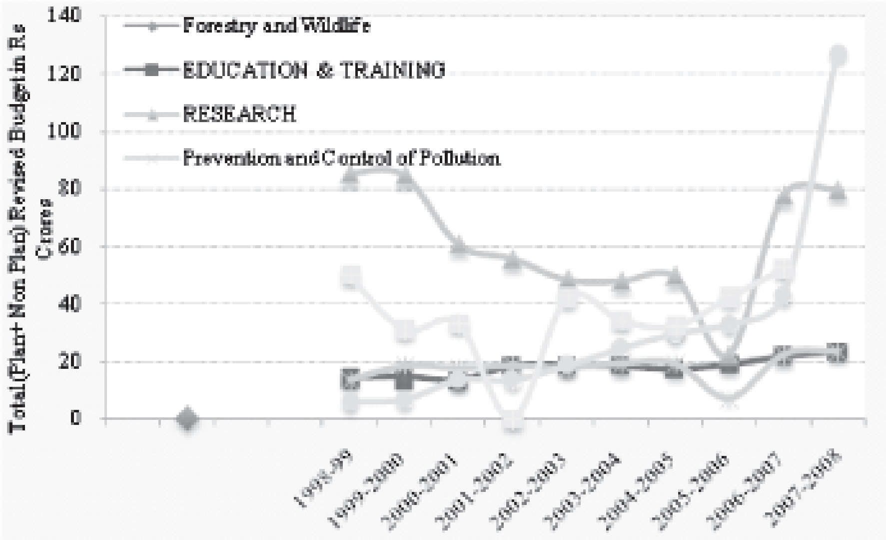


Fig 2-03.01: Trend of Financing of Environmental S&T

Fig 2-03.02 and Fig 2-03.03 show the trend of financing to various educational institutes, colleges and academies under the minor head of *Education and Training.* The three primary schemes working under the minor head of *Environmental Education, Training/Extension* are – Environmental Education Training Scheme; Workshop, Seminars & Symposia; and National Museum of Natural History. The trend shows that Workshop, Seminars & Symposia always received the least budget and Environmental Education Training Scheme got the highest. In the year 2001-02, Workshop, Seminars & Symposia got zero-budget and henceforth it was closed. Environmental Education Training remained in the priority and got the highest budget allocation.

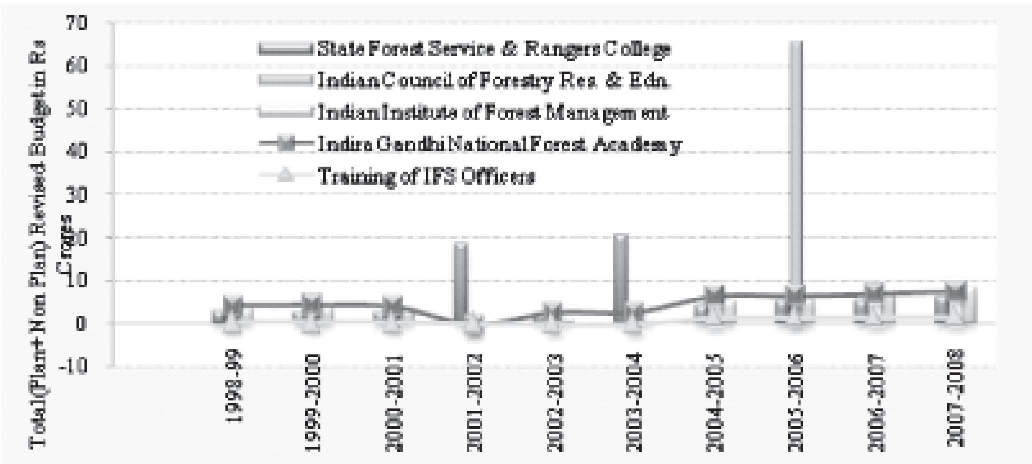


Fig 2-03.02: Funding pattern to various Education and Training Institutes
***Source**: Annual Reports, Demands for Grants, Performance Budget of MoEF respective years*

Ministry of Environment & Forests funding has been for multi-disciplinary aspects relating to environmental and ecosystems protection, conservation and management at various universities, institutions of higher learning, national research institutes and non-governmental organizations in identified thrust areas under its Research

& Development (R&D) Programme. The Research & Development Scheme of the Ministry is a Central Plan Scheme for conservation and management of the environment since 1985. Some indicative areas include: forest conservation, wildlife protection, biodiversity

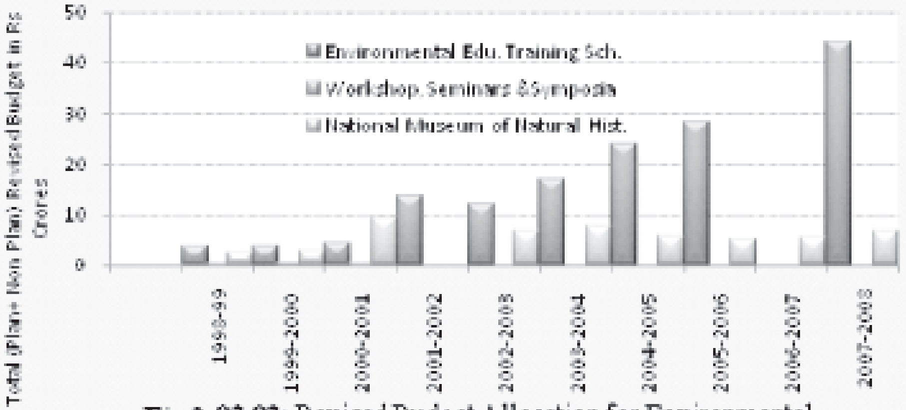


Fig 2-03.03: Revised Budget Allocation for Environmental Education, Training/Extension

***Source:** Annual Reports, Demands for Grants, Performance Budget of MoEF of respective years*

inventories, R&D in environmental management technologies, climate change, public health impacts of environmental degradation, etc. The major research programmes under which environment related research is supported under 'Research' head by the Ministry are:

Environmental Research Programme: It specifically deals with the "Brown Issues", i.e. problems related to pollution, hazardous waste management, agro-chemicals, waste minimization & reuse, carrying capacity studies, development of eco-friendly & cleaner technologies and providing scientific inputs to address policy problems relating to environmental pollution control & management.

Ecosystems Research Scheme: It is an inter-disciplinary programme which emphasizes the ecological approach to the study of inter-relationships between man and the environment and seeks to generate scientific knowledge needed to manage natural resources wisely.

Eastern and Western Ghats Research Program: This programme is intended to evolve scientific inputs and technology packages for solving location specific problems in the fragile areas of Eastern and Western Ghats.

Mangroves and Coral Reefs: This programme supports research for conservation and management of mangroves and coral

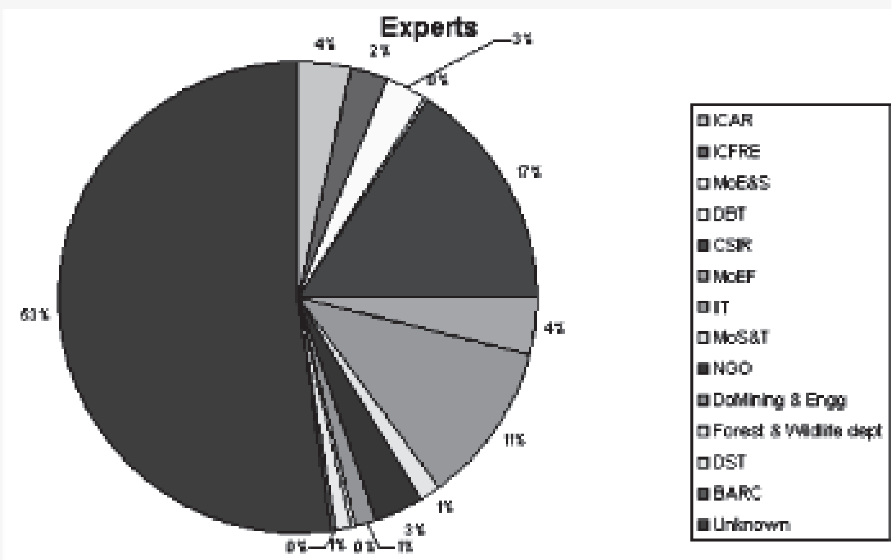


Fig 2-03.04: Trend of Funding received by experts for research in the field of environment from respective organizations

Source: Database of Environmental Experts, MoE&F

reefs ecosystems from degradation, aforestation of degraded mangrove areas, maintenance of genetic diversity, especially of the threatened and endemic species and 'coral reefs' restoration/artificial regeneration and creation of awareness among the people about the importance of mangroves and coral reefs ecosystems.

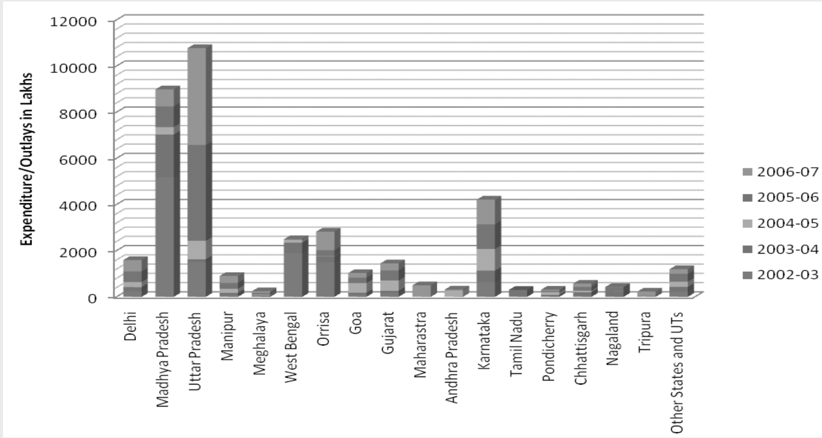


Fig 2-03.05: Trend of Investment in "Ecology and Environment" under Science and Technology head of Development (2002-05 Actual expenditure; 2005-2007 Approved Outlays)

Source: *Annual Plan documents of respective states*

Data regarding experts working on environmental S&T and the grants they receive from MoE&F reveals that experts were from ICFRE (53%), CSIR (17%), IIT (11%). Besides the Central Government, it is good to note that the State Governments have also invested in environmental S&T as is evident from Fig 2-03.05.

It is found that financing of environmental S&T has gained pace over the years in India but if we look at the achievements perhaps there are miles to go. Thus more efforts from different agencies, both public and private, will add momentum to the developments achieved till now. In fact, achievements can be fostered if environmental S&T related activities generate economic activity for the huge unemployed workforce present in the country. The role of governments, donors, and other stakeholders in creating the enabling policy and institutional framework for introducing market-based approaches will remain very significant.

Investment in S&T and Innovation in India

Investment and expenditure on S&T (and on R&D) in India has been rising over the years. Computation of such spending is difficult because agencies ranging from public to private invest or spend, on several items that may not be directly accounted for under the respective heads of either R&D or S&T. The latter is a broader category while the former R&D is more inclusive and limited in scope. Moreover, there are several types and tiers of public agencies in the federal setup who are engaged in investment in S&T. Further, there are other modes of public funding especially as through the banking system or fund-based systems targeted to S&T or R&D. Finally, apart from the foreign investment/engagement in R&D the domestic private sector invests in S&T based innovations that are not accounted for under the head R&D. In this context this section attempts to capture the extent and modes as well as structures of such spending/investment.

Investments made in Research and Development by the developed countries and even by a few developing countries such as China and Brazil, are as percentages of respective GDP higher than made by India. A closer observation of China's investment in R&D however reveals that they have considered many additional parameters under 'development' head in their calculation of the total investments in R&D. While calculating R&D in India, developmental expenses have often been excluded, such as private sector expenditure on non-R&D innovation-expenses has been excluded from the R&D head.

Data on Funding of S&T and R&D

As per the Research and Development Statistics 2004–05 of the DST, Indian expenditure on R&D as percentage of GNP grew from 0.76% in 1992-93 to 0.80% in 2002-03, further rising to 0.89% in 2005-06 (Source: Research and Development Statistics at a Glance: 20007-08, DST). This expenditure is shared by several types of agencies broadly classified under central core S&T ministry, central social sector ministries,

Table 2-04-01: Plan Investment (in Crores) in S&T undertaken by Central Socio-economic Sector Ministries

Plan (Period)	Core S&T Central Ministries		Central Socio Economic Ministries	
	Outlay	Actual	Outlay	Actual
5th Plan (1974-79)	436.13	383.85	375.59	308.65
6th Plan (1980-85)	799.65	1130.1	1100.91	989.66
7th Plan (1985-90)	2022.74	2599.05	1953.49	2408.14
8th Plan (1992-97)	4094	6125.6	4201.863	5303.9
9th Plan (1997-02)	12022	12068	12339	10449
10th Plan (2002-07)	25301.35	23641.26	25967.95	20469.65

Note: *Data for the 8th, 9th and 10th plan period of Socio economic ministries is calculated here, assuming that the trend of expenditure remains uniform over the years and is based on averaging the ratio of allocation of Core S&T ministries to the socio-economic sector ministries for the 5th, 6th and 7th plan. The same ratio is applied to estimate the allocation of the socio-economic sector ministries for the 8th, 9th and 10th plan.*

Source: *http://planningcommission.nic.in/sectors/science.html*

central and state governments' respective expenditures on R&D under education budget, expenditure on education by other ministries at both centre and the states, state governments ministries, public sector undertakings, bank-operated funds (however, in most cases such funds are covered under ministry funds; private bank's fund, as for venture, cannot come under that), private sector enterprises, private equities and other forms of innovation funding sometimes undertaken by the NBFCs, social agencies or charities, multilateral/bilateral R&D funding, and foreign private enterprises investing in R&D in India.

The Table and Figures give an idea of how the S&T expenditure is shared by several types of agencies. Often a problem similar to the problem of distinguishing between expenditure/ investment on S&T vis-à-vis R&D is that of the partitioning the expenditure/investment on education between research-directed or research-productive and pure teaching unrelated to research. We would like to hold the view that a typical academic's salary takes care for both 'pure and unrelated to research' component of teaching as well as a

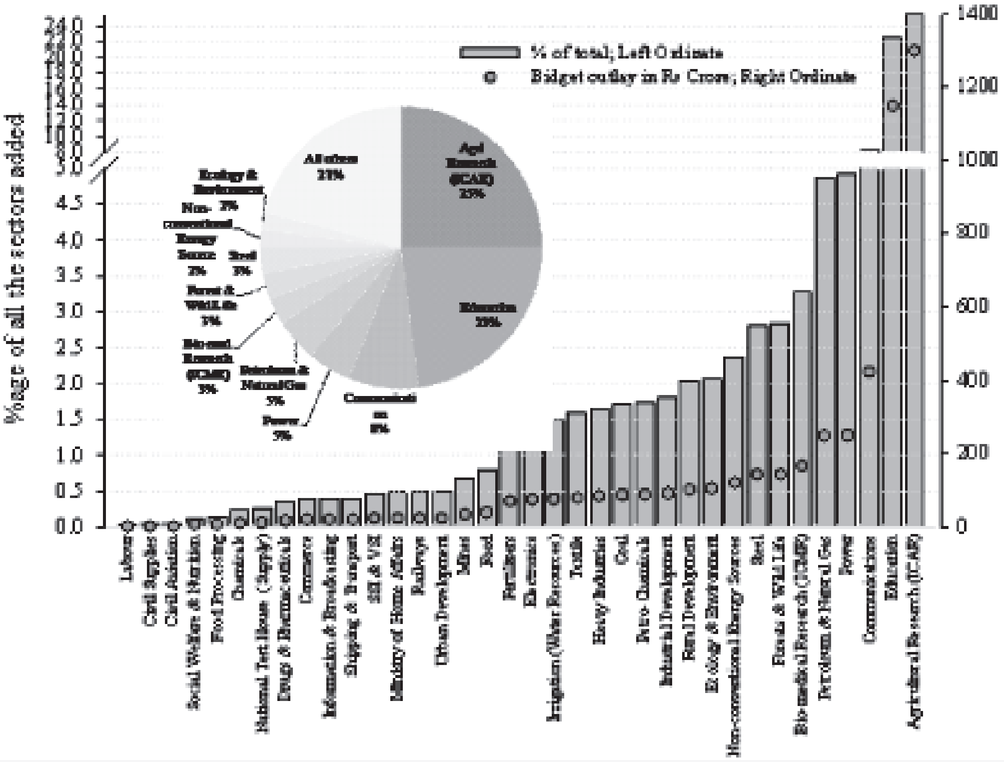


Figure 2-04.01: Plan Investment on S&T incurred by respective socio-economic sector ministries in the 8th Plan;
Source: *http://planningcommission.nic.in/sectors/science.html*

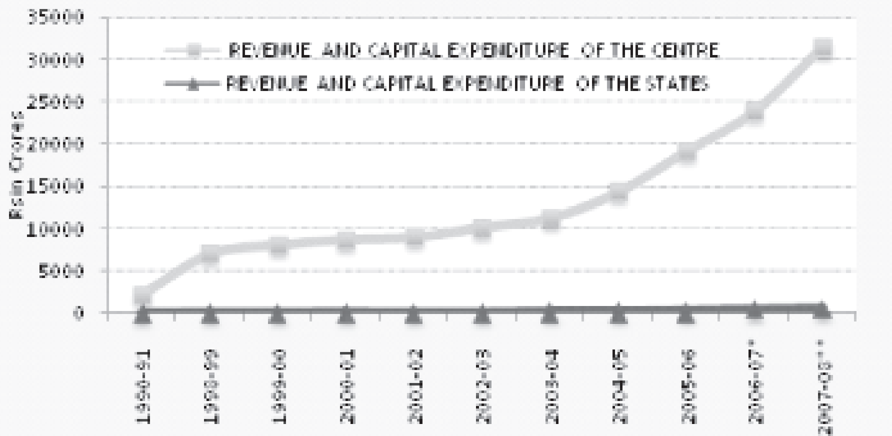


Fig 2-04.02: Trend of budgetary transactions on "Scientific services and research" head incurred over the years
* indicates Revised Expenditure, ** indicates Budgeted Expenditure.
Source: *Indian Public Finance Statistics, 2007-08, Ministry of Finance*

component of research even though the academic might not have received a separate grant for R&D. In fact for dedicated R&D organizations the expenditure statement is accepted as the expenditure on R&D even while the dedicated R&D organizations of the country are currently generating very large number of doctorates and are training very large number of doctoral students. Our observation is based upon the notion that teaching and R&D go together.

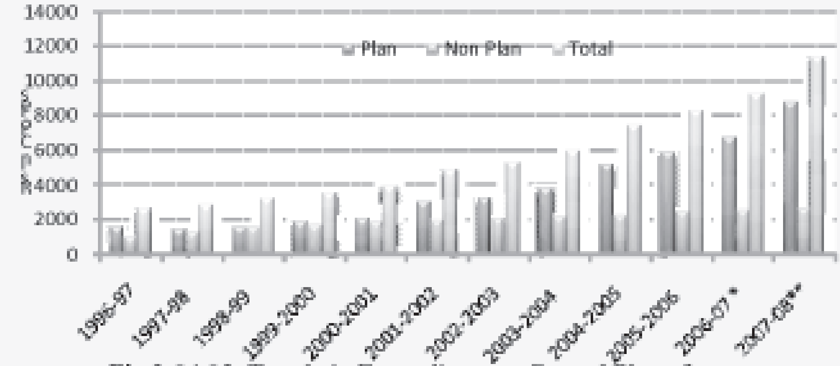


Fig 2-04.03: Trends in Expenditure on Central Plan of Revenue Account under "Science, Technology and Environment"

Source: *Expenditure Budget, Vol1, 2007-08, Ministry of Finance*

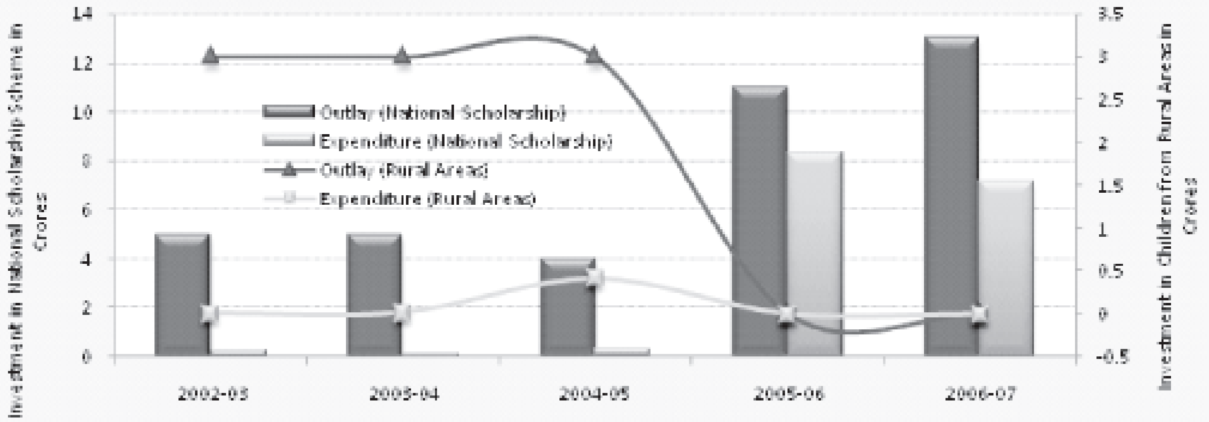


Fig 2-04.04: Trend of Investment in Select Schemes having S&T Component under Scholarship Head

Source: Analysis of budgeted expenditure on education 2007-08, MHRD

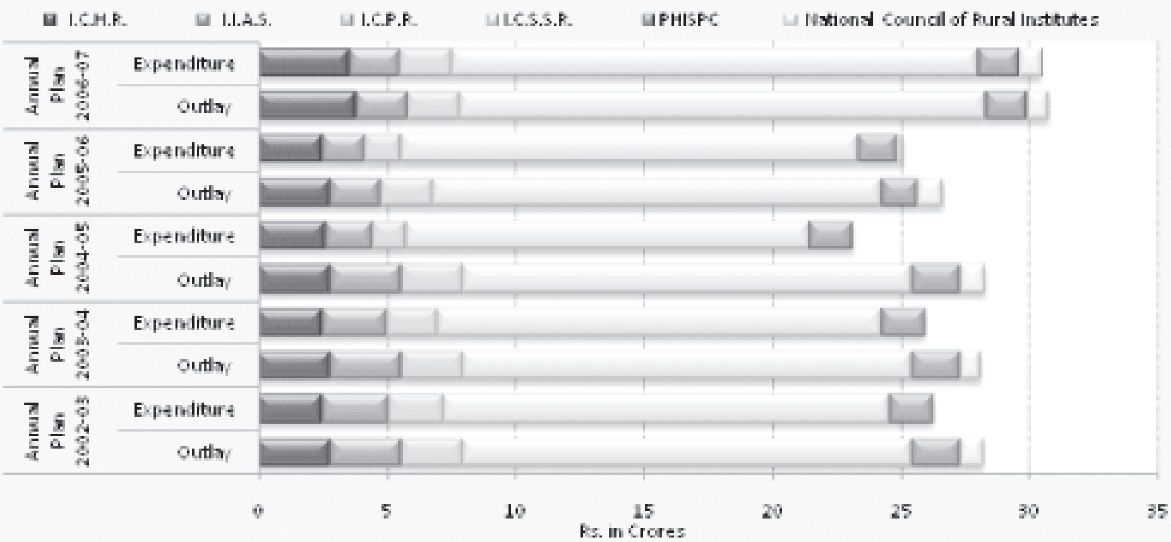


Fig 2-04.05: Trend of Investment in "Institutions of Research" under University and Higher Education Head

Source: Analysis of budgeted expenditure on education 2007-08, MHRD

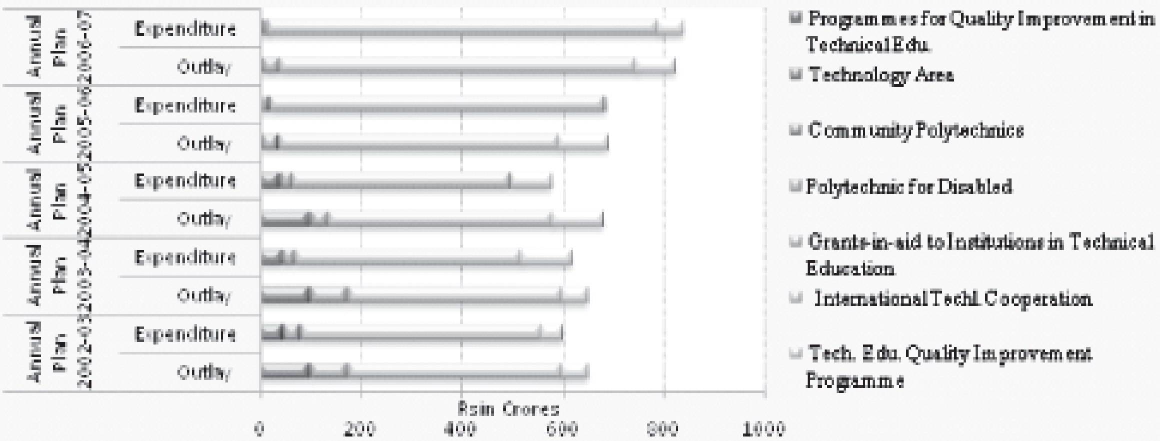


Figure 2-04.06: Trend of investment in select schemes having S&T component under Technical Education head

***Source:** Analysis of Budgeted Expenditure on Education, Ministry of Human Resource Development,*

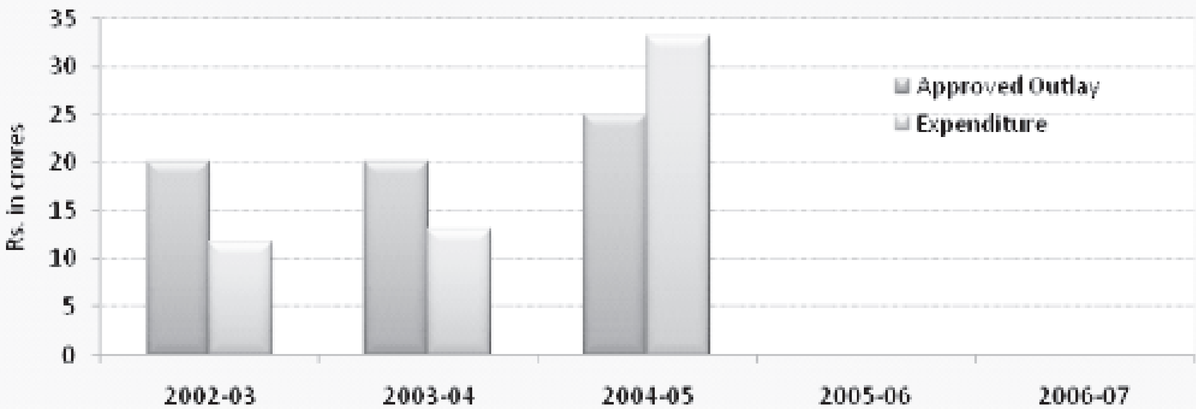


Fig 2-04.07: Research & Development Expenditure under technical education

***Source:** Analysis of Budgeted Expenditure on Education, Ministry of Human Resource Development*

Table 2-04.02: Trend of Plan and non-Plan Expenditure on Education and Training by Centre, for Social sector Ministries. (Rs Crore)

	2003-04	2004-05	2005-06	2006-07*	2007-08**
Plan	12044.4	12877.1	17823.2	24828.1	33351.1
Non Plan	5056.6	5149	5386.6	5808.7	5991.5
Total	17101	18026	23209.8	30636.7	39342.6

***Note:** * indicates Revised Expenditure, ** indicates Budgeted Expenditure*

***Source:** Ministry of Human Resource Development*

The Expenditure Reports of respective education ministries under several heads of ‘scholarships’, ‘R&D’, however provide only an indication to the directed R&D fund under budgets of higher and technical education. The figures reflect the fact but there are many hidden expenditure on S&T undertaken by the Department of Higher education as well as other socio-economic ministries (Table 2-04.02).

Moreover with the current thrust of XI Plan S&T on ‘innovation’, our classification and data definition system would need to capture much of the non-R&D that go into innovation. For private companies, we have considered the CMIE database of listed companies.

Mode of Funding and Capacity in S&T

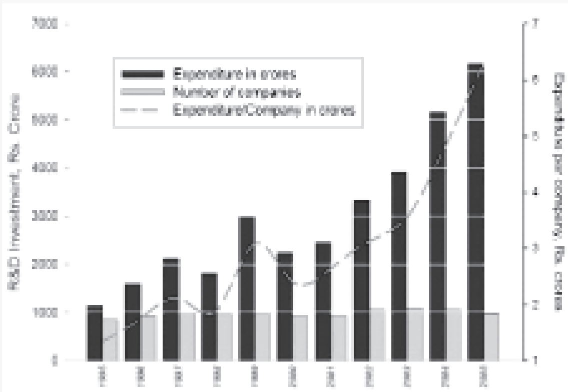


Figure 2-04.08: Expenditure on R&D by Listed Companies

Source: CMIE Database

Most of funding of R&D/S&T happens through planning and budgeting mode of the executive ministry or departments; there is relatively little change with variations in the ownership of executing fund-recipient. Planning/budgeting exercises undertaken at periodic intervals have set up several mechanisms of executive based coordination and monitoring. Hard budget constraints and project/program monitoring at the central level with the involvement of the Planning Commission and a few inter-ministerial bodies is one of the most significant mechanisms. At lower tiers such allocation functions are undertaken within the department/ministry through very similar processes, however, the lower the tier in hierarchy the stricter are the constraints on flexibility in budgeting. Most often, at around the middle tiers of the hierarchy, execution remains the main task and coordination through management of allocations across budget heads or cash flows becomes difficult.

Demands for grants rise as one goes up the hierarchy, where at the higher tiers the bundling of demands is undertaken. The current Plan, for example, has set the broad principles of bundling and one major norm is ‘Supra’ projects at supra-organizational level, or ‘Mega’ and ‘Inter-agency’ projects at multi-institutional level or at cross-disciplinary level. Budget sets the goals and therefore monitoring standards and modes. Inter-period monitoring of goals and outcome achieved and especially the capacity to spend within the pre-fixed parameters of budgetary heads provide the cues to future release of funds. Several documents of the government suggest that the systemic incapacity to spend is a major bottleneck to the growth of S&T budget allocation. The two way process depends crucially upon the interactive mechanisms of bottom-up and top-down flows of information that get bundled at multiple tiers preventing, perhaps often the systemic capacity build up on its own and through these budgetary processes. Generation of projects, major programs and in short the creation as well as generation of demand then is another goal of the entire executive process of planning/budgeting. Relative weakness of the systems of S&T to voice demands reflects upon and influences the slow buildup of the systemic capacity. Major projects or mega programs therefore appear to be important. The XI Plan has emphasized amply this dimension. Another related dimension is the capacity of the systems of the stakeholders, especially of the society who would voice and which in turn would boot up demands for capacity.

Along with these executive based approaches to using planning/budgeting, a few other approaches have in recent periods been considered as well as initiated by the government. One important landmark of XI Plan regarding S&T is its underlying theme of innovation. Creation of demand pulls through innovations to generate the subsequent flow of allocations that in turn would create, from within as well from without the public system of S&T, the dynamism to create additional capacity to absorb funds and build up executive capacity, is one of the principal pillars of the current plan. This approach has therefore created instruments for funding the ‘bridging’ or linkage functions. The emphasis has been on executive controlled departmental or line ministerial linkages. Other modes of market based or social based linkages too are important. For example, generation of standards or extensive modularization creates the pull for systemic build up through market processes. Another mode less deliberated upon is the advanced standards-based public procurement or utilization of part of public development fund or part of restructuring fund or of the infrastructure fund to advance induction of new technology. In the current Plan such indications have been provided in relation to the district-based system of S&T management or in relation to incubation of new innovations or in inspiring youth into the folds of new sciences.

Another dimension of public investment is the foregone taxes, tariffs and similar others. The ensuing private investment in new plants and machinery, new measures on quality, standards or say, productivity and efficiency and especially on new technologies are to be set off against the forgone revenues. Private investments on all this have not been computed, however, our preliminary observations on investments for on-R&D innovations indicate that instead of setting off the investments in R&D alone the private enterprises have undertaken in a few sectors the systemic build up of innovation capacity.

S&T Structure, Infrastructure and Public Space

Overview

S&T infrastructure describes the enabling capacity allowing undertaking of advanced R&D as well as S&T by constituent organizations of a country. In other words, structural distribution of capacities, their coordination and governance, as well as goals of the constituents and the capital and knowledge intensity of experimental and production facilities do indicate the degree of this enablement. The manner in which S&T structure can aid in economic development is closely linked to the country's S&T infrastructure. Performance of schools and workshops, fabrication or prototyping facilities, laboratories and of advanced production and most importantly, the innovation-performance of a country depends crucially on this S&T infrastructure. No wonder a comparator, China, has made a special Plan initiative on S&T infrastructure. In India, policy initiative on S&T infrastructure has appeared not as a special focus but as latent and incorporated under multiple programs of the federated executive and public set up. The democratic governance implicit in this policy therefore depends crucially on how S&T has filtered through the public space. This *theme* only briefly provides snapshots into this whole complex and captures the huge S&T infrastructure existing in the country, with special emphasis on the various modes of coordination and governance vis-à-vis indicative performance.

Beginning with an analytical description of various modes of governance existing in the S&T system of the country, an overview exhibits the huge S&T infrastructure existing in the country. Reflections on the relative performances and different modes of governance are traced through the evolution in regional governance and regional innovation system. Subsequently, a brief overview of the S&T infrastructure across different states of India is followed by several descriptions on performances, such as on technology transfer. A brief profile of S&T in the state of Kerala provides an exemplar of regional S&T state of affairs. Briefly describing technology parks, the theme takes up biotechnology parks and incubators and public initiatives in biotechnology. The theme then covers a strategic player, the CSIR, a premier research organization and its achievements and comments on various R&D partnerships in the country, their performances and the financing mechanism in the partnership initiatives. Thereafter the attention shifts from organization to the social milieu, and an analysis provides glimpses into the public space. Coverage of seven diseases- HIV/AIDS, Diabetes, Dengue, Malaria, Tuberculosis, Chikungunya and Avian Influenza in three Indian English language newspapers for the year 2007 and the coverage of science and technology related items in English language dailies in India throw light on the quantum of space allocated to different subjects by different newspapers, positioning and spread of S&T items, and identify newspapers that accorded priority to science and technology related items.

The full text of these extended summaries is available at *http://www.nistads.res.in*

Coordination and Governance: S&T structure and infrastructure

Several policy documents of the Government of India, including several plan documents, have suggested areas under 'S&T' as being broader in scope than areas 'R&D' could address. The S&T infrastructure of India has therefore embraced large number of economic sectors and various social dimensions. Over several decades of developmental investments and developmental democratic public governance, India has experimented with and has evolved a very complex web of S&T infrastructure and of coordination and governance. In its federated mode of governance, the S&T infrastructure remains governed by: multiple central ministries, multiple ministries of the governments in the states, varieties of structures under the local governments of the Panchayati Raj Institutions (PRI), public non-profit systems including varieties of universities and schools or specialized training schools, several regulators in both the centre and the states, the institutions of audit, the complex web of legal institutions, the federated structures of law-making institutions, scores of establishments in both public sector and public-private cooperated sectors, private sector entities, foreign investments in R&D and other science-related developments, and private charities.

Modes of Coordination & Governance

From the perspective of institutions of governance or from the perspective of comparative governance, the three modes : (1) the executive-based governance, (2) the bank-based governance and (3) the market-based governance, have coexisted, albeit for India the executive-based mode has retained overwhelming control. The executive-based coordination and governance can be further subdivided into several modes, namely: (1) central government, (2) state government, (3) local government, and (4) combinations of the former along with, sometimes, public sector or private sector. Executive control in most cases relies ultimately upon administrative services under the line ministry. Integrative governmental structures exist primarily at the district level local government; however, S&T structures under the district governments are either non-existent or extremely weak. However, in most states most state S&T/R&D institutions are under the line ministries. The Planning Commission, as a quasi-administrative body, brings together the function of coordination primarily through the processes of planning and budgetary measures. A few inter-departmental bodies also function as coordination mechanisms. Regulators, when they exist, also serve as coordinators, however, they cannot/do not fund.

Bank based or fund based financing mechanisms have not operated for S&T/R&D funding especially for the S&T infrastructure including formation of laboratories. This mode of financing that has been operated in few other countries, notably China, employs a small part (often about 5%) of most economic-restructuring large funds, or most disaster-funds, or most developmental or public procurement funds towards inducting new technologies or developing new technologies or for creating huge S&T infrastructure. Such set asides have often employed new technology standards for creating a demand for knowledge goods from public S&T laboratories or even from private sector by way of demanding goods based upon advanced technology standards. The market-based mode has operated in conjunction with public modes in few countries, such as USA, Germany, France, Japan and a few others. Several developing countries especially from West Asia and China in recent times have seen the creation of large private charities for S&T. In India, such coming together had happened historically; however, currently the social foundation of S&T undertaking is considerably weakened.

Governance types

A schematic presentation of the modes of governances of S&T structures and relative strengths of S&T infrastructure, along with numbers of goals and purposes, as well as joint modes of governances - could be presented as follows:

Table 3-01.01: Schematic presentation of the modes of governances of S&T structures in India

	Core S&T	Social sectors	Public sectors	Foundations
Central Government Ministries	Yes; few in number but relatively strong infrastructure, moderate number of goals	Yes; large in number relatively weak infra, many goals	Yes; few and moderately strong infra and few goals	Yes in supporting not-for-profit and very weak infra
State Governments Ministries	Very few and weak infrastructure, moderate number goals	Few and Weak infra, many goals	Only handful, few goals and very weak infra	Yes to few only cases of support and very weak infra
PRI/Local governments		Yes few but widely Distributed goals across line ministries and extremely weak infra	Few instances and extremely weak infra	Few Instances, weak infra and many goals
Private sector	Few Public-Private joint establishments and not strong; several own and moderately strong infra, limited goals	Several joint Pub-Pvt establishments and moderately strong infra, limited goals	Few only jointly and moderately strong infra, limited goals	Few with moderate support, weak infra, moderate no of goals
Foreign Governments/ private	Few with governments and few with private, strong infra, limited goals; several own and moderately strong infra, limited goals		Few jointly and modestly Strong infra, limited goals	Several and weak infra, many goals

Source: Own Compilation

Modes of Funding

The funding mechanism, especially for the S&T infrastructure, is thus primarily now under the management of line ministries. Instrumentation funding or experiment funding has been done in India through three broad modes: (1) as part of a sanctioned project/program; (2) as part of instrument/capacity build up; and (3) as part of a major national mission such as on space. Apart from the fund from line ministry, a proposing organization may seek fund from extramural facility of another ministry, or from the instrument/capacity build up funds from other line ministries.

A facility thus created is in general a dedicated (or laboratory) facility, not easily accessible to outside researchers or outside private parties. Fees based laboratories do exist in India but their functions are almost always limited to testing, standardization, certification areas and/or they happen to belong to public executive authorities such as on standards. Private fees based laboratories do exist at higher secondary school science level and at undergraduate levels. Infrastructure level research, experimentation facilities are yet to come up.

Infrastructure dedicated to S&T

A large number of specialized research institutes have come up over the years. The Research and Development Statistics 2007-08, from the Department of Science and Technology reported the presence of 3,960 R&D institutions in the country in 2006. The central sector core S&T ministries have only a few laboratories under them; especially, the number of laboratories with the CSIR constitutes less than 1% of the total number of R&D laboratories in the country.

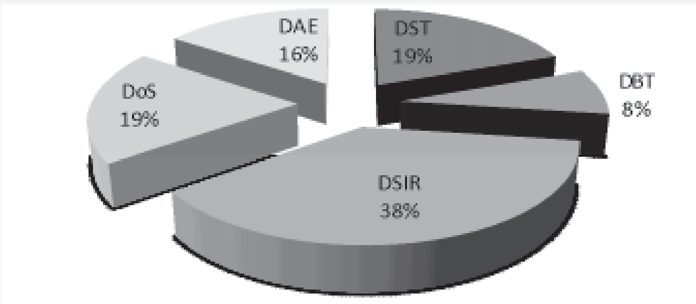


Fig 3-01.01: Percentage of S&T organizations under the Central Ministry of Science and Technology (DST, DBT, DSIR) in blue and the Independent Departments (DoS, DAE) in shades

***Source**: Websites of respective Departments*

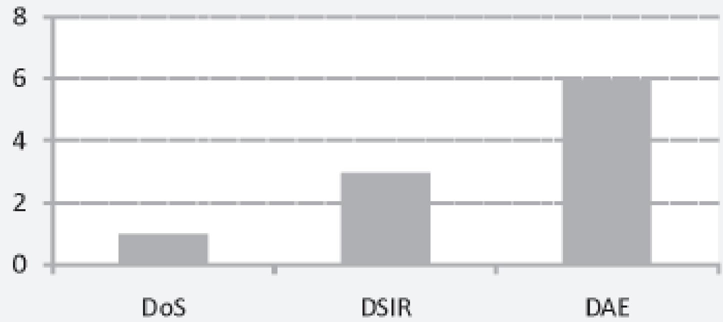


Fig 3-01.02: Number of public sector undertakings under respective independent departments and Ministry of Science and Technology of the Central Government Ministry undertaking R&D

***Source**: Websites of respective Departments*

State-wise distribution, as per the DST Research and Development Statistics at a Glance 2007-08, is: Maharashtra with 835 R&D institutions, Tamil Nadu with 402, Andhra Pradesh with 338, Delhi with 321, Karnataka with 311, Gujarat with 273, West Bengal with 260, Uttar Pradesh with 223, Kerala with 139 and the rest of the states with the remaining 858 R&D institutions.

Fig 3-01.01 and 3-01.02 show the manner in which S&T institutes, which are primarily of R&D nature, spread across the Central Ministry of Science and Technology and some independent departments, e.g. Department of Space and Department of Atomic Energy.

Fig 3-01.03 gives an idea of the various socio-economic sector central government ministries with respective number of institutions involved in scientific research and training. There are, moreover, a large number of S&T/R&D institutes under central science departments, the state managed and state supported S&T/ R&D institutes, and institutes with private sector or social sectors.

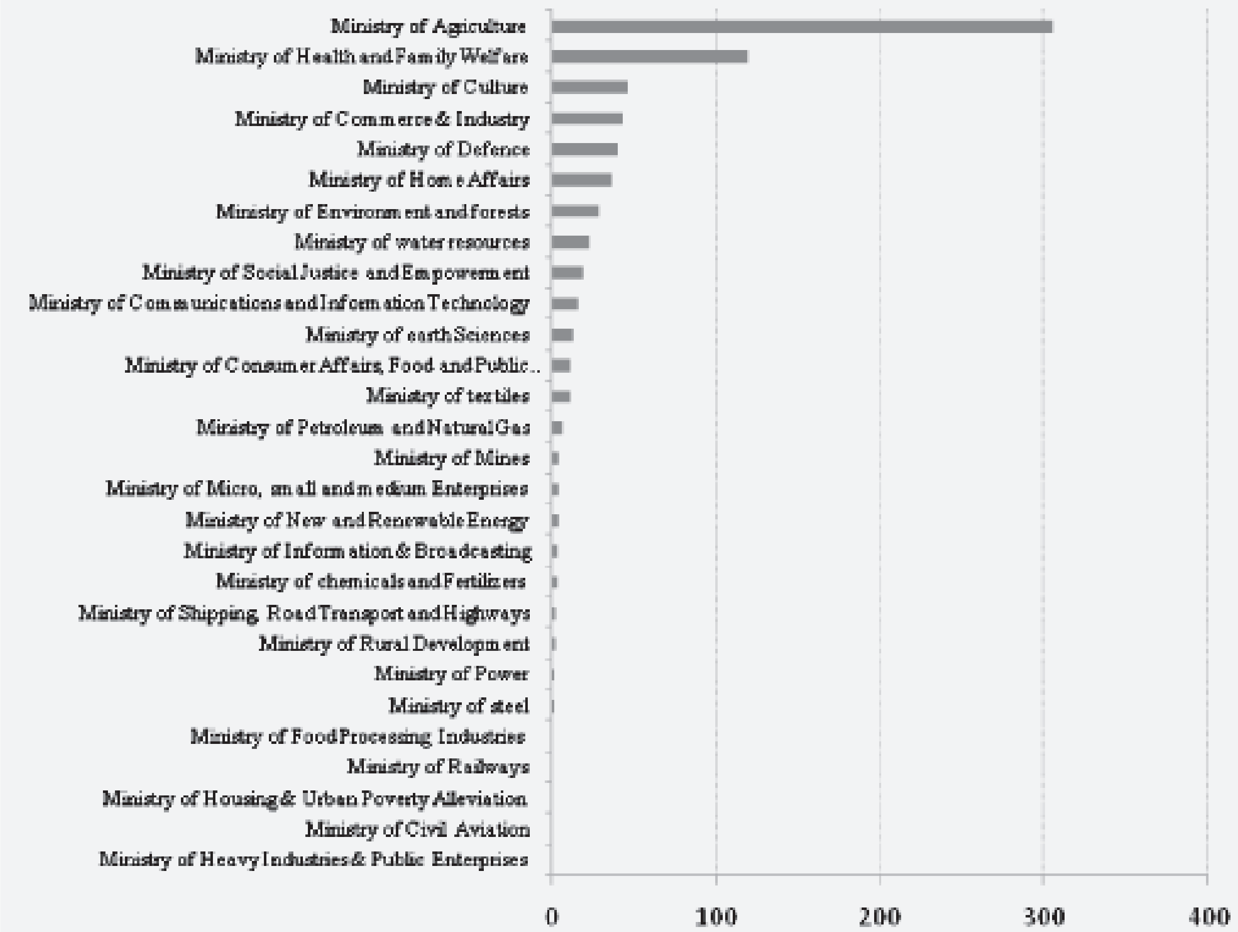


Fig 3-01.03: Number of S&T institutions across several Central Socio-Economic Ministries
***Source**: Websites of respective Ministries*

A schematic presentation of governance structures and their status, in brief, for most of these organizations is provided in Table 3-01.02

Table 3-01.02: Schematic of governance structure and the status of R&D institutions in India

	S&T core	Social sector	Public sector
Central government Ministries	Several departmental laboratories under professionals; strong and often directed research basic and applied and relatively strong infrastructure	Large number of labs often under admin executive; often multiple goals; relatively weak research & infrastructure	Few labs, some under joint management, ultimately under admin executive; more directed developmental research; moderately strong infrastructure
State government Ministries	Only in few states, most for BT, ultimately under admin executive, relatively modest infra	Few labs, multiple goals, often under admin executive; weak research & infrastructure	Few only labs; joint management, mostly under admin executive, and less directed developmental research
Private sector	Several small labs; often weak in research & infrastructure	Few only labs; fewer goals than above & weak in research & infrastructure	Few joint public-private; few goals & more directed but weak research & infrastructure

Schemes and Programmes for S&T Infrastructure Development

In recent years, great concern has been expressed about lack of infrastructure facilities for imparting good quality higher education and conducting advanced research. Considering this, a new scheme "Fund for Improvement of S&T Infrastructure in Universities and Higher Educational Institutions (FIST)" was launched in 2000-2001 by Department of Science and Technology. The state-wise distribution of the Universities & Departments identified & supported during 2000-2007 in FIST Program is available at *http://www.fist-dst.org/statewise_data.pdf.* The Department of Biotechnology has initiated a programme to augment and strengthen institutional research capacity in areas of Biotechnology through support for establishment of Centers of Excellence (COE). The objective of this programme is primarily to strengthen an institution's research infrastructure through the establishment of a thematic research centre with multi-disciplinary research effort. The Ministry of Human Resources Development has been running a few similar programmes, such as on centers of excellence, for last several years. Earlier, few organizations resorted to funding from the World Bank loan; public banking fund has not been deployed.

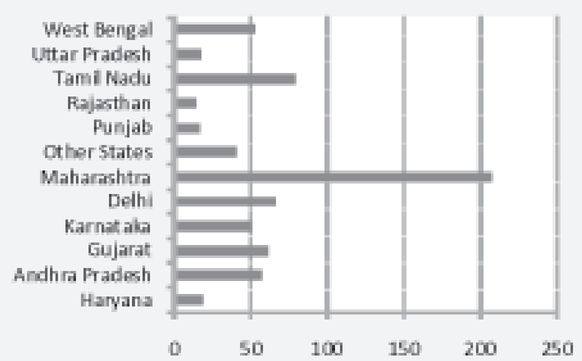


Fig 3-01.04: Statewise Distribution of Private Sector Companies doing R&D in India in 2008
Source: *CMIE Database*

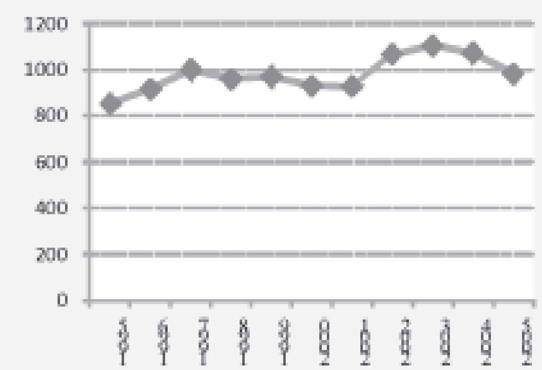


Fig 3-01.05: Presence of Private Sector Companies doing R&D over the Years
Source: *CMIE database*

The private sector has R&D departments/units with respective economic enterprises and sometimes with trusts supported by such private enterprises. Moreover, there are S&T/R&D units with several social sector NGOs/ NPOs. The figures 3-01.04 and 3-01.05 exhibit the distribution of only one type of private R&D units/departments in India.

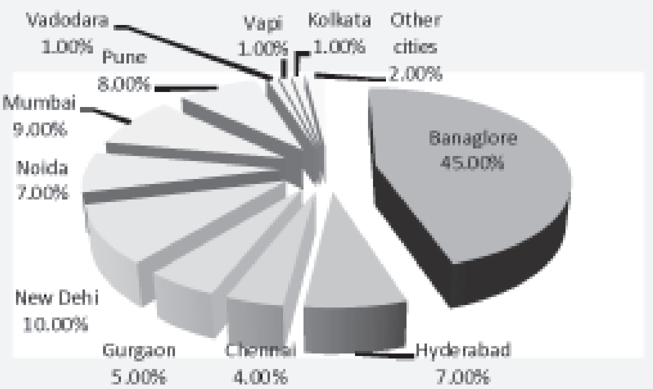


Fig 3-01.06: City-wise distribution of FDI Companies doing R&D in India
Source: *TIFAC Report*

Last few years have seen foreign companies invest- ing in owned R&D establishments in India. Figure 3-01-06 based upon data for the year 2004 (current figure is higher) exhibits the distribution of such R&D establishments.

Professional scientific societies or associations are weak in India relative to several advanced countries, notably the USA. Role of professional control in management of S&T organizations has remained sparse, few and far between, and is often exercised in conjunction with administrative organs and under typically governmental administrative rules, budgetary practices, cash flow managements, information channel controls, organizational processes, audit requirements as prevail in respective ministries/departments controlling the concerned S&T/R&D organization.

The peer controls, the gate keeping roles and peer hand-holding or reviews etc. are naturally very weak and do accommodate administrative rules and principles. The table below provides a sample of councils, associations and boards formed by the Department of Commerce and the Department of Industrial Policy and Promotion under the Ministry of Commerce and Industry with the objective to build up the S&T infrastructure of the nation.

Table 3-01.03: Differences in governance under social sector

Councils	**Boards**	**Associations**	**Autonomous Research Institutes**
Quality Council of India	National Board for Quality Promoters National Accreditation Board for Certification Bodies (NABCB) National Accreditation Board for Testing and Calibration Laboratories (NABL) National Accreditation Board for Hospitals and Health care providers	Automotive Research Assoc. of India	Central Manufacturing Technology Inst
National Productivity Council	Rubber Board Rubber Research Institute of India (8 research Stations)	Indian Rubber Manufacturers Research Association	Institute for Design of Electrical Measuring Instruments
National Council for Cement & Building Materials Centre for Cement Research and Independent Testing (CRT) Centre for Mining Environment, Plant Engineering and Operation (CME) Centre for Construction Development and Research (CDR)	Tea Board National Tea Research Foundation Darjeeling Tea research and development centre	Tea Research Association (7 research stations)	Indian Institute of Packaging
	Coffee Board Central Coffee Research Institute (8 research stations)	United Planters' Association of Southern India (UPASI) (7 research stations)	Central Pulp & Paper Research Institute
	Spices Board Indian Cardamom Research Institute (3 research stations)		National Institute of Design

Source: www.goidirectory.gov.in

Table 3-01.04 provides clues to differences in performance and goals of some of the R&D institutes, directly or indirectly, under the Ministry of Textiles. Large numbers of performance related to intangibles, often remain unstated and are thus inscrutable.

Table 3-01.04: Performances of R&D institutes in the textile sector

Name of the Institute	Publications in last 15 years	Technologies developed and commercialized	Staff strength (S&T/Others)
Wool Research Assoc.			
South India Textiles Research Assoc.	39	45	
Silk & Art Silk Mills Research Assoc.	4		
Northern India Textile Research Assoc	10		51
Indian Jute Industries Research Assoc.	3		
Central Sericultural Research & Training Institute	2	24	368(96/272)
Central Sericulture Research & Training Inst.	14		
Bombay Textile Research Association	90	50	
Ahmedabad Textile Industry's Research Assoc	44		169 (125/46)

Source: *Scopus, Web of Science, Websites of respective Institutes*

Table 3-01.04 reflects the fact that the S&T institutes in India are currently delivering multiple knowledge goods, both tangible and intangible, licensed exclusively or non-exclusively or as simple give-away; they are providing both non-market priced and free advisory/ consultancy, and similar other services. As a result, when computed by number of papers published especially in international journals, patents or distinct novel products, most institutes fail to show up good output. The charters/ agendas have demanded variable outputs and administrative imperatives limit transferring output/knowledge. Thus it stands against the notion that publications in journals of repute are central to measuring output. Social sector laboratories might not show remarkable publication records, but they are working on other aspects of technology development e.g. development of standards, undertaking prototyping, problem solving, providing consultancy and training and similar other services. Now, while measuring the output of such institutions, it is often found that their tangible performance is not uniform. Institutes generating relatively poor research output, however often provide a variety of tangible and intangible outputs and services. It appears that the yardstick of measurement needs to accommodate non-research but developmental dimensions of R&D, and it must identify bridge organizations. Outputs and goals are closely related to coordination modes and governance structure. Restructuring governance has remained the most active agenda in a few comparator countries, notably in China. Diversity in capacities, capabilities and outputs of this complex web of democratized federated structures of governance are assets that could be further strengthened by learning lessons from comparative policies.

Lessons learnt

Thus, it is understood that although over the years growth of S&T infrastructure has taken place significantly, the achievements are yet to become very promising. The socio-economic sector laboratories which are expected to harness S&T for the developmental aspects of the society quite often suffer from mismatch and are expected to perform up to their expected targets. The key reasons behind such mismatch could be shifts in and softening of governance, poor S&T infrastructure including laboratories and workshops, multiplicity of S&T goals, changing S&T charters and research agenda, locked-up levels of skills and competencies of personnel, among others. Absence often of transparent coordination mechanisms or instruments renders this large structure weak. Goals multiplication and shifting charters/agenda often appear to have resulted from changes in governance structures and governance imperatives. This in turn results in a fuzzy set of expected deliverables and locked-up skills and competencies of personnel. Almost always research institutes are run under administrative rules and structures analogous to those prevailing in, and for, the line ministries. The public audit system too has very significant influence on modes of functioning and the capability to deliver.

We also find that India has a huge S&T infrastructure in which there is wide variance in the governance structure. The gains from such varied structures have definitely been very impressive, however, with one caveat. Unlike a singular mode of governance where gains are defined well and beforehand and where measurement of gains are easily computable, visible and are large – the Indian web of federated democratized stakeholders-related governances have defined multiple goals, varied types of deliverables, complex modes of negotiations and regulations and the Indian governances have therefore delivered very large number of relatively inscrutable grass-root gain that are not easily amenable to accumulation. In fact, standard instruments of direction such as laws and audit systems have accommodated, especially in the phases of implementation of S&T based developmental programs, the roles of negotiation and aspirations of the local structures of governance. The distinct gains from this very distributed mode of goals and governances are that widely distributed capacity and very diverse capabilities have been sustained and generated. This is perhaps very unique to India and few nations can be proud of such great diversities. The future of Indian S&T and the developmental discourse needs to recognize these, albeit weak, very diverse capacities, capabilities, gains and governances as the central feature.

The Regional Innovation System: Tracing the evolution in main regional governance characteristics

Innovation Performance and Policy Objectives

By 2006-07, the share of agriculture in GDP had declined to 18.5%, and the share of industry and services had improved to 26.4% and 55.1%, respectively. The lower contribution of industry to GDP growth relative to services in recent years is partly because of the lower share in GDP and does not adequately capture the signs of industrial resurgence.

First, growth of the industrial sector, from a low of 2.7% in 2001-02, revived to 7.1% and 7.4% in 2002-03 and 2003-04, respectively and after accelerating to over 9.5% in the next two years, touched 10% in 2006-07. Second, growth of industry as a proportion of the corresponding growth in services, which was 78.9% on an average between 1991-92 and 1999-2000, improved to 88.7% in the last seven years. Third, within industry, the growth impulses in the sector seem to have spread to manufacturing. Industrial growth would have been even higher had it not been for a relatively disappointing performance of the other two sub-sectors, namely, mining and quarrying, and electricity, gas and water supply. Fourth, between 1951-52 and 2004-05 industry has never consistently grown at over 7% per year for more than three years in a row.

Services sector growth has continued to be broad based. Among the three sub-sectors of services trade, hotels, transport and communication services have continued to boost the sector by growing at double digit rates for the fourth successive year. Impressive progress in information technology (IT) and IT-enabled services, both rail and road traffic, and fast addition to the existing stock of telephone connections, particularly mobiles, played a key role in such growth.

The results of the economic survey show that the annual growth rate of employment has not only accelerated from 1.6% during 1993-2000 to 2.5% during 1999-2005, but also crossed the 2.1% growth recorded during 1983-94. Unemployment has gone up not because of high growth but because growth was not enough.

During April-September 2005, foreign investment flows at Euro 6.4 billion were nearly Euro 4 billion higher than such flows of Euro 1.9 billion in the first half of 2004-05. FDI rose by 98.4% in the first half of 2006-07 and foreign exchange reserves touched Euro 140 billion during that period.

The national investment on R&D activities in India attained a level of Euro 3.5 billon in 2002-03.The same was estimated to be Euro 4.1 billion in 2003-04 and Euro 4.2 billion in 2004-05. During 2002-03, 0.80% of GNP was devoted to R&D.

Sector-wise percentage share of national expenditure on R&D during 2002-03 incurred on central government was 62.2%; state governments 8.5%; higher education 4.5%; public sector industries 4.5% and private sector industries 20.3%. Expenditure on various science and research related activities has increased by 17% in 2006-07 to Euro 4.8 billion. Sectors to gain from the budget are biotechnology, nanotechnology and pharmaceutical research. In continuation of the efforts of the Indian government to create institutions of excellence, three more universities have been allocated special research grant of Euro 9 million. Funding has been provided to National Entrepreneurship Boards to set up Technology Business Incubators enabling concessions to incubatees-entrepreneurs. These incubatees could be universities, R&D institutions and engineering colleges.

The Research and Development expenditure incurred by the Provinces has increased from Rs. 3.65 billion in 1990-91 to Rs. 15.74 billion in 2000-01and declined marginally to Rs 15.28 billion in 2002-03.The average annual growth rate of the R&D expenditure in 2002-03 over 1999-2000 was 5.8% The R&D expenditure by the Provinces accounted for 8.5% of the national R&D expenditure during 2002-03.The R&D expenditure in the Provinces constituted only 0.07% of the GNP at current prices during 2002-03. This share has remained almost the same for the past few years.

While there is a huge variation in the education expenditures across different Provinces, there is also a large difference in the enrolment and other patterns as well as in the number of educational institutes in the Provinces. Indeed what matters is not so much the amount spent by various provincial governments on education but the effectiveness of this, and that is judged by literacy rates and enrolment ratios. The per capita spending of West Bengal and Punjab is higher than Kerala's but it is Kerala that top the literacy charts in the country.

Given its huge geographic area, not surprisingly, Uttar Pradesh has the largest number of universities, though it is Maharashtra that has most colleges in the country. Uttar Pradesh accounts for the country's largest number of graduates (around 15.2%), followed by Maharashtra (13.7%) and Andhra Pradesh (8.1%). Delhi has the most qualified population; around 16% of all persons living in Delhi have at least a graduate degree. At all India level 6% of the country's population (above the age of 10) is at least a graduate, and another 12% has passed class 12 and/or has a diploma. Though Karnataka is considered to be the country's knowledge centre, it is Andhra Pradesh that has the highest proportion of science graduates in the country. Of the12.1 million science graduates and diploma holders in the country, 14% are to be found in Andhra Pradesh, Tamil Nadu is next with 11.9%, Maharashtra third with 11.1%, Uttar Pradesh fourth with 10.2% and Karnataka gets into the list next with 7.5%. Not surprisingly, Maharashtra leads in terms of stock of commerce graduates (22%). In terms of those enrolled in commerce at the graduate and higher levels in the country, 16% are to be found in this Province. Gujarat again expectedly, ranks second with a 13.8% share in the stock of commerce graduates. Indeed, over 30% of all Gujaratis who are either graduates or diploma holders have studied commerce for their degrees. Of those who have enrolled in 2004, a third are studying commerce.

In the year 2003-04, 2,469 patents were sealed out of which 1,078 patents were sealed by Indians from Maharashtra region with a percentage share of 28.6%. USA topped the list of application for patents filed in India by foreign countries with a share of 33.3%.

As on 1 April 2000, nearly 2,96,000 personnel were employed in R&D establishments in the country including in-house R&D units of public and private industries. Of these, 31.7% were performing R&D activities, 30.4% were performing auxiliary activities and 37.9% were providing administrative and non-technical support.

The *modus operandi* of the technology policy thus evolved has been two pronged as in the case of industrial development in general. The policy has sought to provide protection to local technology/skills from the imported ones, and on the other hand, the local generation of technology has been accelerated directly and indirectly. The technological capability that has accumulated as a result of these policies is no doubt immense and has brought the country near technological self-reliance in a number of industries. India has even been able to export a wide range of technologies and products to other countries.

Indian software industry has made amazing progress over the last five years. Its export earnings were Euro 18.7 billion with a growth rate of 26% despite a slow-down in economy. India exports software to 95 countries; some of the major countries being USA, UK, France, Germany, Japan, China, South Korea, Taiwan and Hong Kong. In the Drugs and Pharmaceutical industry, India has become a base for outsourcing drugs having low cost of production.

Major Innovation Challenges and Policy Response

Challenge No. 1: *Science and Technology capacity building in state enterprises and its impact on innovation* - With the establishment of scientific agencies like the Council of Scientific and Industrial Research (CSIR), the Indian Council of Agricultural Research (ICAR) etc. India came to acquire a huge infrastructure for science and technology, but excellence in technology development could not be achieved so as to compete in the international market — the reason, India never had an export-oriented policy of economic development. So far National Laboratories have only taken care of the protected domestic market. They have not oriented themselves to developing highly sophisticated technologies. With the liberalization of the Indian economy late in 1991, the competition has ratcheted up several levels. It is necessary for Indian Science and Technology, therefore, to develop quality products and compete internationally. Scientific research and technological development will benefit by developing self-reliance through learning-by-doing by way of focusing on state enterprises as hubs for technology development.

Challenge No. 2: *R&D excellence in Information Technology and Biotechnology* - The IT industry is highly knowledge intensive and requires R&D inputs on a regular basis. Most of the leading international players especially those in Very Large Scale Integrated (VLSI) Chip design have set up their design and R&D centres in India. Some Indian companies have also made successful entry into global R&D services for developing world-class products. However, even though the software sector has done so well, there are still a few challenges that have to be met.

The software export industry has been mainly concentrating on the services sector. Here, the overall productivity, which is much lower than in the developed countries, needs to be increased. The IT services sector has been able to provide sustained growth over the last decades. To continue with this growth Indian industry needs to take immediate steps to move up the value chain. Though Indian professionals in the software industry have contributed to the development of intellectual property, the Indian industry owns very few patents. The performance of the software industry has been below expectations. For India to become an IT superpower, it is necessary that an integrated approach that boosts the hardware and software sectors, and strengthens manufacturing and lays emphasis on education, R&D and generation of IPR is evolved and implemented.

India is well poised to embark upon Biotechnology-based national development. The underlying assumption of the policy framework is that developments in the field of Biotechnology will have the greatest impact on food, nutrition, health, environment and livelihood security.

Challenge No. 3: *Technology development in manufacturing sector* - Every sector of the Indian manufacturing industry needs to be revamped by developing new innovations, whether it is information technology, capital goods sector or pharmaceutical industry. India is quite well off in the software sector through the innumerable outsourcing jobs undertaken for foreign companies but is far behind in the hardware arena. For instance, India is exporting hardware goods worth only Euro 2 billion whereas China is exporting hardware goods to the tune of Euro 40 billion. The reason India has a weak electronic component base is because it is difficult to keep up with the latest technologies in microelectronics. The same is true for the capital goods sector. India has to come up with an infusion of new technologies in the manufacturing sectors to make them world class.

Intensive efforts should be launched to develop innovative technologies of a breakthrough nature and to increase the share of high tech products.

Innovation Governance and Policy Trends

India was the first country in the world to have, in 1951, a Ministry of Scientific Research and National Resources for organizing scientific research for national development. The Scientific Policy Resolution passed by the Parliament in 1958 laid down scientific objectives—pure, applied and educational. Active pursuit of these policies bore fruit and educational institutions and scientific laboratories were established so as to reap the benefits of scientific progress.

The next major landmark in the policy domain was the announcement of the technology policy of the Government of India, at the Indian Science Congress held in January 1983 at Tirupati, Tamil Nadu. Apart from reinforcing the above objectives, this resolution specifically called for developing internationally competitive technologies with export potential, energy-saving technologies and technologies that would recycle waste material. As for priorities, it called for consideration to be given to employment, energy efficiency of activities, and environment.

In the field of acquisition of technology though, it called for a selective role of import of technology and foreign investment. The policy specifically stressed the need for absorption, adaptation and subsequent development of imported know-how through adequate investment in R&D for which importers of technology were expected to contribute. In the context of the efficiency of the invention-innovation process, the role of CSIR is of paramount importance.

Much has been written about the strengths and weaknesses of CSIR. The CSIR Review Committee in 1986 found that the multiplicity of objectives, sub-objectives, scale of operation, the lack of sustained and meaningful interaction between the CSIR and its actual and potential users, and the lack of suitable incentive support had in the past limited the usefulness of the CSIR. Some of the factors were beyond the control of the scientific institutions; they were also affected by the industry’s influence and the regulatory regime.

Innovation governance: Key changes and issues: It is encouraging that CSIR issued a white paper, *CSIR 2001: Vision and Strategy*. Among other things, it set the goal to achieve self-sufficiency in financing by 2001, primarily through development of some niche areas in globally competitive technologies, holding of a patent bank and realising 10% of operational expenditure from intellectual property licensing. Moreover, as a strategy for achieving these goals, it called for development of an effective marketing system and adoption of a stimulating intellectual property oriented outlook.

In 1991, the government introduced a liberalised policy for technology transfer. Apart from giving a large number of tax concessions for R&D, the government also implemented a number of policy measures with far-reaching significance in the field of science and technology. A Technology Development Board was established with a three-fold strategy: a) facilitating development of new technologies, b) assimilating and adapting imported technologies, and c) providing catalytic support to industries and R&D institutions to work together.

Lately, the *Science and Technology Policy–2003* declared by the Prime Minister recognises the changing context of scientific enterprises to meet present and future national needs in the era of globalization

Trends in innovation policies: In the budget for 1994-95, the Fund for Technology Development and Application was created wherein 5% cess on payment for royalty for imported technologies was credited. The budget for 1995-96 strengthened this fund and released Euro 5 million. It proposed a one-time matching grant for the modernization of laboratories of the CSIR and ICAR. Every commercial Euro that CSIR and ICAR earn incrementally will be matched by another Euro from the budget.

In the draft of Eleventh Plan, among the specific issues that call for closer attention are: creation of a conducive environment in the R&D institutions for minimizing hierarchical bureaucracy; emphasis on human resources development and motivation as an element of qualitative fundamental research and applied research; and development of scientific laboratories as nodal institutions forming consortia with the industry and other departments.

The development of India's technological capabilities may be reflected in the changes in sectoral composition of gross fixed capital formation (GFCF) at constant prices. The share of machinery and equipment in GFCF has gone up substantially. India has a history of some 40 years of manufacturing capital goods. Both kinds of capital goods, the special purpose equipment for process plants (for chemicals, metals, minerals, consumer goods, electrical power) and the general purpose machines amenable to mass production (machine tools, transport equipment etc.) have been produced. In the process of vertical integration of manufacture from assembly stage backward to individual components, a wide production base has been created. However, capabilities of designing and further improving upon the product have not been developed for many kinds of capital goods.

Future Actions and Opportunities for Policy Learning

What is the government's role in advancement of science and technology up-gradation in a liberalized market? In popular parlance, liberalization is equated to the withdrawal of state from the economic domain. However, science and technology is a field where such a popular notion may turn out to be fallacious. It is widely argued that there are three sources of market failure, viz., indivisibility, uncertainty and externalities. R&D that seeks to generate knowledge suffers from all three types of market failure. Moreover, when there is a wedge between private and social profitability; something that exists in pure research, private finance may not be forthcoming. Thus, even in a deregulated regime, the state will have three specific and selective roles in fostering science and technology, viz., financier of fundamental research, provider of infrastructure, and regulator of property rights. The government is required to coordinate and guide technology development since free markets might not suffice to create the technological dynamism that industrial growth needs.

India has come a long way in her quest for scientific pursuit, both in material and intellectual spheres. Winds of change have been blowing in the field of science in India. Information technology poses new challenges and has opened up new opportunities. True, there is still much to be done in the policy and legal spheres. But the direction is right. In the liberal environment, let thousands of ideas bloom and be trans-created into innovative ventures by entrepreneurs. India has the talent, the skills and the resources to be in the forefront of the technological revolution taking place in the new sectors of growth in the global economy.

Science in Kerala – a snapshot

Having recognized that Kerala has had a long tradition of literacy and school education, it is of concern to note that it is still behind leading states of the country, let alone comparative regions of the world (e.g. South Korea, or the Scandinavian countries), when it comes to higher education and research. Although Indian Scientific and Technological Research and Development activities have received substantial support, it has still a long way to go to reach the level attained by the advanced economies. While a large number of R&D establishments have been set up in the country, Kerala's share in this has been insignificant. Opportunities for those who are interested to pursue research in Kerala are meagre.

This section identifies the champions of research in Kerala and brings out a brief region-wise research profile of Kerala on the national landscape. Data from SCOPUS (with emphasis on the output from Kerala for the last ten to fifteen years) was used to do the analysis. It was found that leading researchers in the state have either retired or are approaching retirement age. It is also to be noted that very few of them are from the engineering area. So, there is an urgent need for generation of young researchers. Nevertheless, the current resource can still be tapped as mentors and champions for spearheading the new initiative. They also come from a few institutions, indicating that excellence in Kerala is highly concentrated in a few premier centers.

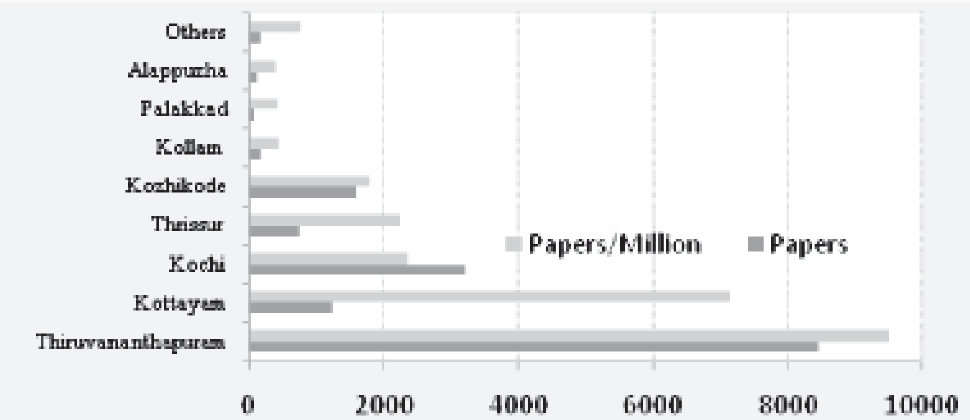


Fig 3-03.01: Region-wise distribution of papers published vis-à-vis Papers/Million of population in various educational institutes in Kerala over the last 15 years,
Source: Scopus Database

To get the regional performance profile in terms of research intensity, the number of papers published from various regions of Kerala was weighted for population of the corresponding cities (or conglomerations, where appropriate). Thiruvananthapuram tops the list for research intensity, followed by Kottayam, Kochi, Thrissur and Kozhikode (Fig 3-03.01). However, we also see that vast tracts of Kerala hardly have a research culture. This should guide us to take remedial steps so that such imbalances are removed and bring in the culture of research to regions where they do not exist now.

From a recent NISTADS study, it is seen that on Papers/Million of Population/Year basis, Kerala has only a very middling performance, joining the company of states like Arunachal Pradesh and Mizoram. This is worrying, given that Kerala has had a long and much vaunted tradition of literacy and school education. Fig 3-03.02 suggests that while a large number of R&D establishments have been set up in the country, and the UTs and small states (Chandigarh, Pondicherry, Delhi, Goa) have benefited from this, Kerala's share in this has been insignificant.

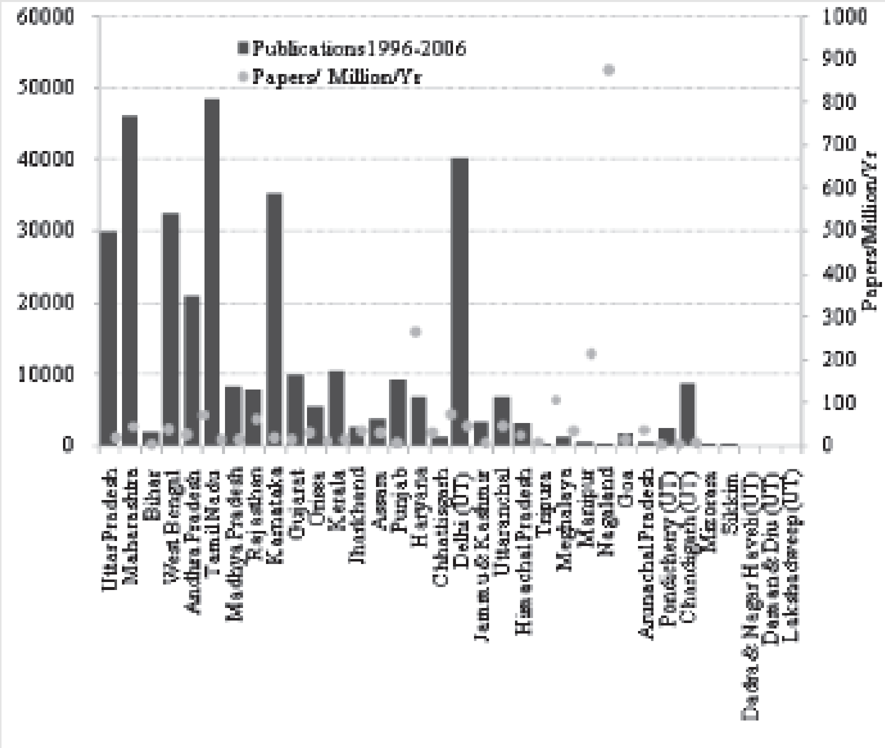


Fig 3-03.02: State-wise distribution of Publications vis-à-vis Papers published/Million Persons/Year during 1996-2006

The Council of Scientific and Industrial Research (CSIR) promotes scientific research in universities by providing financial support for research projects under their Extramural Research Projects scheme. In a four year period, Kerala completed four projects, of which three were in Life Sciences and one in Chemical Sciences. No project in Physical or Engineering Sciences was proposed. Weak generation of demand from Kerala reflects upon the state's internal process. From an analysis of the current status of project grants given by CSIR under its extramural research schemes in physics it was observed that even if all projects, i.e. newly proposed, those actively under progress, and even those being terminated, are accounted for, there is no current proposal from Kerala being funded by CSIR under this scheme! This is indicative of the general poor health of Kerala's research.

Science and Technology Mapping in States of India

Science and Technology have largely been the domains of Indian government since independence. Within the central government, there are under the ministries/ departments, the lower-level agencies, and institutions involved in the science and technology infrastructure. In the 11th Five-year plan, the chapter on "Science and Technology" has been renamed as "Innovation and Technology". This section provides a range of S&T infrastructure spread across select states of India to highlight the growth of India's S&T capacity in the figures that follow. The aim is to give the readers a quick glance across a broad set of S&T indicators, with trends or other multiple data points, wherever possible. The indicators covered are:

- Education, training and research and development
- Science and Engineering manpower
- S&T Expenditure

Data sources include Annual report-2006-2007, Ministry of Labor and Employment; Directory of R&D Institutes, DST (2006); India Yearbook, 2008; Manpower Profile, 2008; Census of India (2001); *http://education.nic.in/stats/StateProfile0506.pdf* and *http://planningcommission.nic.in/plans/outbody.html.*

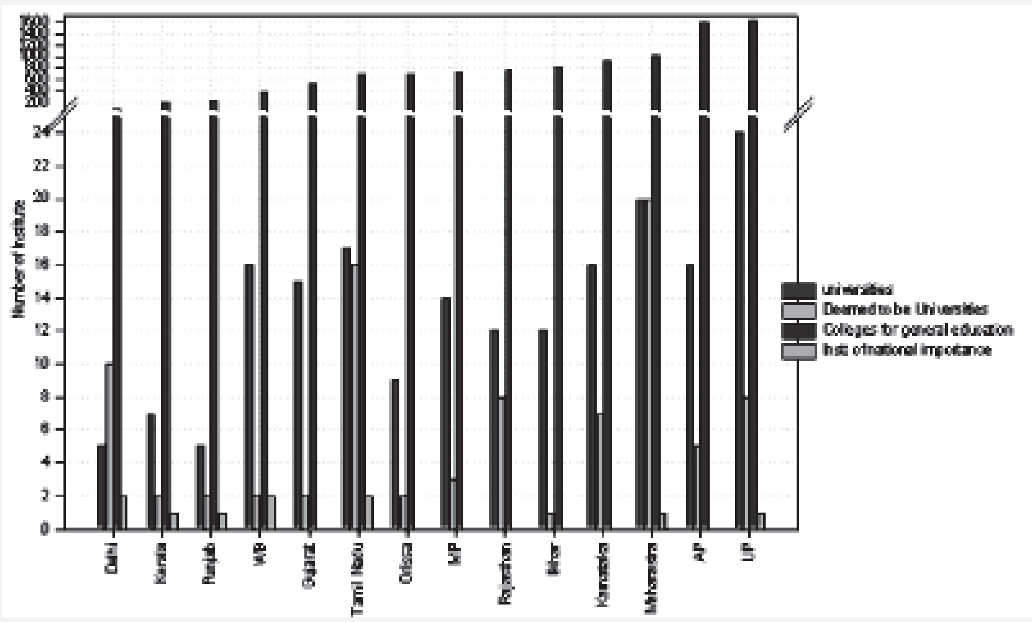


Fig 3-04.01: Distribution of centre/bodies of higher education in India over the years in select states

Source: *http://education.nic.in/stats/StateProfile0506.pdf*

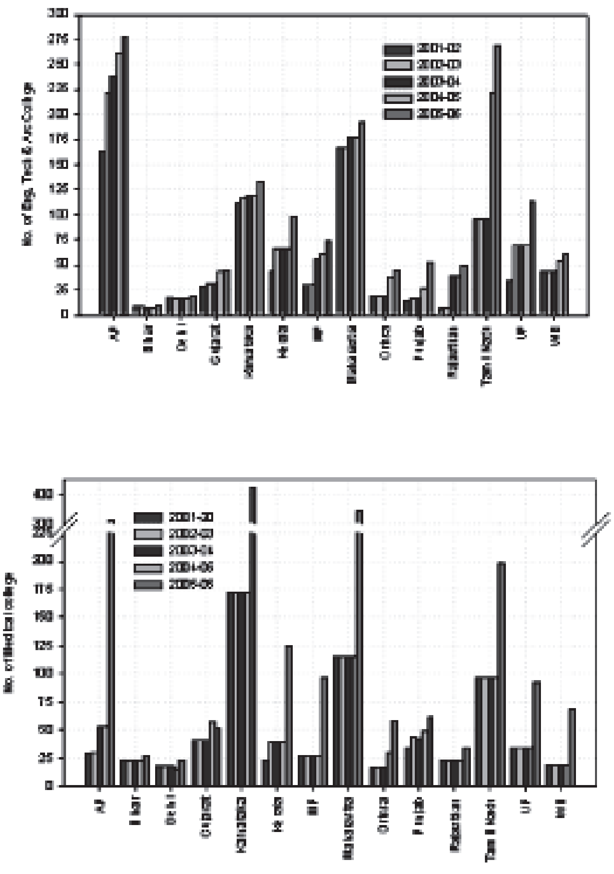


Fig 3-04.02: Distribution of institutes imparting engineering & medical education in India over the years across select states

Source: *http://education.nic.in/stateProfile0506.pdf*

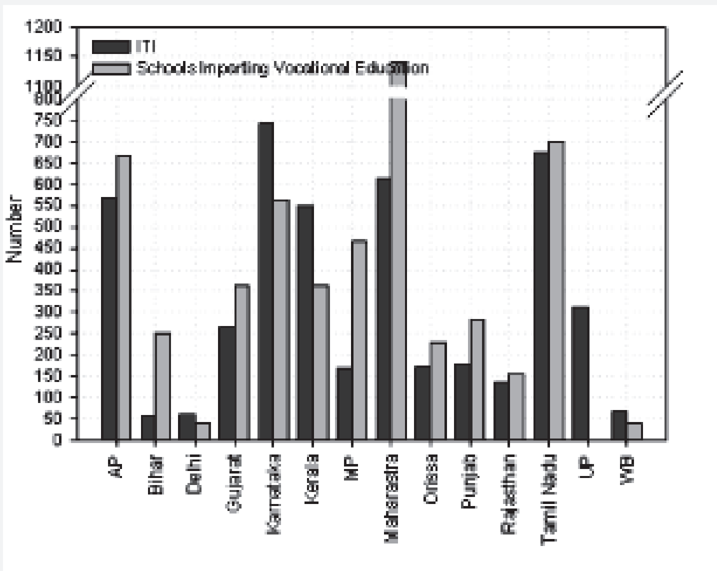


Fig 3-04.03: State-wise distribution of ITIs and vocational schools in India
Source: *Ministry of Labour and Employment, Annual report-2006-2007.*

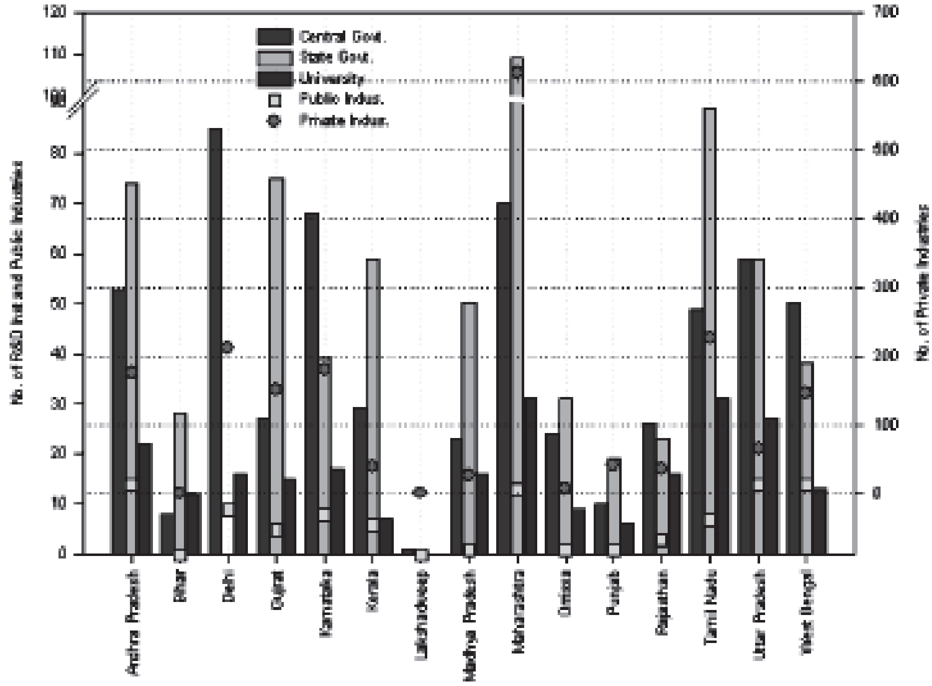


Fig 3-04.04: Research and Development Institutes across the States

Source: *Directory of R&D Institutes, DST (2006)*

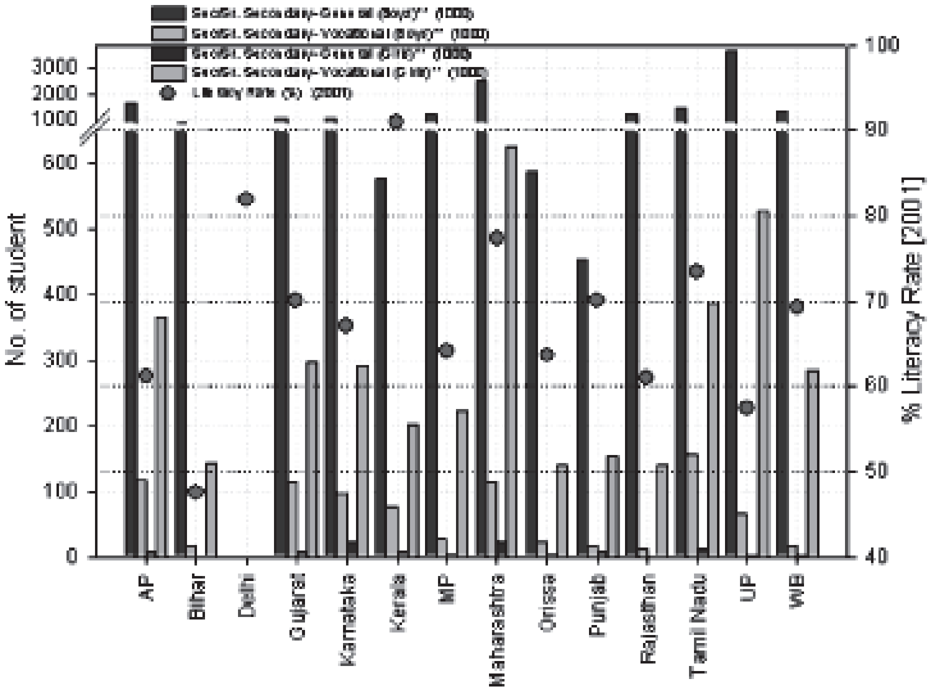


Fig 3-04.05: State-wise Enrolment Status of Sec/Sr. Secondary--General & Vocational (Boys & Girls) vis-à-vis literacy rate

Source: *Min of HRD (2004-05), Census of India (2001)*

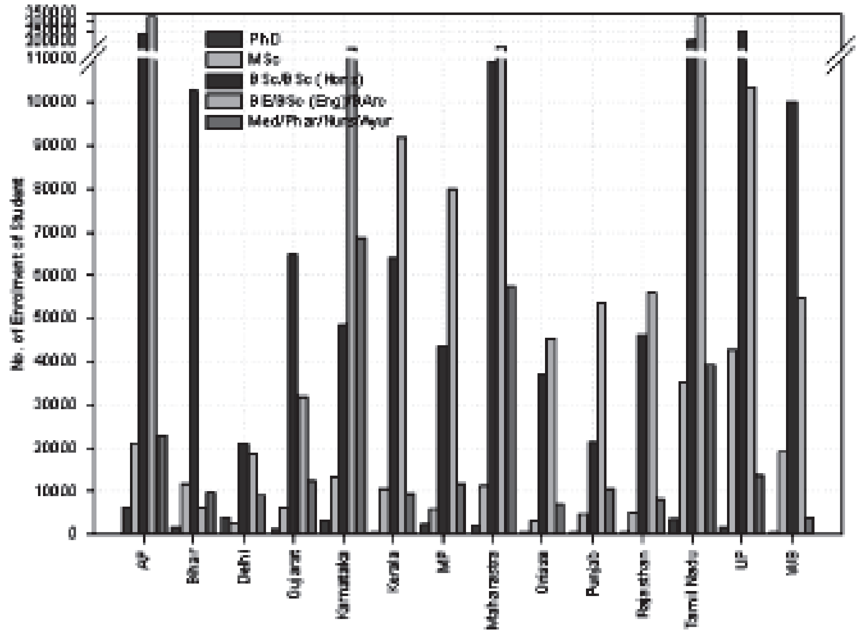


Fig 3-04.06: State-wise enrolment status of various degrees of higher education over the years

Source: *http://education.nic.in/stats/StateProfile0506.pdf*

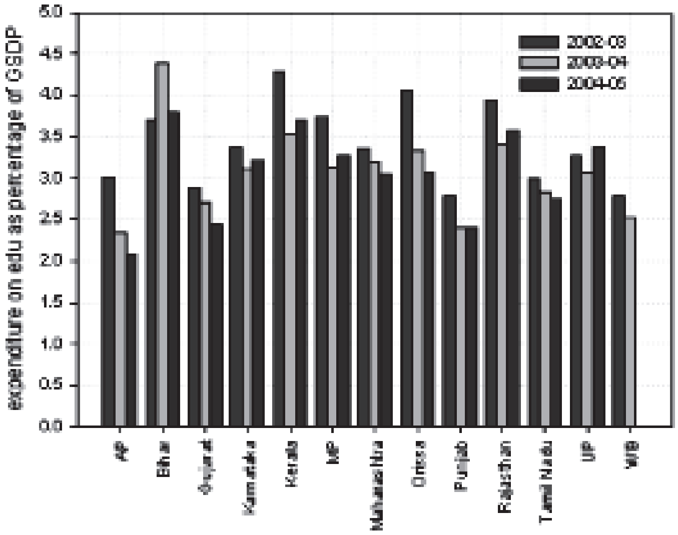


Fig 3-04.07: Expenditure on Education as percentage of GSDP in select states

Source: *http://education.nic.in/stats/StateProfile0506.pdf*

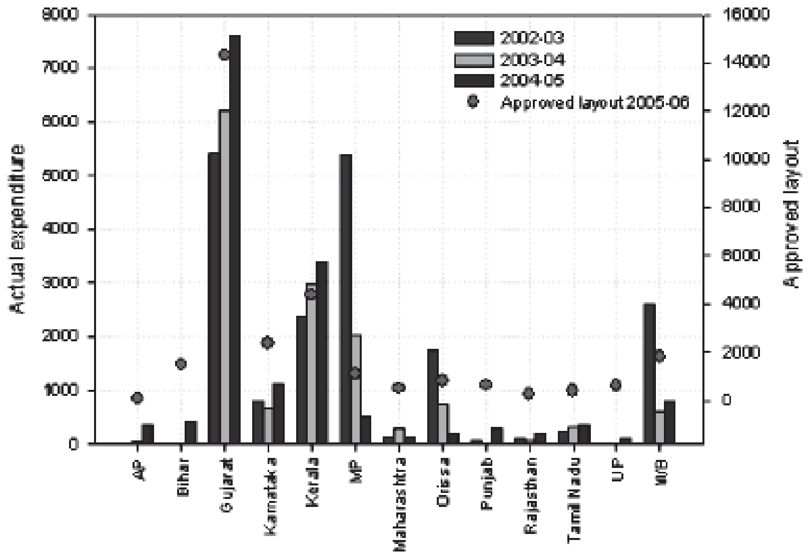


Fig 3-04.08: Expenditure incurred on S&T by respective states

Source: *http://planningcommission.nic.in/plans/outbody.html*

As reflected from the figures, some important observations are: the manpower generated in various states, is not necessarily retained in the respective states. Moreover there exist disparities across states with respect to presence of educational and R&D institutes, as well as in enrolment status. States like Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu show large number of engineering and medical colleges (Fig 3-04.02) due to presence of private institutes. Fig 3-04.07, however shows uniformity to some extent in expenditure on education amongst the states. There is no wonder why Gujarat is a leading state as seen from Fig 3-04.08, wherein the state expenditure on S&T is highest and at the same time it is increasing over the years.

Technology Transfer Structure: Glimpses

Technology transfer (TT) from the linear perspective is the process by which basic S&T research is developed into practical and commercially relevant applications and products for transferring to ultimate recipients. TT from public funded research institutions to industry happens through:

a) Another organization acting as interface such as the National Research Development Corporation (NRDC) and the Biotech Consortium India Limited (BCIL)

b) The efforts of research organizations.

The **NRDC** is a premier Knowledge Transfer Organization (KTO) in India. It is a Section 25 company established in December 1953 under the Ministry of Science and Technology with a mandate to commercialize, develop and promote indigenously developed technologies from universities, individual inventors, national R&D Institutions, and similar bodies (*www.nrdcindia.com/index.html*). Up till 1986, NRDC had the sole and absolute right to unencumbered intellectual property, produced by CSIR laboratories. Abid Hussain Committee (1986) recommended an end to NRDC's monopoly on knowledge generated in CSIR laboratories, and CSIR laboratories became free to license and commercialize their technologies.

Mechanism of Technology Transfer - Value Addition: Actual transfer of technology takes place after a legal agreement is executed by the client and NRDC which provides for certain initial payment and also royalty at a fixed percentage of sales value for a specified period. Mechanical technology was dominant during 1950's, chemical technologies during in the 1960's and later it was import-substitution and reverse-engineering till economic liberalization in the 1990's. At present, life science and biotechnology related technologies are prominent. For the commercialization of many unproven lab scale technologies, the Corporation does value addition by developing them either through equity participation or providing developmental loans or grants. Amongst the very few profitable such entities the world over, the NRDC has been earning modest profits. Over the years the Corporation has acquired more than 2,000 technologies and licensed them to over 4,500 entrepreneurs. Trends in royalty earned, patents filed, number of technologies received and the technology transferring agencies are shown in Fig 3-05.01, 3-05.02 and 3-05.03, respectivly. Most technologies from the CSIR laboratories, post-1986, have been transferred directly to the transferees.

Case: Vaccine against Peste Des Petits Ruminants (PPR)

Technology Development: National Rinderpest Control Program was launched by Indian Council of Agricultural Research during 1996. Indian Veterinary Research Institute (IVRI), Izatnagar undertook the research to develop the vaccine against peste des petits ruminants (PPR) using a lineage 4 virus isolated in India. The developed vaccine was tried on animals at laboratory level and then at state level. The technology was transferred to NRDC for commercialization. However, the developed technology required further development for industrial use.

Value addition by NRDC: Corporation worked towards exact identification of the strain, basic engineering and data generation for the upscaling the plant.

Commercialization of Vaccine: Technology was successfully commercialized by NRDC to two leading vaccine manufacturing companies of India, Indian Immunological Ltd (IIL), Hyderabad and Intervet Ltd, Pune. NRDC agreement with IIL was signed during 2004. Rs. 2.5 million was received as licensee fee (70% share for IVRI), with a royalty at 3% for 10 years.

Results: IVRI at its Mukteswar and Izatnagar campuses has an annual sale of about Rs. 10 million since 2005/06. Indian Immunological has sold vaccines worth more than Rs. 2 crores. Intervet has also scaled up the vaccine production process.

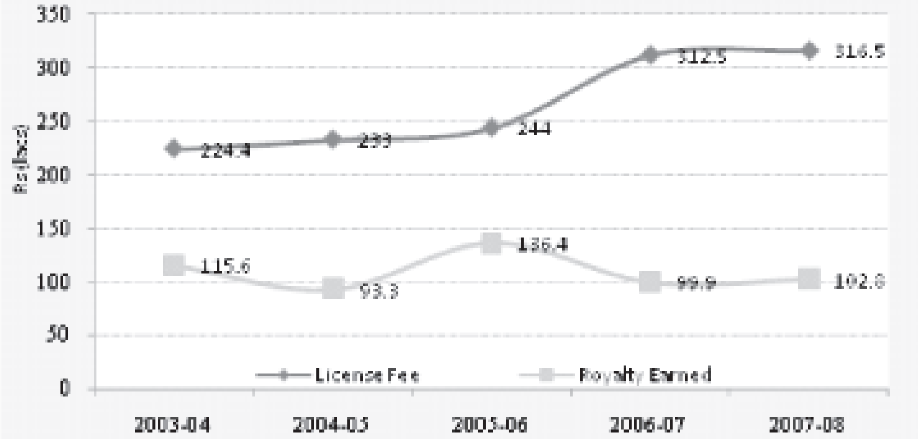


Fig 3-05.01 :License Fee & Royalty earned by NRDC

Source: *Author's communication with NRDC*

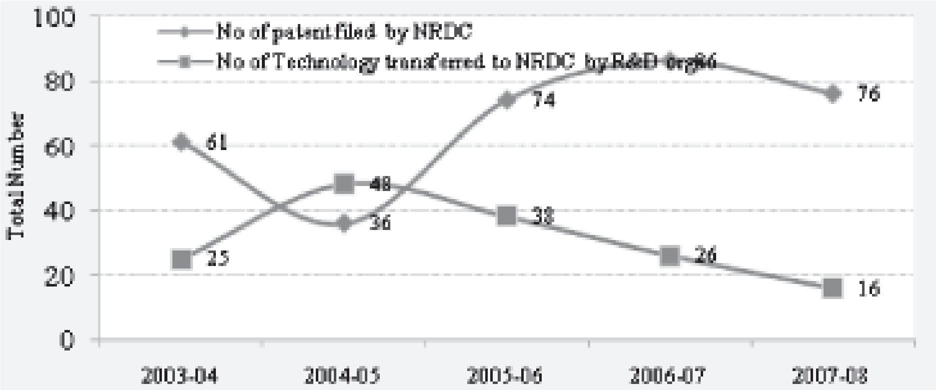


Fig 3-05.02 : Patents filed by NRDC and number of technologies transferred to NRDC

Source: *Author's communication with NRDC*

The **BCIL** was incorporated as a public limited company in 1990, under the Indian Companies Act 1956. It is promoted by the Department of Biotechnology, Government of India and financed by the All India Financial Institutions and corporate sector. BCIL has been actively involved in technology transfer along with commercialization of other biotechnology related activities. BCIL acts as an interface between technology sources and technology seekers both within and outside the country. By virtue of the network of national and international linkages, it assists in technology sourcing, marketing tie-ups and identification of joint venture partners. Technology transfer by BCIL involves screening for leads; evaluation of international linkages; assistance in technology sourcing and marketing tie-ups; validation; scaling up; packaging; technology pricing; entrepreneur selection; technology transfer; monitoring, support and consultancy. There are number of technologies available and many of them have already been transferred to industries. BCIL makes efforts for the successful commercialization of the technology by the licensee and continues to be a link between the technology transferor and the technology recipient.

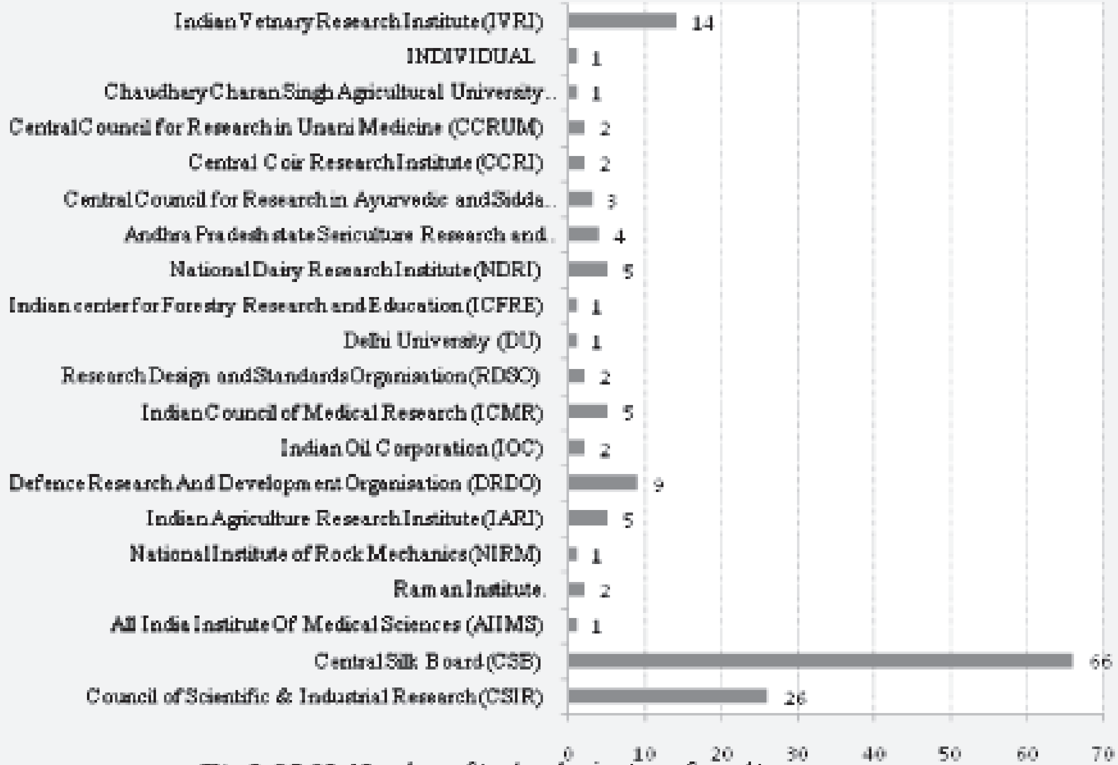


Fig 3-05.03: Number of technologies transferred to NRDC by various organizations (2003-04 to 2007-08)

***Source:** Author's communication with NRDC*

Table 3-05.01 : Know-how transfer earnings and patents granted by BCIL

Year	Intellectual Know-how Earnings (Rs. Lakhs)				Total	Patents Granted
	Technical Assistance (TAP)	Premium and Royalty	Analytical Charges	Consultancy	Intellectual Earnings	
2000-01	3.1	10.25	4.26	17.04	34.65	N.A.
2001-02	8.66	1.61	2.86	25.23	38.36	N.A.
2002-03	0.58	4.6	19.99	28.53	53.70	2
2003-04	1.63	27.47	3.94	23.8	56.84	4
2004-05	4.21	14.25	5.21	32.78	56.45	18
2005-06	8.69	5.85	3.42	50.28	68.24	13

***Source:** BCIL Annual Reports*

A Technology Park is an Industrial complex where all types of facilities are provided for the growth and development of Technology Business Enterprises (TBE). However, the technology and business incubator incorporates a new feature 'graduation', which implies that a start-up firm attains certain level of maturity after a specific period of probation.

Software Technology Parks of India (STPI)

Set up in 1991, STPI is an autonomous organization under the aegis of Ministry of Communications and Information Technology, with its headquarters in New Delhi. The very existence of STPI is to promote 100% export of Software and IT services. STPI acts as a single window in providing services to software exporters and incubation infrastructure to SMEs. Companies are allowed complete duty-free import and they do not need to pay corporate tax till 2010. At present there are 52 STPI Centers all over the country.

STPI- A case of Karnataka

The first Software Technology Park of India was set up in Bangalore (STPI-B) in 1990. STPI-B has in the past incubated over 15 companies including the likes of Infosys in its early days. Fig 3-06.01 to Fig 3-06.04 below show the performance in terms of growth of software units, share in national export and export in various categories.

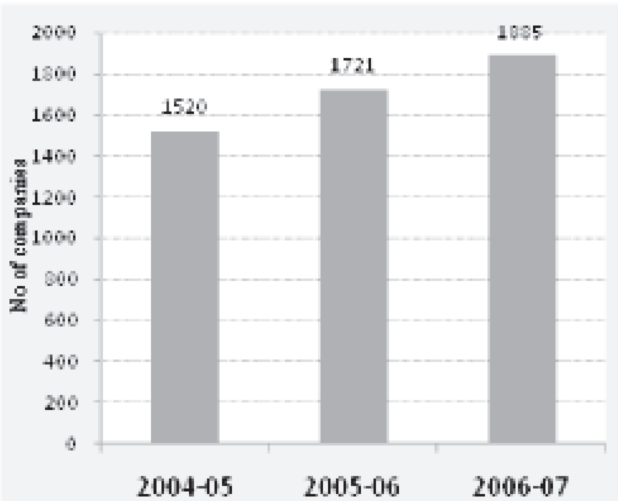


Fig 3-06.01: STP Units Growth in Karnataka (Cumulative)

Source: *http://www.blr.stpi.in*

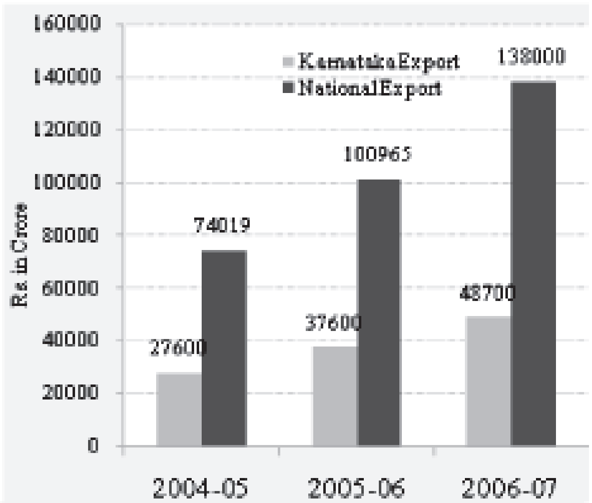


Fig 3-06.02: Karnataka's share in National Export

Note: *Karnatak's export growth 30% ; Karnataka's share in National Export is more than 35%*

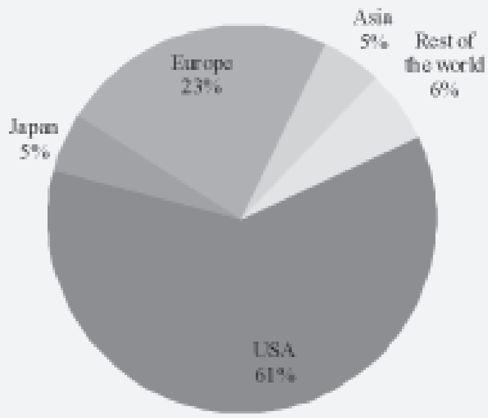


Fig 3-06.03: Continent-wise Export 2006-07 from Karnataka

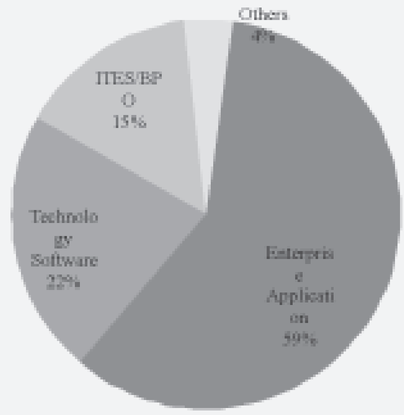


Fig 3-06.04: Segment wise Export 2006-07 from Karnataka

Source: http://www.blr.stpi.in/psp_segemnetwiseswexp.htm

Biotechnology Parks and Incubators: Glimpses

The biotechnology parks and biotech incubation centers provided a good template for the promotion of biotech startup companies and for the promotion of public private partnerships. Such parks have been established at Lucknow and Hyderabad. Other projects approved for Himachal Pradesh, Karnataka and Kerala for setting up of biotech incubation/pilot plant facilities are at various stages of development. These parks have come up through collaborations and are results of Central and State Government initiatives. Some of them are:

Lucknow Biotech Park

Set up by the Department of Biotechnology on 8 acres of land provided by the Department of Science and Technology, Government of Uttar Pradesh, the Biotechnology Park is now operational. It has a number of facilities like a distillation unit, vermin-composting facilities, extraction plant, bio-business centre and also a bio-informatics centre. Through the hardening facility for tissue culture, the park is supplying hardened banana plants to State Horticulture Department for various districts. The park, in collaboration with National Botanical Research Institute (CSIR), Lucknow has also supplied 3,70,000 elite quality Jatropha Curcas. There are around 17 tenant companies across various areas (*www.bitechcitylucknow.org*).

MITCON Biotechnology Incubation Centre

MITCON Biotechnology Incubation Centre is sponsored by DST, Govt. of India & APCTT, New Delhi. MITCON Biotechnology centre provides comprehensive updates on technologies that can be commercialized, technical/entrepreneurial training, consultancy and product support services. The main thrust area is agri-biotechnology (*http://www.mitconindia.com/biotech_aboutus.htm*).

Shapoorji Pallonji Biotech Park Pvt. Ltd.

A joint venture Company with the Government of Andhra Pradesh. The park is a member of International Association of Science Parks as well as Biotechnology Industry Organization, USA and has agreements for mutual collaboration with the Research Triangle Park, USA, Technology Park Heidelberg, West Germany and the Biotechnologies Park Luckenwalde, New Berlin. DBT has provided support for current good manufacturing practices (cGMP) compliance for Pilot plant facilities. A pre-Biotechnology Incubation Centre Process Generator (PBPG) Centre was set up at Indian Institute of Chemical Technology (CSIR), Hyderabad (*http://spbp.co.in/facilities.shtml*).

Other BT Parks

Ticel Biopark Ltd: It has been established with joint venture of Tamil Nadu Industrial Development Corporation Limited (*www.tidco.com/bulid.html*).

Akruti Biotech Park: It is a project undertaken by Gujarat Akruti TCG Biotech Limited (GATBL), under mandate of the Government of Gujarat (www.akrutibiotech.com) and International biotech park (IBP) is a joint venture project between the Maharashtra Industrial Development Corporation (MIDC) and TCG Urban infrastructure Holding Ltd. (TCGUIH).

New Public Initiatives in Biotechnology

Biotechnology Industry Partnership Programme (BIPP)

Recently Department of Biotechnology (DBT) launched a highly industry-friendly initiative; the Rs 350 crore ($ 70 million), Biotechnology Industry Partnership Programme (BIPP). BIPP got formal federal cabinet approval on November 8, 2008, a year after the unveiling of the New Biotechnology Policy, called the National Biotechnology Development Strategy policy.

BIPP will run as a pilot project for two years, scaled up with additional resources after a thorough evaluation. A notable feature of BIPP is that the operations of the scheme will be handled by an industry veteran who will be assisted by a senior officer from DBT. The funds will be available to companies to take up really innovative research programs and the government, for the first time, will assume all the risks associated with it. The rewards will belong to the innovator/entrepreneur with a small royalty going back to the government to shore up finances for further extension of the scheme. BIPP is also part of DBT's public announcement to allocate 30 percent of its budget allocations to the industry in the next five years. (*http://biospectrumindia.ciol.com/content/editorial/10812051.asp*).

There are specifics goals of this proposed program like increasing the global competitiveness of Indian industry. As a principle, BIPP would strictly promote high risk, transformational technology/process development. No incremental development will be supported. On a broad basis, it is directed at path-breaking research in frontier futuristic technology areas having major economic potential and making Indian industry globally competitive, and focused on IP creation with ownerships by Indian industry (and where relevant, collaborating scientists). Regarding relationship of SIBRI (an ongoing scheme) and BIPP; in SBIRI projects require small initial resources whereas BIPP covers the whole value chain from early stage to late development right through to commercialization.

Biotechnology Industry Research & Development Assistance Council (BIRAC)

BIRAC is being established by DBT to stimulate, foster and enhance the innovation capabilities of SMEs in the Indian Biotech Sector. BIRAC is structured to offer a range of services specially designed to help SME's access key resources, new technologies, testing and validation facilities and financial assistance at the right time. BIRAC would facilitate and promote industrial research through technology transfer and IP management, technology acquisition and technology forecasting. In addition, there would also be a special cell to address training and capacity building needs. The idea behind setting up of BIRAC is to have an instrument of R&D and innovation within the companies, particularly SMEs, by creating a new organization which has DBT, ABLE, BCIL as core partners. Their role in BIRAC would be independent of their role as organizations. BIRAC is an agency, which will become the 'innovation management agency' of the government in biotechnology. At present DBT has started the venture with Rs 350 crore.

Public R&D – Private Industry Partnerships

Linkages between R&D agencies and industry in India, effected through the facilitating institutionalized mechanisms of the government S&T departments and agencies as well as select academic institutions, provide updates on the operational dimensions. Partnerships have assumed new importance in the context of globalization. New paradigms in IPR generation and protection are posing novel challenges. Other factors such as transition to a knowledge based economy, changing life cycles of products, the increasing cost of doing R&D underscore the need for such partnerships.

In order to achieve better linkages India adopted a two pronged approach: one which relates to creating a climate for indigenous development of technology in the country and the other for the transfer and adaptation of technology imported from the advanced countries. However, accessing globally competitive industrial technologies became more difficult due to the integration of the global trade/economy. Thus, in order to survive, Indian industry had no option but to indigenously develop such technologies. The liberalized economy gave Indian industry ample opportunity to develop new ideas and technologies, which could be sold globally.

The government has traditionally been supporting the 'idea stage' as part of its basic research efforts. The idea generated having secured patenting needs packaging the technology or product into a saleable commodity, which requires specialized skills in design and engineering. Commercial viability still remains uncertain and

Table 3-09.01 : Major Government Initiatives promoting R&D Agency – Industry Partnership, 1953-2005

Name of Agency/ Programme	Name of Programme/ Purpose	Launch Year	Accomplishments
NRDC	Transfer of Technologies	1953	Forged strong links with Indian / foreign R&D agencies; has large repository of wide range of technologies in almost all industrial R&D sector; has successfully exported technologies to Brazil, Burma, Bangladesh, Germany, Indonesia, Kenya, Madagascar, Malaysia, Nepal, Philippine, Senegal, Sri Lanka, Vietnam and USA
NSTDEB of DST	S&T Entrepreneurship Programme (STEP)	1984-85	17 STEP's established near educational and research infrastructure to facilitate continued closer ties between R&D agencies and industry
NSTEDB of DST	Entrepreneurship Development Cell (EDC)	1986	EDC set up in 55 academic institutions to provide info to budding technopreneurs; creating entrepreneurial culture, fostering better parent institute – industries - R&D agencies linkages.
DOS	Technology Transfer and Industrial Consultancy Group	~1990	~ 285 technologies of ISRO have been transferred to industries for commercialization and more than 270 consultancy assignments have been undertaken by ISRO for small, medium and large-scale industries
DBT	Biotech Consortium India Ltd. (BCIL)	1990	Provides linkages amongst res. institutions, industry, government and funding institutions to facilitate accelerated commercialization of biotechnology. ~60 technologies transferred to industry.
TIFAC	Home Grown Technology (HGT)	1993	77 projects supported up to 2005-06 of which 60 completed resulting, of which 46% commercialized
DSIR	Programme Aimed at Technological Self-Reliance (PATSER) (now called Tech. Development and Demonstration Prog.)		193 projects supported. 111 projects completed resulting in commercialization of 35 technologies / prototypes; strengthening linkages of industry with over 30 research institutes. 31 companies currently paying royalty / lump sum.
DST	Drugs & Pharma Research Programme (DPRD)	1995	86 projects supported resulting in development of 6 products and filing of 13 process patents. (merged with PRDSF)
TDB	Converting the fruits of indigenous res. into commercial products or services	1996	131 projects of 107 industries resulting in development of many industries, rise of new industry
DBT	Micro-propagation Technology Parks (MTP)	1997	2 MTPs at TERI and NCL; State-of-the-art tissue culture production facility with an annual production capacity of 2 million plants at TERI
CSIR	New Millennium Indian Technology Leadership Initiative (NMITLI)	2001	57 projects with an outlay of Rs. 500 Cr supported resulting in development and commercialization of several major technologies and networking of 270 public R&D institutes and 80 private industries
NSTEDB of DST	Technology Business Incubator (TBI) Scheme	2001	16 TBIs established to provide hand holding, mentoring, specialized support services and networking during start-up phase of an enterprise
DST	Pharmaceuticals R&D Support Fund (PRDSF)	2005	As of 2005 alliances of R&D agencies with 50 Indian industries established resulting in development of new chemical entities, vaccines, assay systems and drug delivery systems at a total investment of Rs. 9 Cr.
DBT	Small Business Innovation Research Initiative (SBIRI)	2005	37 projects sanctioned (worth Rs 155 crores) to a total of 32 companies assuring private sector investment out of which 16 projects are in health, 9 for industrial product and process development and 8 in agriculture and allied areas.

to overcome it the Government initiated various programmes/mechanisms and fiscal incentives, in the pre and post-globalization periods (Table 3-09.01).

Under the zero based budgeting exercise, DSIR has formulated the Technology Promotion, Development and Utilization (TPDU) programme by merging several existing government schemes, viz. RDI; PATSER; Scheme to Enhance the Efficacy of Transfer of Technology (SEETOT) and the related activity of APCTT. The specific components of the scheme include Industrial R&D Promotion Programme; Technology Development and Innovation Programme; Technology Management Programme; International Technology Transfer Programme; Consultancy Promotion Programme; and Industrial R&D and Technology Information Facilitation Programme.

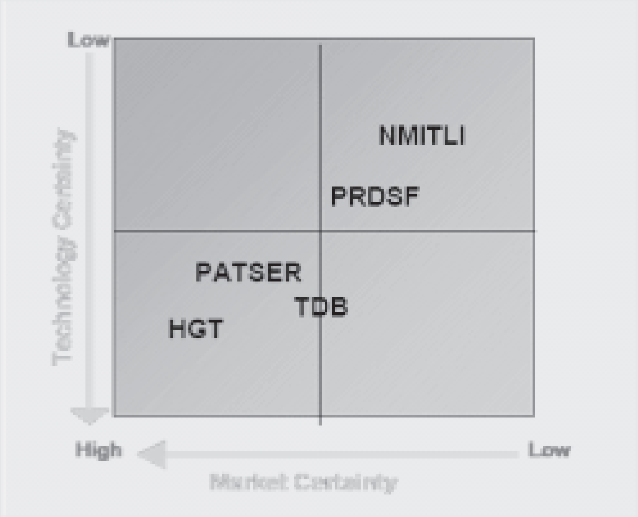


Fig 3-09.01: Level of Market Certainty and Technology Certainty Supported Under GOI Programmes Supporting Partnerships

Organization Specific Partnership Enabling Initiatives

Table 3-09.02 gives a snapshot of the partnership initiatives undertaken by premier R&D and educational organizations of the country.

Besides these, several other initiatives are also taking place in a small way, e.g. the Entrepreneurship Development Institute of India (EDI), an autonomous body set up in 1983, sponsored by apex financial institutions, viz. IDBI, IFCI, ICICI and State Bank of India (SBI) and supported by Government of Gujarat is committed to entrepreneurship education, training and research. To achieve its objectives EDI, with sponsorship of NSTEDB of DST, has set up an Innovation Centre which is a national facility for innovations and it prepares and maintains 'Data Bank' on innovative projects and new and advanced technologies.

Financial Institutions for Promoting R&D Agency-Industry Partnerships

Venture Capital (VC): The Indian VC industry is very young, but has matured fast. In 1988 the Technical Development and Information Corporation of India (TDICI, now ICICI Ventures) was set up, soon followed by Gujarat Venture Finance Limited (GVFL) and Andhra Pradesh Industrial Development Corporation (APIDC) in early 90s, followed by entry of Foreign VC funds between 1995-1999 and emergence of successful India-centric VC firms from 2000 onwards. Today there are about 150 VCFs (Government, Overseas, Corporate, Domestic). The VC activity in India is mainly concentrated in a few places like Mumbai, Bangalore, Delhi and Chennai.

Industrial Credit and Investment Corporation of India Bank Limited (ICICI): The Technology Group of ICICI for the World Bank has been implementing the Sponsored Research and Development

Table 3-09.02: Various Programmes undertaken by CSIR, IIT, IISC, CII

Organization	Partnership Initiatives	Accomplishments
Council of Scientific and Industrial Research (CSIR)	96 projects in the areas of expertise of CSIR including 32 Supra-institutional projects, 46 Network projects, 7 Interagency projects and 11 Facility creation projects. One of the flagship programmes is the development and production of 14-seater small aircraft 'SARAS' involving National Aerospace Laboratories, Hindustan Aeronautics Limited; and Biotechnology programmes in the area of Drugs & Pharmaceuticals.	1) SARAS of National Aerospace Laboratories, which directly involved Hindustan Aeronautics Limited and has received funding from TDB for commercialization. Programme on New Drug Discovery (1997), apart from 20 CSIR laboratories, 13 universities and 3 medical institutes are actively participating in the job. The programme has provided many leads on new chemical entities and new herbal formulations for cancer, tuberculosis, filaria, malaria and ulcer. Interesting leads have been obtained on hepato-protective, immuno-modulation as well as dementia. Toxicity studies of antiulcer lead and antidementia leads have been completed. Few more leads for the identification of disease conditions are in hand for further study.
Indian Institute of Technology (IIT)	IIT, Delhi set up a TTO named 'Foundation for Innovation and Technology Transfer (FITT)', as an autonomous registered society and interface organization and has since been serving as a single window service to industry	The first company 'KRITIKAL Solutions Ltd.' physically moved to in this TBI in Sept. 2002. Presently four companies are housed here. FITT also operates a scheme of 'Corporate Membership' It may be noted that joint centers have been set up by the industries like IBM and Monsanto in academic institutions like IIT, Delhi.
Indian Institute of Science (IISc), Bangalore	Society for Innovation and Development (SID) was founded in 1991 in close collaboration with IISc to enable India's innovations in S&T by creating a purposeful and effective channel to help industries and business establishments to compete and prosper in the face of global competition, turbulent market conditions and fast moving technologies	Completed ~100 research projects and currently houses eight R&D Centers of Indian industries such as, Cadila Pharmaceutical Ltd; Cookson Electronics India Research Centre; Satyam Computer Services Limited; Cranes Software International Ltd., Himachal Futuristic Communication Limited, etc.
Confederation of Indian Industries (CII)	An innovative scheme called 'CII TDB Technology Transfer Centers' Network (CII TDB T NET)' to bring industry closer to R&D agencies	Presently 18 such Centers are operating at various technical universities across the country (2005)

Source: *Author's Compilation*

Programme (SPREAD), design of which was finalized after extensive discussions with the industry, CSIR and other R&D agencies. The SPREAD programme's objective was to encourage industry to substantially increase R&D activities and the programme supported projects at all stages of the R&D cycle starting from laboratory and pre-feasibility studies to prototyping and pilot plant operations. ICICI had assisted by about 2003/04, 101 projects with an aggregate assistance of about Rs. 70 Cr. Out of these, 48 have been commercialized indicating a high success rate for R&D funding. Three industrial sectors, namely pharma/ biotechnology, electrical/electronic and chemicals/petrochem constituted ~65 % of the portfolio and the projects in these sectors achieved more than 50% success rates. CSIR laboratories and institutes of higher education (including IITs) played a major role in the success of the programme.

Industrial Development Bank of India (IDBI): Technology Financing Scheme of IDBI focused on commercialization of indigenous technology, adapting imported technology for wider domestic applications and on projects envisaging higher than normal risk with potential for commensurate high returns. It prefers financing the technology development at the start-up level and provides the support in the form of equity, conditional and convertible loans (preference share).

Small Industry Development Bank of India (SIDBI): The Technology Development and Modernization Fund Scheme of SIDBI was launched to provide support for purchase of capital equipment, for need-based civil works, for acquisition of additional land and need based additional margin-money for working capital, acquisition of technical know-how, designs, etc.

Table 3-09.03 gives an account till 2005 of the various technology development funding mechanisms under different schemes and programs of the government.

Cases of Technology Transfer

Various concepts employed in implementation of partnership programmes are:

- Lap race concept wherein equipment or technology(low end) development and transfer involves R&D agency, industry and intermediary/promotional agency;
- Mother licensee concept wherein the promoter setting up the first project based on the invention becomes the mother licensee;
- High technology, multi-ownership concept;
- Concept based on societal needs;
- Concept driven through Government legislation;
- Disruptive technology concept – which has very long gestation period, requires larger funds through VC and a very large number of partnerships.

The partnerships may be formalized through formal or informal arrangements such as collaborative projects, contracting or sponsoring research, consultancy, turn-key projects, or exchange of information/personnel or sharing of facilities. In order to appreciate these modalities the summaries of fifteen cases of TT are discussed in Table 3-09.04.

Table 3-09.03: Technology Development Funding Mechanisms till 2005

Name of Scheme	Stage of Tech. Development	Recipient Category	Quantum of Funding	Type of Funding Assistance
Scientific Ministries/ Departments	-Basic research -Exploratory research -Capability Building	-Govt funded institutes -Institutes of higher learning –Major Universities	US$500-100,000 except for capacity building	100% grant
-TePP, -NRDC's Patent Protection Scheme -Technology Innovation Board	-Idea stage -Patenting stage -Prototyping -Field demo	-Individuals -Start up SSIs -NGOs	Upto $12,000	90% grant 10% by recipient
DPRD, DST	Bench scale	R&D agency jointly with industry partner		70% grant to R&D agency
NMITLI, CSIR	-Basic research -Lab feasibility	R&D agency jointly with industry partner		Soft loan @ 3%
-Scientific / Societal Promotion Ministries / Departments -Tech. Missions	Application oriented R&D for societal needs	-State S&T Councils -Extension Centres -NGO's	Up to $10,000	50% grant
HGT of TIFAC, DST	After lab scale for Pilot Plant / Semi Commercial Plant	R&D Institute / University, but jointly with industry partner	$5000 - $350,000	Up to 75% grant to institution & upto 25% @6% interest to industry partner
PATSER, DSIR	For pilot stage only	-Industry having in-house R&D -Industry jointly with institute / university	$10,000 - $1.5 million	Up to 50% grant but royalty to be paid to NRDC
Industry Sponsored Research Programme	Any stage prior to commercialization	R&D Institute / University	No limit (generally up to $200,000	100% grant but weightage Tax deduction and exclusive rights upto 5 yrs
TDB, DST	Setting up first pilot plant for development and commercializing indigenous tech. or for adapting imported tech.	Any Industry / R&D Institution	No limit (generally $100,000 – 10 million)	Up to 50% of project cost as loan @5% interest, or up to 50% equity to industry and grants to R&D institutions
SBIRI, DBT	Phase I: pre-proof-of-concept research Phase II: product & process development	-in-house R&D unit(s) of industrial firms; alone -Jointly by Industry (or a group of industry) and R&D agencies	Phase I: upto100 lakhs Phas II: upto 10 crs.	Most funding as grant Phase I: 80% as grant for projects upto Rs 25 lakhs; 50% as grant for projects between Rs 25 – Rs 50 lakhs; and Rs 50 lakhs grant + soft loan upto 50 lakhs for projects over Rs 100 lakhs. Phase-II - Soft loan @ 1% upto Rs 100 lakhs & 2% between 100 lakhs to Rs 10 crs.
NRDC Equity / Loan Scheme	For demo / commercial plant	NRDC's Licensee Company only	$20,000-$120,000	Upto 50% equity or equity loan combination
VC Funds of Public Sector Banks	Commercial Plant	Any industry	No specified limit	Equity/loan at 9% interest
Private Sector VCF's	Commercial Plant	Any industry	No specified	Equity/loan on case to case basis

Table 3-09.04: Summary of Case Studies

Technology Developed	Main R&D Agency	Industry	Inter-mediary	Other Partners	Financing	Status of Commercialization
Palm Oil Technology	RRL – T, CMRI (CSIR) MERDO, CPCRI (ICAR)	AP Oil Federation	NRDC	DBT, Karnataka, AP & Maharashtra States	1.26 Cr by TDB, NCDC, Oil Mission	Commercialized
Zeolite 'A' Intermediate for Detergent	CSMCRI (CSIR)	NALCO	NRDC	EIL	Equal share of Rs.30-40 Lakhs	Commercialized in India and abroad
Rice Husk Particle Board	IPRI	PPBL	NRDC	-	50% NRDC Equity + 40 Lakh VCF-IDBI loan	Commercialized by MHEL Malaysia + Indonesian company
Clot Busters TPA, UK, SK	IMT (CSIR)	Godrej	-	Cadila	-	Commercialized
Specialty Monomers	NCL (CSIR)	Vinati Organics	-	-	Vinati Rs. 40 Lakh + TDB 40 Cr.	Commercialized
Drug (Amlodipine) Molecule	NCL (CSIR)	Emcur Pimpri	-	-	Emcur Rs. 5 lakhs	Commercialized
Leaf Cup Making Machine	CFTRI (CSIR)	10 Machine Fabricators	NRDC	SISI, NGO etc.	By R&D agency	Commercialized
Biodegradable Plastics	CTCRI CPRI	Hindustan Lever	NRDC	SIRI	50% from HGT (DST)	Licensed and being considered for commercialization
Catalytic Process for Butadiene Conversion	NCL (CSIR)	Gharada Chemical			Gharada Rs. 20 lakhs	Licensed to industry, but could not get commercialized
Sol-Gel Abrasives	RRL –T (CSIR)	Company 'X'	-	-	Rs. 35 lakhs from 'X'	Licensed, but could not get commercialized
Flux Bonded Fly Ash Components	RRL –T (CSIR)	Company 'Y'	TIFAC	-	'Y' + Fly Ash Mission	Technology transfer in progress
Coke less Cupola for Foundries	NML (CSIR)	TKES	TIFAC	AIFA	Rs. 45 lakhs (TIFAC) + Rs. 20 lakhs (CSIR)	Technology transfer in progress, but not smooth
Bioactive Molecules fm Plant Extracts	CSIR Labs	Arya Vaidya Sala	Dr. Valiathan	TSM Partners	Share as per Agreement	Technology development in progress
FEM of Structures and Components	SERC (CSIR) ISR	-	-	NIIT INTES	'2+2' bilateral Project	Knowledge Generation
Satellite Imagery Digitization	ISRO	-	-	MPD, SOI (DST), IGNOU	-	Often free for societal needs

The CSIR

The Council of Scientific and Industrial Research (CSIR), established in 1942 is an autonomous society and is an ensemble of 37 state-of-the-art institutes and 3 centers; over the years, the CSIR has served as a springboard for scientific and technological activities in a wide variety of S&T domains. (Website: *www.csir.res.in/*)

CSIR has a stock of highly specialized 4,600 scientists and 8,000 scientific and technical support personnel. Apart from this it supports 7,000 research scholars at any given time for doctoral research in S&T throughout the country and current project projection for annual production of doctorates in sciences and engineering is about 1000 to 1500. CSIR is the single largest global source of expert manpower for the leather, food processing, instrumentation and mechatronics; with internationally recognized training courses.

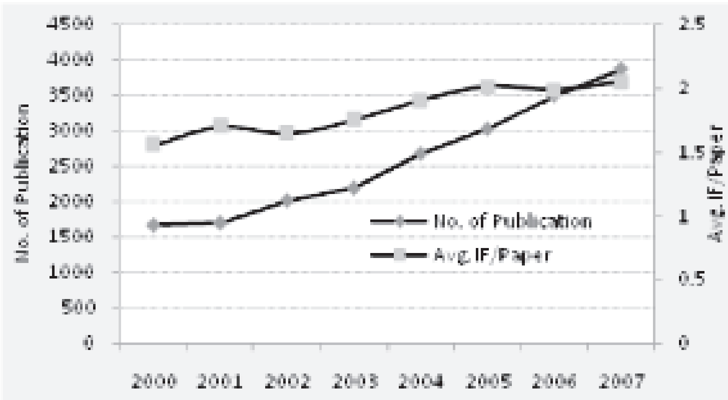


Fig 3-10.01: CSIR's Global Science Presence

The research papers emanating from CSIR's laboratories are noted for their quality with average impact factor/paper showing an upward trend in the recent years with nearly 4,000 papers in 2007 having an average impact factor/paper of 2.04 (Fig. 3-10.01). CSIR publishes about 17 research journals and two abstracting journals and comprehensive state-of-the art reports on specified subjects, and databases such as the TKDL. As per WIPO Report 2007, among global public funded R&D organizations, CSIR ranks eighth in PCT filing (98); and capture about 50-60 percent of total US patents granted to Indians (excluding foreign assignees) during last several years. In India, CSIR tops the list of patent filers at IPO. It currently holds a sizeable portfolio of about 1,800 foreign patents and about 1,500 Indian patents.

Inventions

Development of indelible ink, baby food from buffalo milk, tractor (Swaraj & Sonalika), pioneered DNA fingerprinting, anti-malarial drugs, technology for early detection of diseases, transgenic crop plants, energy foods, leather bio-processing, aircraft (HANSA & SARAS), energy saving buildings & Wealth of India series of monographs, to name only a few.

Recent Initiatives

Open Source Drug Discovery (OSDD): A model similar to open source models in information technology; it is an initiative to provide a global platform where the best minds can collaborate and collectively find solutions associated with discovering novel therapies for tropical diseases like tubercularia.

CSIR 800: A project which enables 800 million poor Indians to enhance daily income through innovative S&T based solutions in the areas of agriculture, energy and health.

New Millennium Indian Technology Leadership Initiative (NMITLI): A first of its kind model was initiated to support R&D programmes in Public-Private Partnership (PPP) mode. It seeks to build, capture and retain for India a leadership position by synergizing the best competencies of public funded R&D institutions, academia and private industry.

Social Causes

Rural development: Rural development through inducting and infusing S&T based innovations in rural life has been a vital mission for CSIR. Such S&T solutions cover a wide range of technologies from mechanized agriculture, new cultivation techniques, water purification techniques, low cost housing and traditional ceramic products utilizing locale-specific endowments etc. to name some.

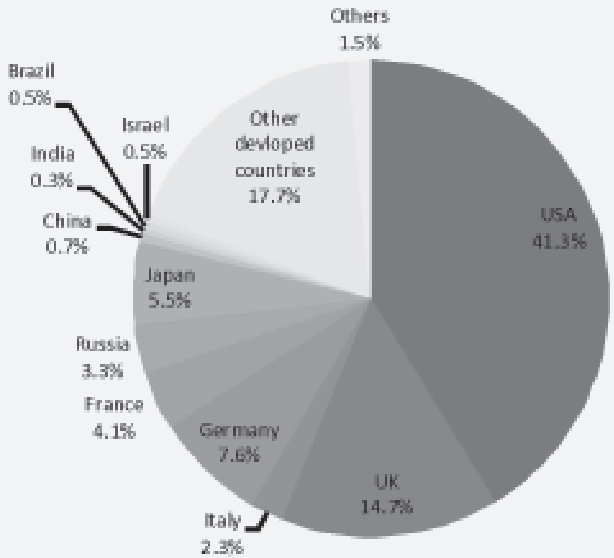
Disaster management: A few examples - devastating Tsunami in 2004 or of floods in Bihar, CSIR undertook the largest production of instant food by its R&D lab and provided 55 tonnes of food and also made available sweet drinking water through reverse osmosis and electrodialysis techniques; and extended support through large scale geoengineering experiments.

Drug development: But for technologies from the CSIR, the once costliest drugs could not have become the globally cheapest; consistently working on affordable life saving drug development for the poor at a global level, the CSIR has developed several processes and knowhow. It is worth mentioning that eleven out of the fourteen new drugs developed in India are from CSIR. Some of them are anti malarial drugs- Elubaquine & Arteether, technology for oral insulin and hepatitis B vaccine, anti-HIV cocktail etc.

Editors from India in Global Journals

A research journal as a forum for conducting discourses on science systematizes fields of knowledge. While conducting discourses, the journal involves very large number of peer reviewers who indeed act as gatekeepers and provide the field of knowledge an emergent structure. Readers of the journal appear only secondarily in this process of discourse.

Countries in the periphery of S&T knowledge publish only a few research journals. More importantly, even fewer number of peer reviewers of the submissions to journals published from the core developed countries are drawn from the peripheries. Only a handful of journals publish such listing of peers. From the few published sources it appeared that almost the entire community of peers resided and worked in proximate geographies within the journal publishing developed countries. Dialogical space remained bounded therefore within the geographies of publishing countries. From the journals, however, we computed country affiliations of the editorial boards and/or editors who significantly influence the discourse. Such influences prove critical in the selection of research problems. In other words journal editors often set the research agenda. The following figure reflects on the distribution of editors.



8474 editors and their country affiliations in editorial boards of 2660 international journals published by several publishers

Publisher	No. of Journals
Society Publishers	299
Blackwell Publishing	93
Cambridge Univ	64
Taylor & Francis	177
Wiley	116
Marcel Dekker	40
Academic Press	104
Kluwer	255
Oxford Univ	74
Springer	299
Elsevier	534
Others from Dev. countries	605

Fig 3-11.01: Country-wise distribution of editors of global journal (2003-04)

Distribution of publications infrastructures greatly varies over countries. We collected data about more than thousand global journals and 40% of these appear from USA alone, 16% from UK, 8% from Germany, 6% from Japan, and the developed countries together (excluding Russia and Israel) publish 93% of these journals. Only 1% of these come out from China (however, publishing business houses in recent time have started bringing out more journals from China). India brings out less than 1% of these journals.

Disease Coverage in Web Editions of three Indian English Language Dailies

The coverage of seven diseases- HIV/AIDS, Diabetes, Dengue, Malaria, Tuberculosis, Chikungunya and Avian Influenza in three Indian English language newspapers for the year 2007 shows how public discourse gets shaped by S&T. The newspapers selected for the study were web editions of Hindustan Times, Times of India and Indian Express. Search was carried out using the name of the disease as the keyword. Fig 3-12.01 and Fig 3-12.02 indicate the distribution of articles and words in different newspapers for different diseases.

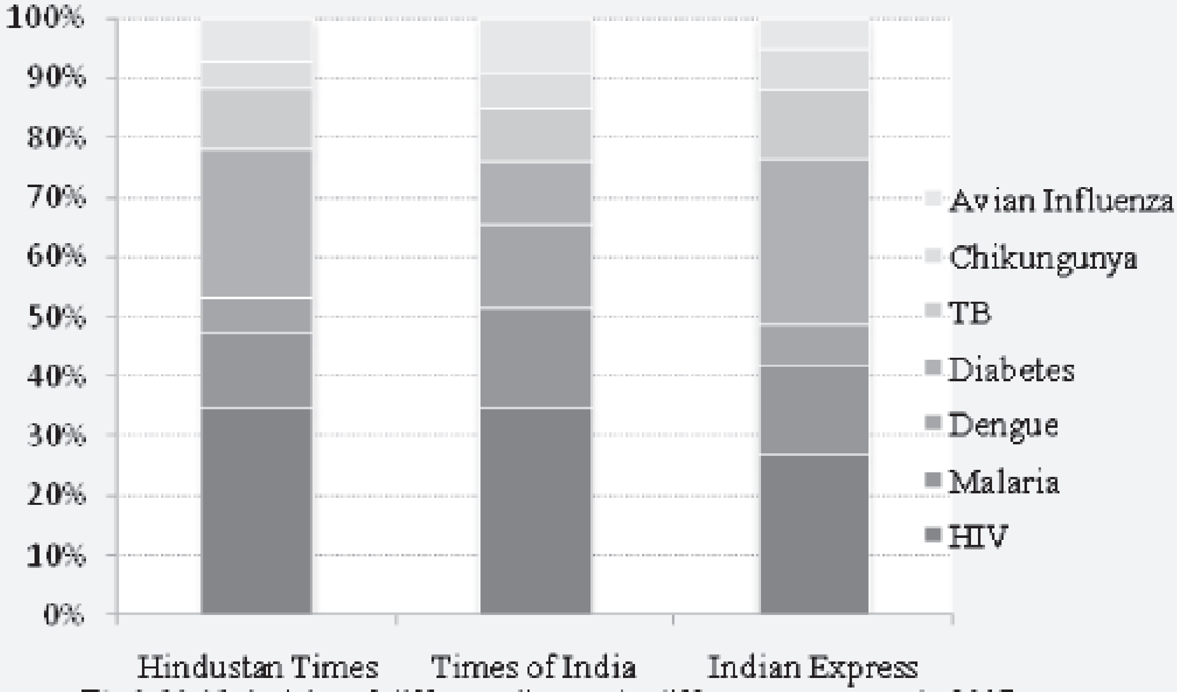


Fig 3-12.01 Articles of different diseases in different newpapers in 2007

Source: *Author's Compilation*

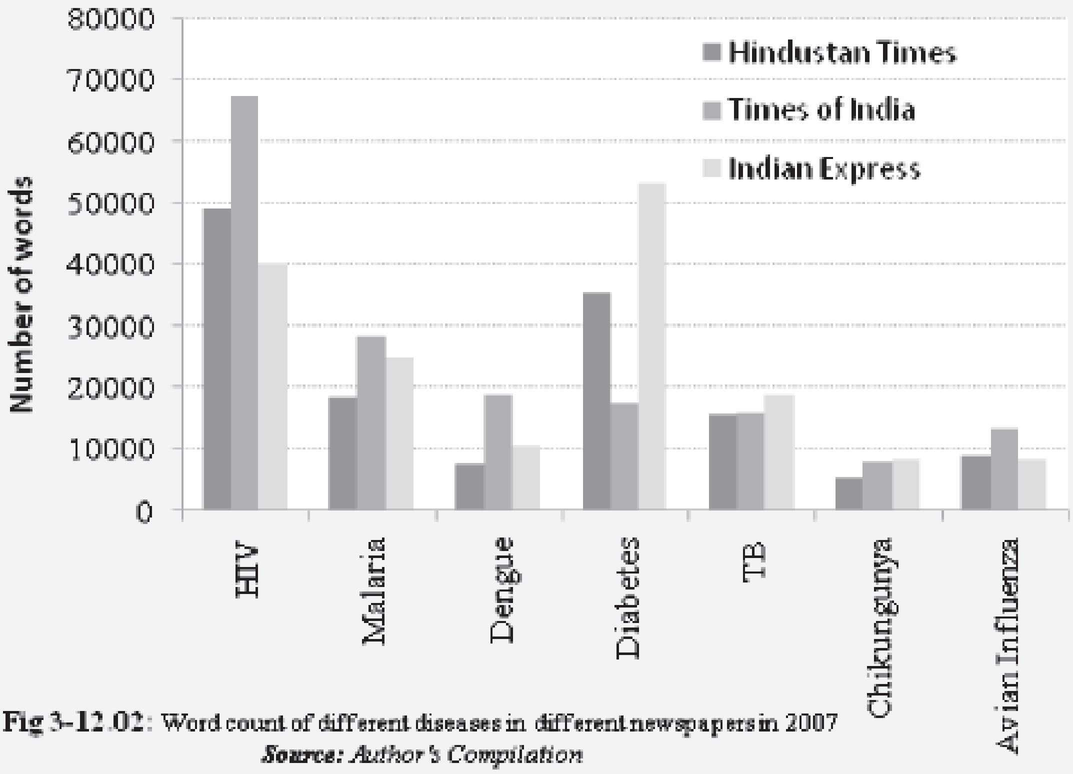


Fig 3-12.02: Word count of different diseases in different newspapers in 2007

Source: *Author's Compilation*

S&T Coverage in English-language Indian dailies

The coverage of science and technology related items in English-language dailies in India throws light on the quantum of space allocated to different subjects by different newspapers, positioning and spread of S&T items, and identifying the newspapers that accorded priority to science and technology related items.

The study is confined to a period of three months from 01-3-2008 to 31-05-2008. A set of 36 newspapers published from different parts of the country were taken for the purpose and an attempt was made to cover almost all the regions. In case of newspapers publishing multiple editions, only the main edition formed the source of this study. The newspapers were scanned to identify the science and technology (S&T) related items, which were subjected to content analysis. These S&T items were categorized into 31 different subjects. The space occupied by each item was measured in square centimeters (cm^2) and its positioning in the newspaper along with column spread was also recorded.

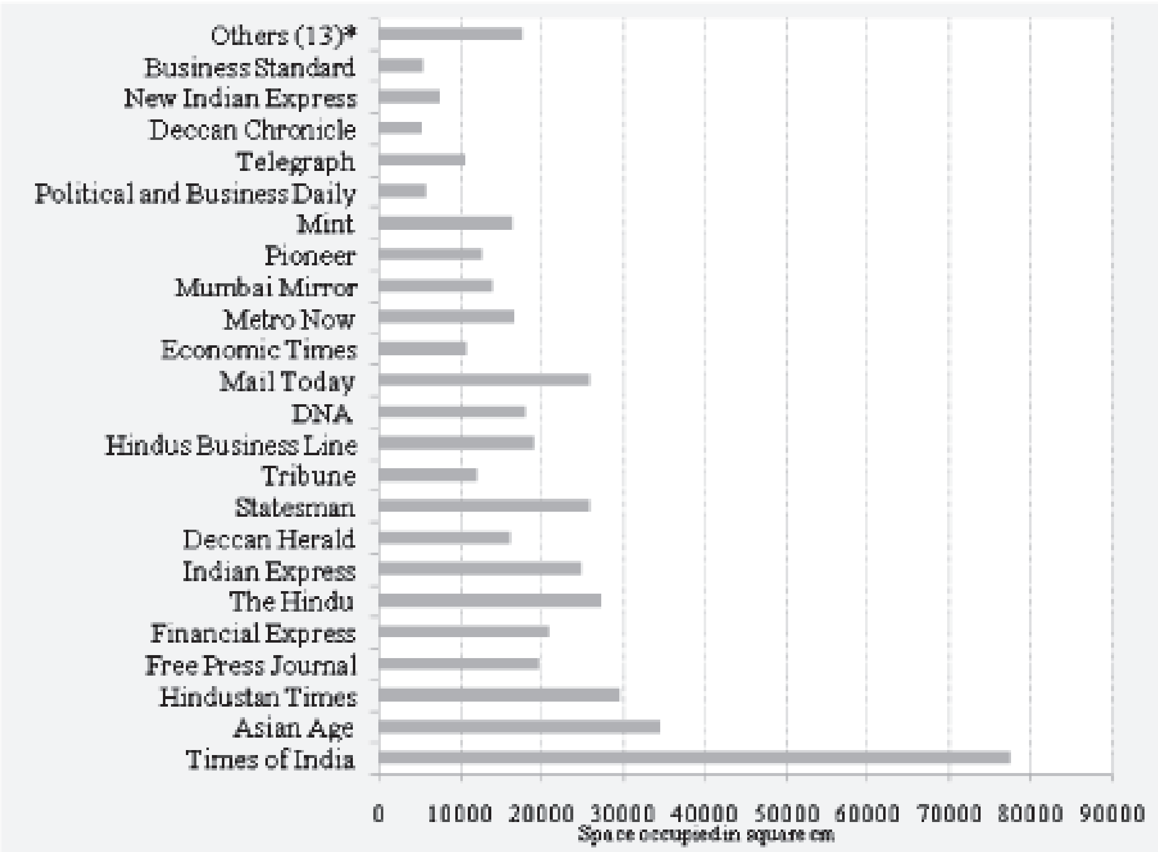


Fig 3-13.01 : Distribution of S & T related space in different newspapers

Source: Author's Compilation

The Times of India published from New Delhi emerged as the leading newspaper, which carried the maximum number of items (577) allocating maximum space (77,412 cm^2), followed by The Asian Age (177 items and 34,451 cm^2), The Hindustan Times (155 items and 29,508 cm^2). Among all the 31 subjects, the maximum number of items (939) was published in the area of health, followed by environment (343), astronomy (162), biological sciences (146) and space science and technology (133). These five subjects together accounted for 72% of the items and ~ 66% of the total space. The rest of the space was distributed among 26 other disciplines. The area of health and biological sciences together constituted 45% of all the items occupying 34% of total space. Fig 3-13.01 presents the total S&T space in different newspapers and Fig 3-13.02 depicts the broad distribution of S&T related items.

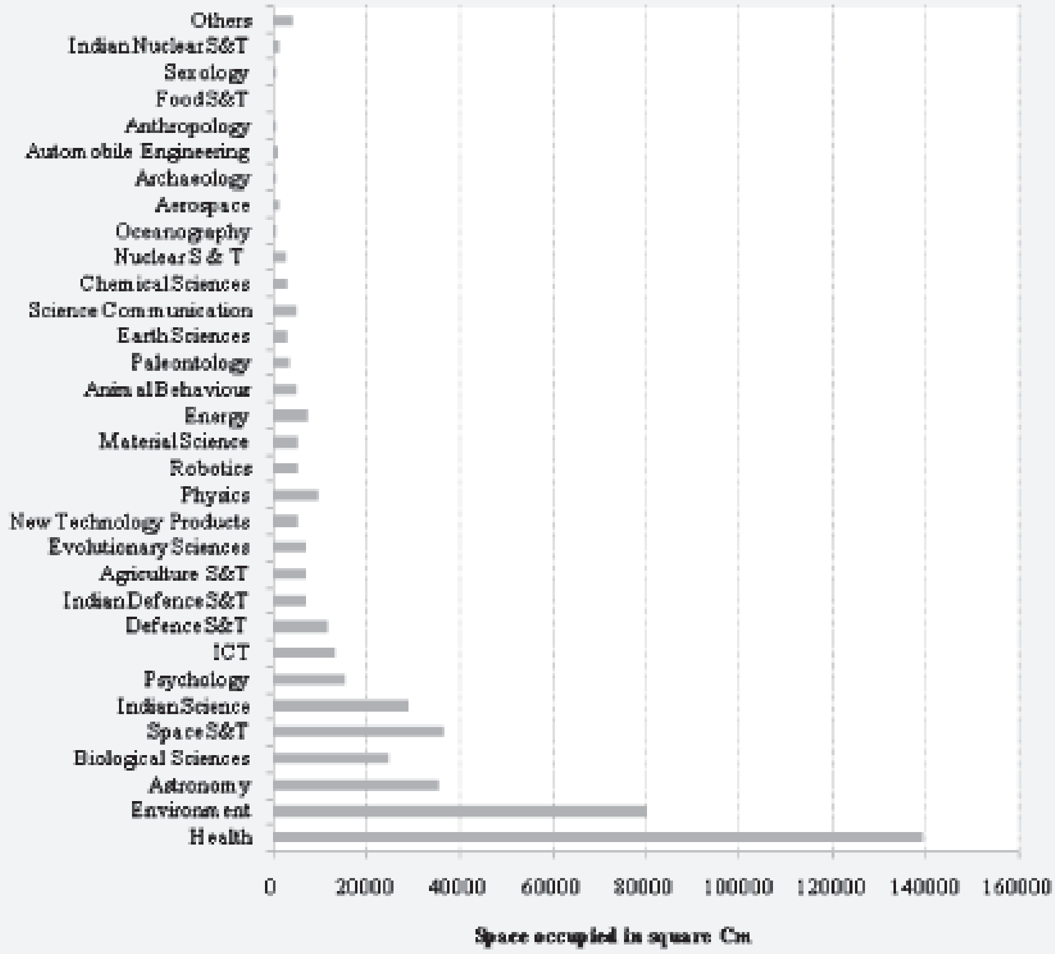


Fig 3-13.02: Broad subject distribution of S&T related items in different newspapers
Source: Author's compilation

S & T and Industry

Overview

The role of S&T for the industry of the country in the age of increasing returns must be novel. Industrial institutions developed over last six decades remained influenced by institutions under decreasing return. The complex of banking and financial institutions, stock markets, regulatory institutions and fiscal, legal or the executive and the managerial systems often celebrated structural models of industry that were expected to grow large. Contemporary concerns refer to sustainability, resources constraints, globalisation of resources, increased global control over commodities and increasing global cartel control over knowledge resources. Justifiably S&T for industry needs to take care of national security, inter-generational security and ecological sustainability, most importantly of generation of employment and wealth as well as its redistribution. The global dominance of market-based institutional approach is currently suspect; a degree of balance between complex wings of state political/executive control and market based institutions appear to be the preferred middle path. Market institutions, moreover, when under influences of very large incumbent corporations remain distorted. S&T is often expected to unleash the entrepreneurial bazaar of tiny industrial players that would, assisted by increasing returns knowledge institutions, upturn the applecart of large incumbents' domination.

Post-WTO the distance between domestic and global markets has shrunk. S&T for industry thus needs to be politically strategic, taking into consideration the dynamics of globalisation and its imperatives, while formulating policies for small local domestic markets. The country's S&T policies for XIth Plan thus made innovation the central theme. Innovation in the knowledge-age of increasing returns demands the setting up of new policies, instruments, infrastructures and geographies, and especially of S&T capability as well as capacity. Last few years witnessed several policy departures and experienced the process of setting up of new mechanisms such as grants to R&D, restructuring funds, sector regulations, sector financing, skill development funds and similar other funds. In parallel large private incumbents from industry undertook more R&D; the small and medium units initiated productivity gaining innovations of non-R&D types. However, large unemployment, inefficient use of resources and less than desired expansion of domestic market in many sectors remained serious and Indian S&T for industry faces multiple tasks: care for the poorest multitudes especially in the rural areas through envisioning a sustainable development model of knowledge intensive resources-saving small centres of production; care for the high-tech ultra-rapid growth possibilities of increasing return industries; care for security of the country; and support gains in productivity in old industries.

The following description through coverage of multiple facets, bring out only certain saliencies. The challenge to the country is complex and Indian S&T system requires a very large boost in building up of capacity, capability and increasing-returns institutions. S&T would provide the most important resources to the industry of the near future.

In the following snapshots the description begins with a macro picture of three sectors and subsequently captures through input consumption scenario the innovative changes in Indian industry at the inter-sector level. The subsequent sections capture two major strands: the R&D based fiscal policy supported innovations, and, other policy supported non-R&D innovations in industries. Further down the pages, new instruments supportive of innovations such as the fund-based mechanisms and their successes have been captured. Still later narrations capture S&T in conjunction with sectors of automobiles, biotechnology and pharmaceuticals, telecommunications, herbal, biomedical, energy and advanced materials.

The full text of these extended summaries is available at *http://www.nistads.res.in*

After a moderate growth for over thirty years since 1950, Indian economy experienced a major structural change whereby the growth rate jumped up dramatically. But there was no commensurate growth in employment. The structural change also involved changes in the composition of output and employment in the major sectors. In keeping with the trend for the overall economy, a noticeable change in the growth of manufacturing and services has also been observed since 1979, much before the initiation of economic reforms in the country. For the agricultural sector, the break occurred long back, in 1965 marked by the introduction of Green Revolution technology.

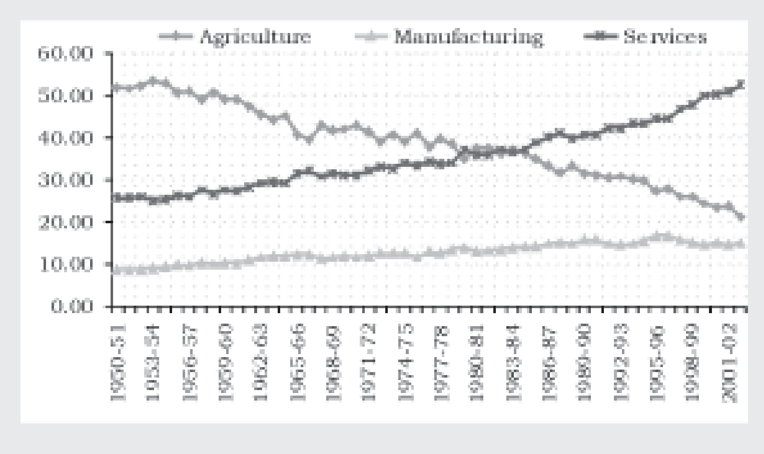


Fig 4-01.01: Sectoral Changes in NDP

Table 4-01.01: Share of states in gross output (at constant 1993-94 prices) by factory sector in India

	1971-72	1975-76	1981-82	1985-86	1991-92	1995-96	2001-02
Andhra Pradesh	4.9	5.6	5.2	6.0	6.5	6.9	6.8
Assam	1.5	1.6	0.9	1.4	1.1	0.8	1.0
Bihar	5.6	6.1	5.9	5.4	4.6	3.5	2.8
Gujarat	10.1	10.4	11.6	11.3	10.6	11.8	15.1
Haryana	2.5	2.5	3.2	3.3	3.6	4.2	4.7
Himachal Pradesh	0.3	0.2	0.3	0.4	0.4	0.5	0.6
Jammu & Kashmir	0.1	0.1	0.2	0.3	0.2	0.1	0.2
Karnataka	4.2	4.0	4.2	4.1	4.8	4.9	5.5
Kerala	2.7	3.0	3.2	2.5	2.5	2.2	2.6
Madhya Pradesh	4.3	4.3	4.1	4.9	5.4	5.9	5.1
Maharashtra	24.7	24.5	22.9	22.4	21.2	21.4	19.3
Orissa	1.6	1.6	1.6	1.7	2.0	1.8	1.4
Punjab	2.9	3.4	4.1	4.1	4.6	4.2	3.8
Rajasthan	2.0	2.2	2.6	2.9	3.3	3.4	3.2
Tamil Nadu	9.9	9.9	10.7	10.7	10.4	11.0	10.2
Uttar Pradesh	7.1	6.8	7.4	8.0	9.5	8.9	7.6
West Bengal	13.4	11.1	9.2	7.8	5.9	4.9	4.4

Note: Figures shown in the Table are in percentage to all India total.

Source: *Annual Survey of Industries, Various issues, CSO, Government of India*

The share of NDP originating in agriculture declined substantially from more than 50 percent in 1950-51 to around 20 percent in 2003-04. As is clear from Fig 4-01.01, in manufacturing, income share has been rising at a slow rate from less than 10 percent in 1950-51 to around 15 percent in 2003-04. The services sector, in terms of its income share, grew at a relatively faster rate.

One of the important features of rapid economic growth has been the regional differentiation in industrialization. Maharashtra and Gujarat together account for almost 34 per cent of the total value of gross output by the country's factory sector. Maharashtra has been continuing to occupy the top position despite its share declining from 24.7 percent in 1971-72 to 19.3 percent in 2001-02. Gujarat gained second position by raising its share significantly from 10 percent to 15 percent during the same period. The eastern region states, on the other hand, have been continually losing their prominence. West Bengal's share in value added by India's factory sector declined drastically from 13.4 per cent in 1971-72 to 4.4 per cent in 2001-02. Rajasthan and Uttar Pradesh in the north-west and Madhya Pradesh in the central region experienced a marginal increase in their shares, as did the three southern states of Andhra Pradesh, Tamil Nadu and Karnataka (Table 4-01.01).

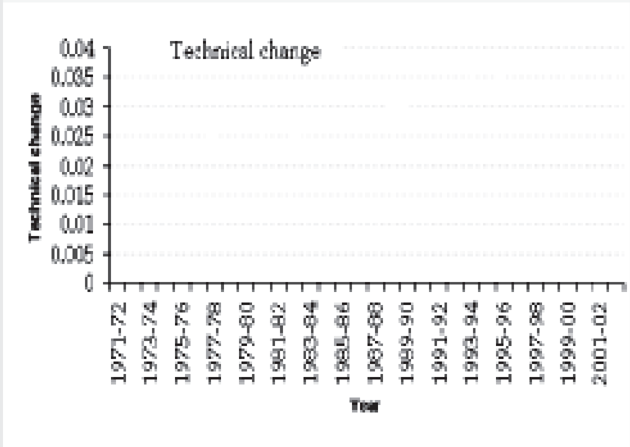


Fig 4-01.02: Contribution of technical change in industrial output

Table 4-01.02: Technical change across major states in India

State	Technical change 1971-2002	1971-1985	1986-2002
Andhra Pradesh	0.019	0.016	0.021
Assam	0.021	0.020	0.022
Bihar	0.030	0.028	0.032
Gujarat	0.030	0.020	0.038
Haryana	0.036	0.031	0.040
Himachal Pradesh	0.039	0.035	0.043
Jammu & Kashmir	0.028	0.019	0.036
Karnataka	0.035	0.030	0.039
Kerala	0.018	0.013	0.023
Madhya Pradesh	0.038	0.034	0.041
Maharashtra	0.038	0.030	0.045
Orissa	0.031	0.028	0.033
Punjab	0.032	0.028	0.036
Rajasthan	0.033	0.027	0.039
Tamil Nadu	0.026	0.021	0.030
Uttar Pradesh	0.026	0.018	0.034
West Bengal	0.022	0.016	0.028

An analysis of the growth performance in the pre and post-reform periods indicates that a large number of states namely, Andhra Pradesh, Assam, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Uttar Pradesh were able to raise their output growth rate of the registered manufacturing sector, whereas it declined in the remaining states. The phenomenon of job-destroying growth was quite prominent in most states during the pre-reform period, which has become more wide spread in the post-reform period.

Indian industries also exhibit significant inefficiency, with the mean efficiency score varying from 32 percent in 1970-71 to 84 percent in 2002-03. Productive efficiency had been accelerating in the second half of 1970s, followed by a decelerating phase. At the end of this decade Indian industries experienced efficiency loss and in the 1980s it showed a rising trend, although at fluctuating rates. In the early part of 1990s, the efficiency was again decelerating which began to rise in the second half with a high degree of fluctuation. There has been substantial inter-state variation in efficiency score in industrial activities. The mean efficiency scores in industries of the western states over 1970-71 to 2002-03 are significantly higher than that of the other regions. Maharashtra has been at the top in mean efficiency score over the past three decades and Gujarat ranked third. West Bengal, in the eastern region, experienced relatively lower efficiency not only compared to the western states but also compared to many other states of the country. During this period the mean efficiency has been the lowest in Orissa. Mean efficiency score however, increased at varying rates in all the states after deregulation – it was much higher for the western states and lower for the eastern states.

The time path of technical change follows a more or less rising trend, with some fall in early 1980s and late 1990s (Fig 4-01.02). Although technical progress had improved roughly consistently between these periods, it started to deteriorate since 1997-98. There is a sharp variation in technical change across major states (Table 4-01.02). Technology contributes relatively more in the industrial leading state of Maharashtra together with some other states like Himachal Pradesh and Madhya Pradesh. Gujarat however, lags behind them and many other states in the country in terms of technical change. Andhra Pradesh and Kerala experienced lowest contribution of technology in the factory sector. Technical progress in West Bengal has been just above these southern states. Technological advancement in industrial activities contributed more to output growth during 1986-87 to 2002-03 compared to the earlier period at relatively faster rates in some states like Gujarat, Maharashtra, Uttar Pradesh and West Bengal.

Technical Changes in the Indian Economy as Evident from Input-Output Tables 1993-94 and 2003-04

Input-output (I-O) tables published by the Central Statistical Organization (CSO), Ministry of Statistics and Programme Implementation, Government of India, provide details of the use of the output of one industry/sector by all the other industries/sectors and the use of the outputs of all the individual industries/sectors as inputs by each industry/sector for its production. The data on input is in terms of factor costs and cannot indicate quantity of respective inputs. The Input-Output table also provides technology matrix where each column represents different amounts of the various commodities, shown in the rows, required to produce one unit of the commodity represented by the column.

A change in the elements of a column vector of the technology matrix over an interval of time represents technological changes in the production of the commodity. Technological changes in the input-consuming commodity production allow changes in inputs and technological changes in some or all of the input commodities allow substitution or other kinds of changes in the input-vector constituents or in their relative weights. Further, a technological change brings about changes in relative prices and thus we might argue that innovation is about bringing about changes in relative prices which reflect the bargaining strength of respective producers as captured by the changes in the column vectors of the I-O matrix in the post-innovation phase.

Innovation in the Economy

A large number of descriptions of innovation remains limited to novelty within a firm or at the most within a sector or within a competition milieu. A firm or a sector is embedded within a larger matrix of input-output and therefore, changes within the former are bound to create repercussions within this I-O matrix. In the inter-sector framework, innovation in one sector would thus entitle that sector to cheaper capital, cheaper better resources, larger market and most importantly better or monopoly price entitling that innovator to the innovator's profit. Innovation is thus the dynamic engine operating a shift in the economic structure. In a two period system of two matrices, this structural shift can be captured to indicate whether the economy as a whole has innovated or failed to do so. Although there are alternative definitions of innovation, we would simply describe the shifts in the inputs as descriptors of corresponding changes in both technology and relative prices. In this section we have analyzed some sectors of the Indian economy by observing changes in a few select inputs, such as energy, feedstock including agricultural inputs, machine tools and other mother machineries.

Assuming increased use of machine tools and other capital machineries indicate enhanced capability and innovation and lower use of energy also similarly enables better innovative positioning of a sector, the following description provides a guide to the inter-sector movements in innovative capability.

Technological Changes in Relation to Crop Production

Among food crops, paddy, wheat, and pulses have experienced substantial raise in input consumption per unit value of output primarily due to higher value of inputs coming from food crops (which in turn reflects high increase in the prices of seeds) and industrial input, between 1993-94 and 2003-2004 (Table 4-02.01). Energy input has increased substantially for rice, but for wheat input of electricity has in fact fallen. In all the cases inputs from industry have risen (less so for maize) and correspondingly the inputs of innovations in non-agricultural sectors have raised their relative share in the consumption by food crops production system.

Table 4-02.01: Food and non-food Crops

	Paddy		Wheat		Maize		Pulses	
Inputs	**1993-94**	**2003-4**	**1993-94**	**2003-4**	**1993-94**	**2003-4**	**1993-94**	**2003-4**
Food crops	0.157	0.291	0.122	0.376	0.041	0.040	0.135	0.238
Allied Agriculture	0.006	0.014	0.002	0.001	0.016	0.006	0.011	0.024
Chemical	0.086	0.103	0.106	0.118	0.055	0.095	0.050	0.045
Other machinery	0.077	0.079	0.097	0.101	0.048	0.067	0.044	0.026
Transport equipment	0.000	0.001	0.001	0.000	0.001	0.000	0.001	0.000
Total inputs	**0.393**	**0.582**	**0.400**	**0.653**	**0.273**	**0.278**	**0.408**	**0.514**
	Sugarcane		**Jute**		**Cotton**		**Tobacco**	
Inputs	**1993-94**	**2003-4**	**1993-94**	**2003-4**	**1993-94**	**2003-4**	**1993-94**	**2003-4**
Food crops	0.052	0.158	0.000	0.000	0.000	0.000	0.000	0.000
Allied Agriculture	0.003	0.004	0.020	0.007	0.014	0.003	0.005	0.002
Chemical	0.032	0.080	0.015	0.058	0.061	0.086	0.045	0.050
Other machinery	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Transport equipment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total inputs	**0.156**	**0.342**	**0.141**	**0.209**	**0.214**	**0.425**	**0.138**	**0.159**

Among the non-food crops, input value per unit value of output increased substantially for sugarcane and cotton and moderately for jute and tobacco. Use of chemical inputs increased in most of the cases. Use of allied agricultural products as inputs has increased only in sugar cane but declined in all other cases. Food crops as input were found only for sugarcane where it increased substantially. In contrast to food crops, inputs from industrial system in non-food crops had marginal rise over this period.

Technological Changes in Relation to Allied Agricultural Activities

In allied agricultural activities, input value per unit of output value increased only for other livestock products and for rest of the cases it either remained constant (e.g. forestry products and fishing) or declined (milk and milk products) as shown in Table 4-02.02. Use of food crops for the production of per unit value of milk and other livestock products, although quite high per se, declined.

Table 4-02.02: Allied agricultural activities

INDUSTRY	Milk and milk products		Other livestock products		Forestry and logging		Fishing	
Inputs	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**
Food crops	0.013	0.008	0.050	0.013	0.000	0.000	0.000	0.000
Allied Agriculture	0.003	0.002	0.000	0.001	0.004	0.002	0.020	0.014
Food Products	0.014	0.014	0.027	0.025	0.000	0.000	0.004	0.005
Textiles	0.009	0.005	0.001	0.001	0.001	0.001	0.024	0.035
Wooden Furniture & Products	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.001
Chemical	0.000	0.001	0.002	0.002	0.000	0.000	0.005	0.000
Transport equipment	0.000	0.000	0.000	0.000	0.004	0.005	0.030	0.020
Total inputs	**0.217**	**0.190**	**0.320**	**0.443**	**0.096**	**0.096**	**0.154**	**0.149**

Technological Changes in Relation to Agro-processed Industries

In agro-processed industries, the input values per unit of output value are found to decline for vanaspati and tobacco products and increase for sugar and edible oils. However, the input values are very high for both

Table 4-02.03: Sugar, oil, beverage and tobacco products

INDUSTRY	Sugar		Hydrogenated oil (vanaspati)		Edible oils other than vanaspati		Beverages		Tobacco products	
Inputs	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-904**	**2003-04**
Food crops	0.531	0.433	0.097	0.080	0.543	0.154	0.024	0.003	0.000	0.000
Allied Agriculture	0.003	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.069	0.039
Food Products	0.007	0.023	0.105	0.184	0.011	0.046	0.060	0.229	0.001	0.016
Beverage and Tobacco	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.055	0.042	0.090
Textiles	0.012	0.001	0.007	0.001	0.002	0.001	0.001	0.010	0.004	0.002
Wooden Furniture & Products	0.001	0.004	0.004	0.009	0.002	0.003	0.020	0.001	0.006	0.008
Chemical	0.009	0.009	0.106	0.012	0.009	0.006	0.040	0.062	0.015	0.018
Other machinery	0.005	0.031	0.000	0.002	0.001	0.002	0.009	0.009	0.023	0.005
Total inputs	**0.778**	0.828	**0.882**	0.836	**0.777**	0.816	**0.555**	0.661	**0.585**	0.505

the set of years indicating very high level of consumption of industrial inputs. In sugar, the use of food crops, allied agricultural products and textiles as inputs per unit value declined and that of food products, wooden furniture, chemical and other machinery increased (Table 4-02.03). This indicates relative decline in the prices of food crops vis-à-vis agro-processed products, inter alia this indicates lower outcome of innovation for food crops vis-à-vis agro-processed products.

Technological Changes in Relation to Textiles

In textile industries such as Khadi, silk textiles, silk carpet weaving and readymade garments witnessed increase in input consumption per unit value of output whereas for cotton, woolen, jute and miscellaneous textiles products there has been marginal change in input consumption per unit value of output (Table 4-02.04). In art silk and synthetic fibres, the major increase occurred for the inputs from chemical products and the major decline occurred for the inputs like textiles, and other machinery. Predominance of a few petro-chemicals producers enabled them to raise relative prices of their products like synthetic fibres or filaments. In garments, the use of textiles as inputs declined to a large extent per unit value of output

Table 4-02.04 (a): Textile industries

INDUSTRY	Khadi, cotton textiles (handlooms)		Cotton textiles		Woollen textiles		Silk textiles	
Inputs	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**
Allied Agriculture	0.000	0.000	0.001	0.000	0.089	0.078	0.128	0.003
Textiles	0.254	0.270	0.077	0.129	0.281	0.270	0.156	0.163
Wooden Furniture & Products	0.002	0.001	0.000	0.002	0.002	0.001	0.004	0.002
Leather footwear & Products	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chemical	0.016	0.010	0.047	0.017	0.056	0.008	0.025	0.174
Machine tools	0.001	0.000	0.000	0.000	0.001	0.000	0.003	0.000
Other machinery	0.010	0.007	0.007	0.012	0.007	0.068	0.013	0.002
Total inputs	**0.472204**	0.593872	**0.748774**	0.75908	**0.720196**	0.714191	**0.570011**	0.682486

Table 4-02.04 (b): Textile industries

INDUSTRY	Art silk, synthetic fibre textiles		Jute, hemp, mesta textiles		Carpet weaving		Readymade garments		Miscellaneous textile products	
Inputs	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**	**1993-94**	**2003-04**
Allied Agriculture	0.009	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.009	0.001
Textiles	0.290	0.193	0.041	0.043	0.199	0.227	0.411	0.349	0.298	0.235
Wooden Furniture & Products	0.004	0.004	0.001	0.001	0.002	0.003	0.001	0.005	0.001	0.003
Leather footwear & Products	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.002	0.000	0.013
Chemical	0.142	0.261	0.021	0.005	0.017	0.016	0.032	0.029	0.078	0.049
Machine tools	0.000	0.000	0.001	0.000	0.002	0.025	0.000	0.004	0.000	0.022
Other machinery	0.009	0.007	0.027	0.011	0.002	0.029	0.008	0.019	0.011	0.034
Total inputs	**0.717**	0.813	**0.680**	0.643	**0.422**	0.588	**0.651**	0.713	**0.660**	0.658

reflecting larger value addition to fabric or changes in relative bargaining positions of the garmenting and fabrication sectors. With the exception of carpet weaving, all the textiles categories raised the consumption of energy inputs per unit value of output.

Technological Changes in Relation to Furniture, Wood Products, etc.

The industry groups: furniture, wood & wood products, paper, leather, food processing and leather products - have reduced the use of other machinery as input per unit of value of output. Printing and publishing too has reduced consumption of machine tools while increasing marginally the consumption of other machinery as its input. The same pattern is noted with respect to the use of allied agricultural products as input. The use of chemical products increased for furniture and wood & wood products and declined for paper, printing, leather footwear and leather & leather products. In fact the input of products directly from industry has decreased in most of the sectors. In wooden furniture and wood products and leather and leather products energy inputs in the unit value of their outputs increased whereas it declined in the case of paper and paper products, printing and publishing and leather footwear due to decline in electricity consumption.

Rubber, Plastic Petroleum and Coal Products

In rubber products the total input per unit value of output has slightly increased over the period. Among its inputs major increment is found for chemical, and major decline is found for textiles. For the plastic products the share of inputs in unit value of output increased significantly although the use of chemical and other machinery declined. Total inputs cost decreased for petroleum products and for coal tar products. Energy intensity declined for rubber, petroleum and coal tar.

Chemical Industries

Among the chemical industries major increase in the value of input per unit output is found for inorganic heavy chemicals, organic heavy chemicals, fertilizers, synthetic fibres & resins primarily due to increase in consumption of chemical products. Drugs & medicines and other chemicals also moderately raised consumption of chemicals per unit value of their output. Pesticides, paints, varnishes and lacquers, soaps, cosmetics and glycerin reduced consumption of chemical products but the first and last groups reduced total input consumption in unit value of output. This would again reflect the corporate control of the industries wielding greater market power and thus the ability to raise relative prices. Excepting inorganic heavy chemicals, fertilizers and other chemicals, all the groups reduced energy intensity.

Non-metallic and Metallic Mineral Products

For most of the industry groups in this category the general trend has been towards reduced input values for machine tool and other industrial machinery while the feedstock, most often from allied industrial sectors and rarely from agriculture, either raised or failed to decline in general their respective input values. Quite likely this decline in use of machinery reflects stagnation in technical changes. Increase in value of industrial feedstock is also possible from a rise in relative price, consequent to technical stagnation and capacity underutilization in respective feedstock industries. The broad picture might therefore indicate stagnation in industrial technological changes.

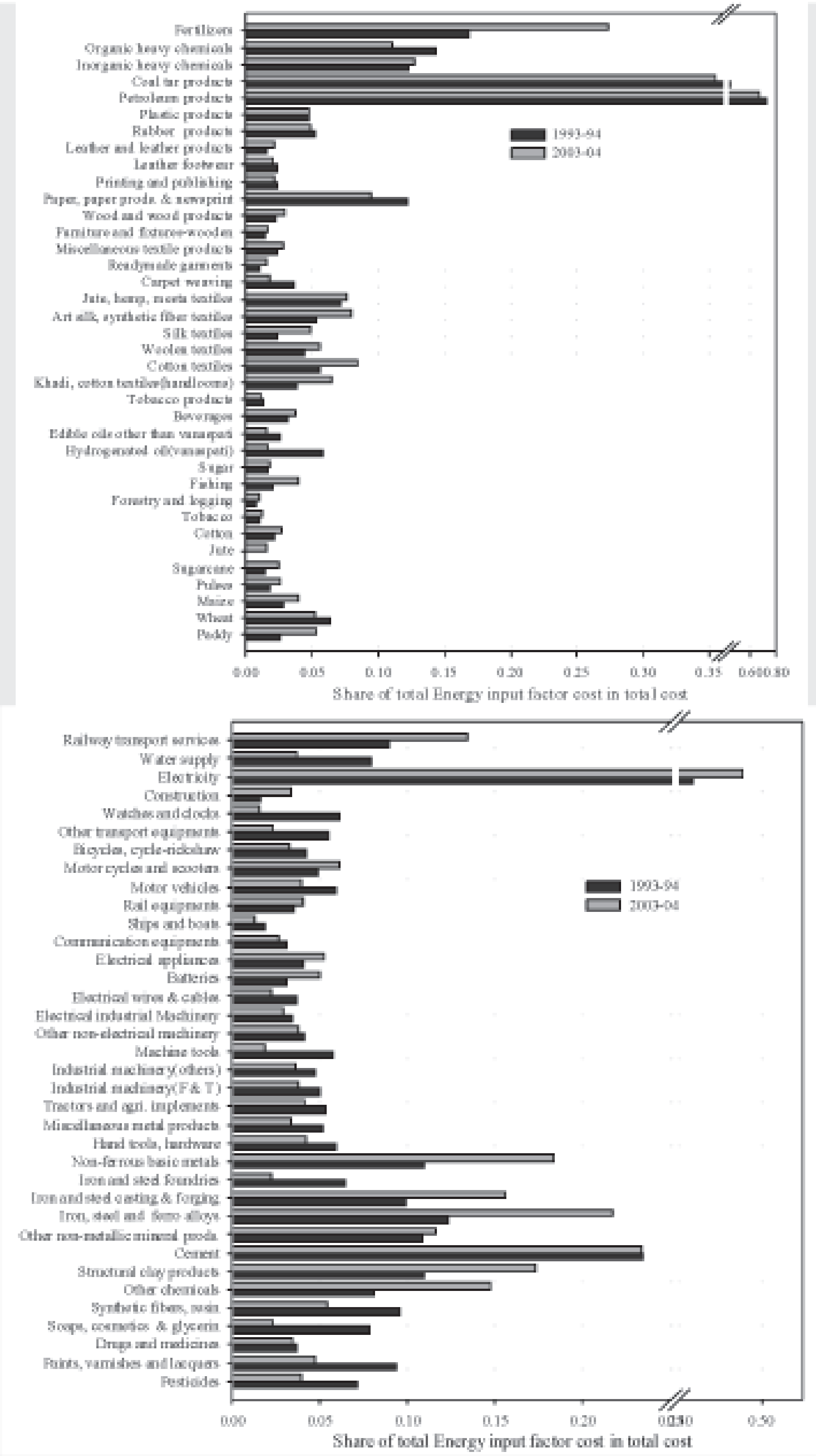


Fig 4-02.01: Change in share of total energy input cost in total input cost in several industries over time period (1993-94 & 2003-04)

Machinery Industries

The uses of machine tools and other machines have substantially increased in the unit value of the output of ships and boats, rail equipment, motor vehicles, motorcycles and bicycles. The use of wooden furniture on the other hand declined in all these cases excepting rail equipment. As it appears, these two broad groups have generated technological changes as reflected in their upward consumption of generative capacities embedded in machine tools and other industrial machinery.

Imports of Technology Intensive Inputs

I-O Tables, along with the production and flow of different commodities across all the commodities, also provide data on imports of different commodities. Although it is not possible to discern whether the imported good is used for production or consumption, or to locate the industry using the particular good, looking at the nature of the imported good one can have an idea whether it is used for production or consumption or both. Estimates of the ratio of import to total production indicate that it substantially declined for machine tools (34.5 to 19.2%) and other machinery (33.7 to 21.7%), transport equipment (26.9 to 9.4%) and chemical products (15 to 13.9%) between 1994 and 2004. Energy sector, however, substantially raised the ratio from 19.8 to 28.9% over the period. The decline in the ratios for capital goods or heavy chemicals implies that either the domestic capital goods sector is capable of meeting the demand generated by the domestic industries, or the domestic demand for capital goods did not rise much during this period. But the actual domestic production of these goods increased many fold as indicated by I-O tables. It needs to be mentioned that since imported capital goods embody latest, often state of the art technologies, their decline would slow down modernization of industries in general.

Trends in High Technology Trade

The Indian economy is now on a high growth trajectory, registering a growth of around 8 per cent in the present decade. The economy is now more integrated with the world. While the process of reforms has moved the economy to a higher plateau, the natural question is whether India can move up the technology ladder like the East Asian tigers? It should be manifested in the growth of high-technology manufacturing industries and knowledge-intensive service industries. It should be accompanied with the growth of India's trade in the above two segments in the global marketplace. Below, we have made an objective analysis to examine the status of the same vis-à-vis other major economies.

What constitute high technology segments? The standard approach that is commonly used to identify technology-intensive industries and products is the product approach. The product list is based on the calculations of R&D intensity by groups of products (R&D expenditure/total sales). Exports and imports of these products comprise high technology trade. According to European Union's definition of high technology trade, the following commodities comprise the same:

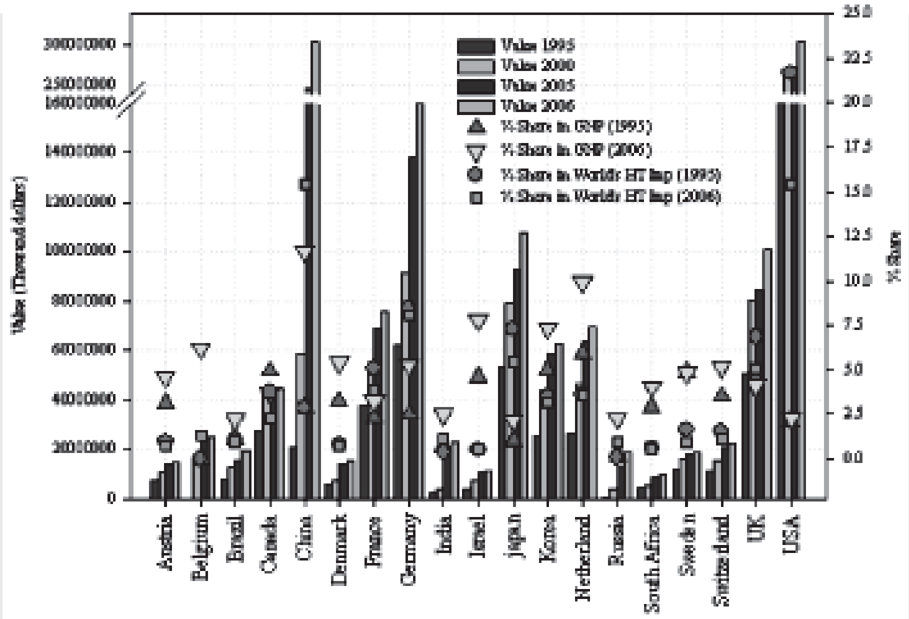


Fig 4-03.01: High Technology Import
Source: WTIS online database, (World Bank)

(1) Aerospace (2) Computers-office machines (3) Electronics-telecommunications (4) Pharmacy (5) Scientific instruments (6) Selected Electrical machinery (7) Selected Chemicals (8) Selected Non-electrical machinery (9) Armaments

India's high technology trade has increased from US $ 1,021 million in 1995 to US $ 4,463 million in 2006. During the same period, the export of high technology trade of Brazil has increased 8 times, while that of China has risen by 25 times! The share of high technology trade in India's GNP at 0.49 percent in 2006, is the lowest among the group of selected countries. If India has to emerge as an economic powerhouse in the 21st century, the country needs to improve its position significantly in the arena of high technology trade. Between the years 1995 and 2006, India's share in global high technology trade has increased marginally from 0.14 percentage points to 0.23 percentage points. India lags far behind China in capturing global market place. This is not surprising given the fact that India's share of high technology exports in total manufactured exports has hardly changed between the years 1995 and 2004.

With the opening up of the economy and easing of the embargo on high technology imports, India seems to have improved its position between the years 1995 and 2006. India's import of high technology trade has jumped from US $2,621 million in 1995 to US $23 billion in 2006. This corresponds to a share of 1.16 percent in world's high technology imports in 2006 as compared to a partly share of 0.36 per cent in 1995. However, its share in GNP is still small compared to other emerging/developed economies or BRIC member countries.

A principal reason for India's insignificant position in the global space of high technology trade is her virtual absence in some of the product categories. For instance, take the case of aerospace instruments. India exported only US $5 million in 2006, whereas a country like Israel exported US $39 million, Korea US $547 million and Brazil US $3,585 million.

India exhibits a better presence in the global market of trade in computer office equipments. India exported US $275 million and imported US $3,760 million worth computer office equipment in 2006. Except China,

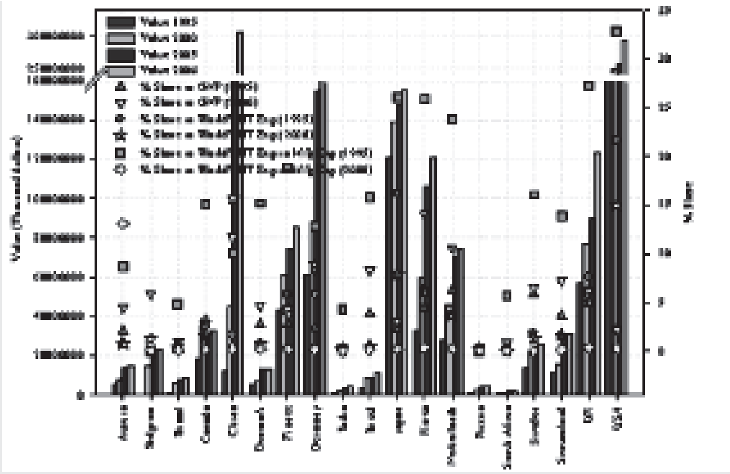


Fig 4-03.02: High Technology Export
Source: *WITS online database, (World Bank)*

India compares favourably with respect to other BRIC countries. Among the selected developing countries, India ranks high in respect of global import in this product category signifying the deepening of the IT spreads in the Indian economy.

Pharmacy is the only high technology sector where India has a marked presence among the developing countries. India's share of exports at about 5 percent in 2006 is the highest among developing countries (except China) and is even higher than some OECD countries like Japan, Canada. In fact, in this product category alone is the divide between India and China slim. By contrast, India's share of global import in this category stands at less than 1 percent in 2006. To some extent the low figure could be ascribed to the restriction on imports to India, by developed countries due to IPR issues.

The low level of trade (imports and exports) in scientific instruments by India is a cause for concern. This probably portrays the state of scientific research in India. While the share of China in global imports of scientific instruments stood at 24 percent in 2006 after rising from 3.5 percent in 1995, the share of the same for India has risen merely from 0.83 percent in 1995 to 1.05 percent in 2006. India exported only US $563 million of instrument in 2006, whereas a country like Israel exported nearly US $ 2 billion in 2006.

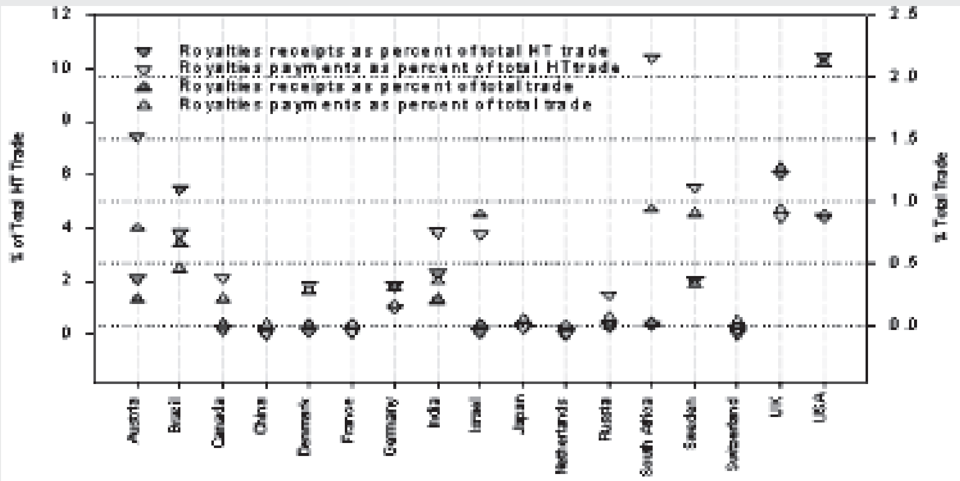


Fig 4-03.03: Royalties receipts and Payment
Source: *WDI online database, (World Bank)*

India is a late entrant in the global marketplace of armaments. Recently India has made a decision to be a player in this market. India has been able to increase its exports of armaments from US $325 million in 1995 to US $4,363 million in 2006. Its share of 0.05 per cent in the global export market is currently low given the size of her economy. There is no reason why India cannot improve her position in this category.

In the last two decades, the service sector has been growing faster than the manufacturing sector and is driving economic activity around the world. The aggregative picture is encouraging. India's commercial exports have more than doubled between the years 1995 and 2006. The share of India in world exports of commercial services stands at 0.64 percent in 2006, which is even higher than that of China, Korea, Israel, South Africa. The category commercial services include transportation as well as travel, which is not a knowledge intensive service industry. The share of computer, communication and other services in commercial service exports of India, which basically represent knowledge intensive service industry, stands at 74 percent in 2006. Thus, it indicates that India has been fairly successful in the global market of knowledge intensive service industries. India's position is the highest among the BRIC countries in this category.

By and large, India's performance on the high technology manufacturing trade front is not too impressive. Unlike China or Brazil, India is a small player in most of the product categories barring pharmacy sector. In the last ten years period, India has not been able to increase her presence significantly in most of the segments. By contrast, China, starting from a similar base like India in some of the segments, has exhibited marked improvement. Since pharmacy is one sector where India is doing well, it would make sense to nurture this sector. It is also surprising that India, with a large scientific base, occupies such a small share in respect of trade in scientific instruments. As our analysis indicates that there is a direct link between royalties and high technology trade, it is important to encourage this segment.

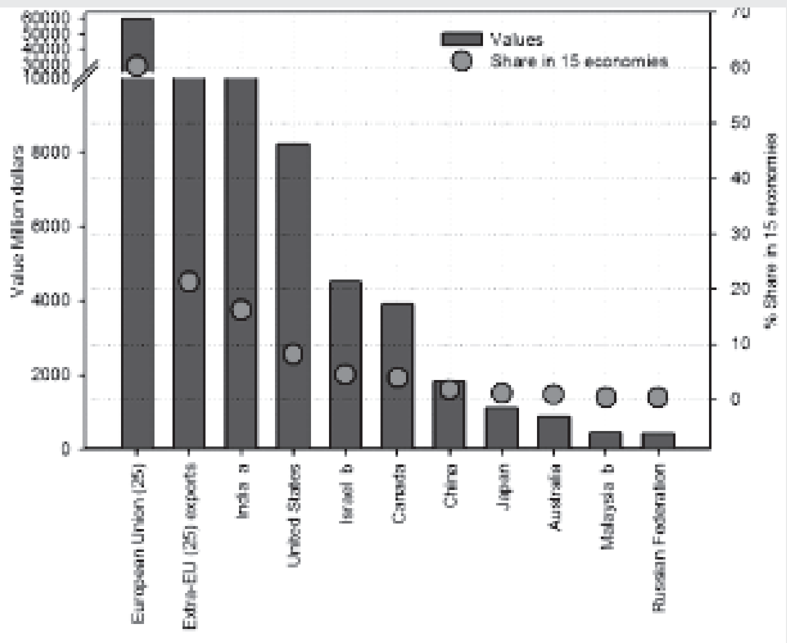


Fig 4-03.04: Major exporters of computer and information services, 2005
Source: *WTO, International Trade Statistics, pp 141*

Our analysis indicates that India has performed relatively well in the knowledge intensive service industries. However, this has happened primarily due to the significant growth of the area of computer and information services. However in the coming years, other segments like financial services, insurance services, health services, entertainment services are more likely to grow at a rapid pace. If India is to emerge as an important player in the knowledge intensive service industries, we need to improve our presence in these segments. At present, we are small players in these categories.

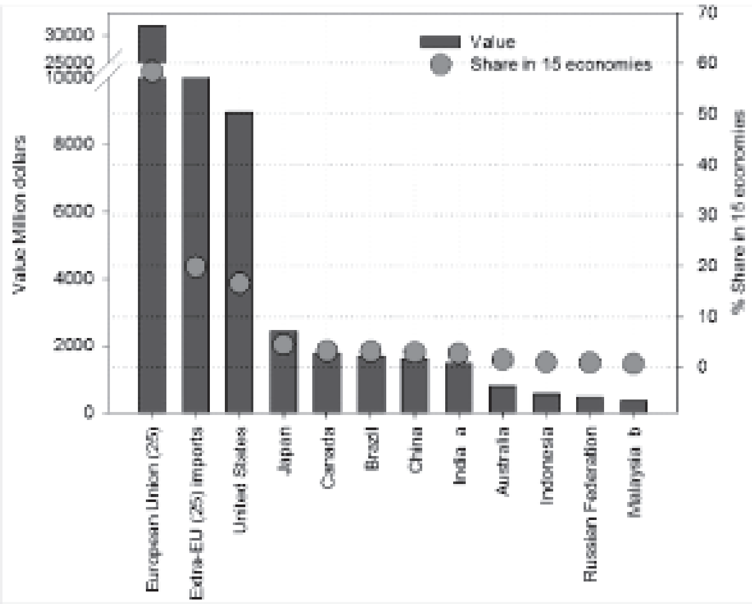


Fig 4-03.05: Major importers of computer and information services, 2005
Source: WTO, International Trade Statistics, pp 141

Industrial R&D in India: Broad Indications

There are two sources of data on industrial R&D in India. The first one is a Department of Science and Technology (DST) publication called "R&D Statistics" and the second one is the on line database "Prowess" of the Centre for Monitoring Indian Economy (CMIE). The main difference between the two is that the latter is much more disaggregated than the former. Moreover it is the only source from where one can get firm level data. We use the DST data in this analysis.

DST based data: Three conventional indicators used are:

i) Trends in R&D investment;

ii) Trends in patenting;

iii) Trends in technology trade balance.

Trends in R&D Investment

Both in nominal and in real terms, there has been a decline in the overall Gross Expenditure on R&D (GERD); and the GERD to GDP ratio has declined during the post reform period. From this, one has to be very cautious in drawing any strong inferences about the innovative potential of the country. This is because much of the GERD of the country is performed in the public sector in defence, space, atomic energy, health and agriculture. However the share of the business enterprises sector has shown sharp increases. It now accounts for about 20 per cent of the R&D (Table 1-04.01). The corresponding figure for China is as much as 64 per cent. The higher education sector represented by universities and research institutes accounts for only 5 per cent of total R&D performed in the country. Notwithstanding data problems, it is clear that the share of this sector has shown only slight increases during this period.

Growing privatization of Industrial R&D: Increasingly much of the industrial R&D is actually expended by private sector enterprises. An important hypothesis is that one sees a decline in the growth rate of industrial R&D when increasingly that R&D is performed by private sector enterprises (Table 2-04.02). Does this mean that the private sector is experiencing any *Arrowian appropriability* problems? This hypothesis makes the study of external financing of industrial R&D in India a relevant one. During this phase when investments in R&D are declining one sees that the government is putting in place a number of financial support measures that seeks to reverse this declining trend.

Table 4-04.01: Sector –wise GERD in India, 1970-71 to 2004-05 (% shares)

Year	Government	Industry	Higher Education
1970-71	89.55	10.45	
1975-76	88.13	11.87	
1980-81	84.13	15.87	
1985-86	87.82	12.18	
1990-91	86.16	13.84	
1995-96	78.26	21.74	
1998-99	75.79	21.17	3.04
1999-00	77.21	18.46	4.33
2000-01	77.94	18.05	4.02
2001-02	76.48	19.33	4.20
2002-03	75.56	20.27	4.17
2003-04	75.44	20.05	4.51
2004-05	73.92	19.81	4.88

Source: *Department of Science and Technology (2006)*

Industry-wide distribution of R&D: Within the industrial sector six industries (pharmaceutical, automotive, electrical, electronics, chemicals and defence) account for about two-thirds of the total industrial R&D. The

Table 4-04.02: Growing privatization of industrial R&D in India, 1985-86 to 2002-03 (Rs. in Millions at current prices)

Year	Government			Private Sector enterprises	Industrial R & D	Share of Private Sector In Total Industrial Development
	Public Sector Enterprises	Govt.Research Institutions	Total government			
1985-86	1986.18	1622.7	3608.88	2519.44	6128.32	41.11
1986-87	2356.99	1723.36	4080.35	2916.33	6996.68	41.68
1987-88	2884.66	1851.29	4735.95	3102.67	7838.62	39.58
1988-89	3421.24	2093.28	5514.52	4176.25	9690.77	43.10
1989-90	4129.01	2395.21	6524.22	4905.94	11430.16	42.92
1990-91	4145.33	2491.88	6637.21	5499.81	12137.02	45.31
1991-92	4843.88	2745.50	7589.38	6369.44	13958.82	45.63
1992-93	5139.50	2993.65	8133.15	8362.47	16495.62	50.70
1993-94	5428.11	NA	NA	9825.37		
1994-95	4146.09	3564.00	7710.09	13188.70	20898.79	63.11
1995-96	4275.76	4116.99	8392.75	16270.69	24663.44	65.97
1996-97	5360.52	4440.00	9800.52	23307.50	33108.02	70.40
1997-98	5392.40	5641.30	11033.70	24382.50	35416.20	68.86
1998-99	6738.70	7133.20	13871.90	21766.10	35638.00	61.08
1999-00	7576.30	7808.82	15385.12	21781.10	37166.22	58.60
2000-01	8428.80	8641.20	17070.00	24114.00	41184.00	58.55
2001-02	7673.70	8922.60	16596.30	27874.80	44471.10	62.68
2002-03	8089.50	9512.50	17602.00	30649.30	48251.30	63.52

Source: *Department of Science and Technology (2006)*

5-86 to 2002-03 (Rs in Millions at current pharmaceutical industry alone accounts for about 20 per cent of the total R&D expenditures. It may not be incorrect to say that India's national system of innovation is dominated by the sectoral system of innovation of the pharmaceutical industry. Second in line is the automotive industry. Both the industries are also characterized by competitive structures with a number of foreign and domestic manufacturers co-existing and competing with each other.

Trends in Patenting

Among the BRICS (Brazil, Russia, India, China and South Africa) countries, India has registered the highest growth rate in patenting (Table 2-04.03). From an earlier analysis, it is seen that most of the Indian patents are by domestic companies and that too in the pharmaceutical area. However in the more recent period, the share of patents secured by affiliates of MNCs based in India is on the increase.

Table 4-04.03: Trends in US Patenting of Indian Inventors, 1994-2007 (number of utility patents)

	Pre 1994	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Compound rate of growth
China, P.Rep	431	48	62	46	62	72	90	119	196	289	297	404	402	661	772	23.82
South Africa	2390	101	123	111	101	115	110	111	120	113	112	100	87	109	82	-1.59
China, Hong Kong	702	57	86	88	81	160	155	179	237	233	276	311	283	308	338	14.67
India	428	27	37	35	47	85	112	131	178	249	342	363	384	481	546	26.02
Russian Federation	3	38	98	116	111	189	181	183	234	200	203	169	148	172	188	13.09
Brazil	752	60	63	63	62	74	91	98	110	96	130	106	77	121	90	3.17

Source: USPTO (accessed on April 11 2008)

Triadic patent data [patents secured by an inventor from three different patent offices (USPTO, European Patent Office and Japanese Patent Office)] also show that India has registered one of the highest growth rates in Triadic patent grants during the period 1975 through 1995.The performance of the country in patenting confirms the results obtained in R&D investments, namely that most of the patents are secured by domestic private sector companies that too in the area of pharmaceutical technologies.

Trends in Technology Trade Balance

India's technology trade balance has been negative and rising all through the more recent years. However, in the period since 2005, it has turned positive essentially due to the receipts under R&D outsourcing. India, along with China has now become a major recipient of R&D outsourcing deals. Most of India's R&D outsourcing deals is in the areas of pharmaceutical and telecommunications industries.

Thus, based on the evidence presented it can safely be argued that India's innovation performance has actually improved if one takes the output measure of R&D. Regarding investments in R&D, although the growth rates in GERD have actually declined; that expended by the industrial sector, led by private sector enterprises, has actually shown an increase. Another point appears from the analysis is that the country's innovative performance is concentrated in certain specific industries such as the pharmaceutical and as such is not widespread.

Industrial R&D in India: Contemporary Scenario

Technological/economic success of a country is deeply intertwined with its ‘capabilities’ (competencies) for carrying out innovation of technologies that compete at the state-of-art in the world market. Capability development is a long term process that requires a country to pass through different phases of learning, creating the required physical infrastructure, human capital, institutions that support these activities, and creating inter-linkages among them. National capabilities and competitive advantage to a large extent emerges from investment in R&D and its successful translation. Assuming that a country’s capability is largely determined by the firms’ capability in turn emboldened by the firms’ investment in R&D, this analysis exhibits how Indian firms are doing R&D and the analysis is based on an expanded dataset.

Protectionist barriers (fiscal and non-fiscal), many regulatory barriers, rules and regulations, government controls acted as impediments for Indian firms to expand R&D. They directly or indirectly affected firms focusing attention in R&D. However, there has been a significant shift in the last few years. Liberalization of the economy that began in the 1990s has been institutionalized to a large extent, greater integration with world economy has taken place, and many of the firms have established global footprints. Indian firms particularly in the pharmaceutical sector have been compelled to invest in R&D due to India’s adherence to TRIPs agreement, etc.

Here we investigate the R&D investment scenario in India with specific focus on industrial R&D. In the first part of this section we examine international R&D investment trends in major industrialized and emerging economies. The international investment provides a benchmark for Indian R&D investment. In the second part we examine R&D investment by public limited firms in India. Examination was done for 2006-07. Average data was taken to mitigate the effect of any idiosyncratic fluctuations. Broad trends for earlier years were analyzed to get a proper perspective of contemporary investment trends.

Expanded Data-set of Companies doing R&D

R&D Statistics periodically brought out by the DST (Department of Science and Technology) is the prime source for assessing the intensity and extent of R&D undertaken in the country. Information is solicited from R&D units recognized by DSIR (Department of Scientific and Industrial Research). These R&D units include public and private limited companies. This compilation by DST is important as it provides an indication of the R&D activity of the country. However, there are limitations in using these statistics for gauging the current scenario. One of the main drawbacks is that the data is dated. The latest available report by DST is “R&D Statistics 2004-05’; this captures industrial R&D expenditure data up to 2002-03. Also restricting the survey to data collection for R&D units recognized by DSIR leads to missing gaps. A recent study shows that there are 1,208 public ltd. firms involved in R&D in India, not covered by DST R&D statistics. Non-inclusion of these firms has strong bearing in estimating the R&D expenditure and the inventive/innovative activity of the country. For example, inclusion of the R&D expenditure of 1,208 firms pushes the national R&D expenditure during the period 2002-03 up by 3.7% and industrial R&D expenditure up by 16.3%. The 1,208 firms have also undertaken a large number of technological as well as non-technological innovations which shows that Indian firms are building up technological capacity/capability. This investigation, keeping in view the constraints of using DST statistics, has captured data from various sources to reflect upon the contemporary industrial R&D activity.

Capturing data from public sources was confined to public limited companies as they divulge their detailed data (i.e. as per legal requirements only public ltd. firms have to submit details of their various activities including R&D to the Ministry of Company and Law Affairs). The limitations of this investigation are mainly in two. Firstly, private firms make limited disclosures as they have no legal binding to divulge their capital and other activities in details and therefore, sketchy account of their R&D expenditure and related statistics can be gathered from secondary sources. Thus, these firms were not considered in this investigation. Secondly, primary survey provides valuable insights which cannot be captured by secondary sources. However, a good estimation of contemporary scenario of industrial R&D activity can be obtained by investigating public limited companies, as studies have shown that they are the major driver of industrial activity in the country.

There are approximately 10,000 public limited companies that have time series data available at least for three years. This constitutes the target population. All firms within this population that have shown R&D investment is taken as the sample for this study. It is possible to get the time series data of the above 10,000 companies from CMIE, through their Prowess database. Among the reasons of using this database for the above assessments is that these 10,000 or so companies contribute 70% of industrial revenues and are thus indicative of the industrial activity of the country. This motivated the use of this data source to examine industrial R&D in India. Annual reports, IBID (newspaper clipping database), red herring listings, company websites were also used to enrich the data.

R&D Investment : International Scenario

R&D spending by a country is used as one of the primary indicators in gauging the competitive capability of a country (see for example World Economic Forum, 2008). India is the 4th largest economy of the world in PPP (purchase power parity) terms after US, China and Japan. However, it fares poorly in the world map of R&D spending. Table 4-05.01 highlights this aspect.

Table 4-05.01: Share of Total Global R&D Spending 2006-2008

	2006	2007	2008 (estimated)
Americans	35.70	34.5	33.1
United States	32.70	31.4	30.1
Asia	36.90	38.8	40.8
China	13.50	15.6	17.9
Japan	13.00	12.8	12.4
India	3.70	3.7	3.7
Europe	25.20	24.6	23.9
Rest of world	2.20	2.2	2.1

Source: *Global R&D Report 200 (www.rdmag.com).*

The low investment in R&D is an indication that India is still involved in activities that are not creating higher value at different levels. This assertion can be made as expenditure in research is an indication of commitment of a firm/research organization to search for novel ways of producing/ creating new products. It can also be observed from Table 4-05.01 that India's spending has remained constant from 2006 to 2008. China shows upward trends. Fig 4-05.01 depicts the source of R&D funding in some major economies.

From Fig 4-05.01 two groups of countries can be discerned based on source of R&D funding. Mainly the industrialised economies and some emerging economies (such as China) have industry as the major source of R&D funding. On the other hand, government funding is the major source for R&D in developing economies such as India, Brazil, and Hungary. Industrialised economies in general have R&D expenditures over 2%

of GDP. Developing economies have R&D expenditures ranging between 0.5% to 1.5% of GDP. From the above we can deduce that R&D investment by industry plays a major role in pushing the R&D spending as a share of GDP. One of the lessons one draws from the above analysis is the importance of industry in investing in R&D activity.

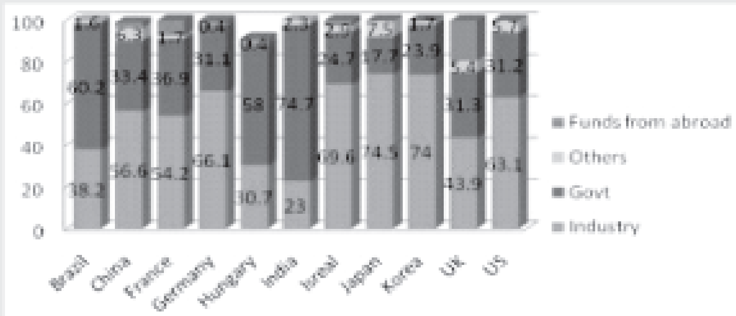


Fig 4-05.01: Source of R&D funds (%) for select country
Source: *Global R&D Report, 2007*

The results of R&D spending are reflected in various intangible (such as patents) or tangible outcomes such as new products/processes developed (or more efficient products/processes), high technology exports. Patenting particularly in the US patent office (USPTO) has been used as yardstick to measure the competitive capability of a country, and is widely used for inter-country comparison on R&D productivity. India's overall patenting activity in the USPTO in terms of granted patents was less than the other major Asian economies namely China, Israel, Korea and Taiwan (Fig 4-05.02). Further, it may be observed that MNC's in India and China were more active in patenting then domestic firms. India's high technology exports were also less than other Asian economies. For example in the total manufacturing export, India's high technology export was only 4.88% in comparison to China's 29.19 % in 2005 (World Development Indicator, 2006).

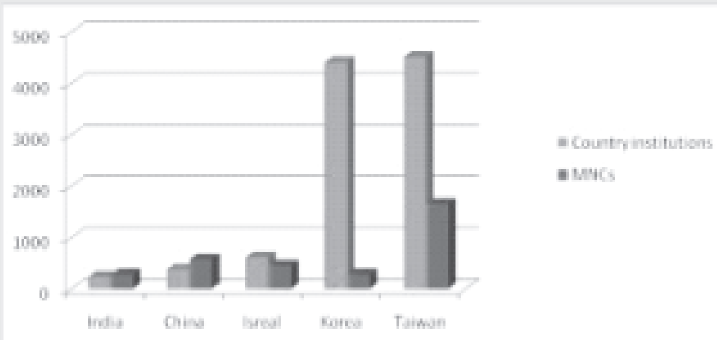


Fig 4-05.02: US patents granted to inventions of various countries, 2005
Source: *R&D India Newsletter October, 2006, DSIR, New Delhi*

Industrial R&D-Indian Scenario

India has a huge R&D infrastructure with 400 national laboratories, 1,300 recognized in-house industrial units, besides several government departments and private institutions and foundations engaged in scientific research. R&D is also undertaken in the 358 universities in the country. There are approximately 500 foreign R&D centers in India. In spite of this impressive R&D infrastructure in the country, the amount of funds invested in R&D is below 1% of GDP. However, during the last few years positive trends in R&D investments were observed. The National R&D expenditure in 2005-06 was Rs. 28,776.65 crores and has been projected to attain a level of Rs 32,941.64 crores in 2006-07 and Rs 37,777.90 crores in 2007-08 (R&D Statistics at a Glance, 2008). The share of R&D expenditure as a percentage of GNP has also increased from 0.58% during 1990-91 to 0.89% in 2005-06. Industrial R&D expenditure comprising both public and private sector was about Rs. 8,748.20 crores. The investment in R&D has more than doubled for private sector industries in 2004-05 from that in 2002-03. For 2005-06 private sector investment was Rs. 7,444.21

crores and is expected to reach Rs. 11,192.86 crores in 2007-08 (ibid). The industrial sector spent 0.55% of its sales turnover on R&D activities in 2005-06.

Besides regular R&D budgets allocated to various organizations, extramural funding is also provided by scientific departments/agencies to R&D organizations to build general R&D capabilities and provide special encouragement to scientists to pursue research careers. The extramural R&D funding commitment by Central government S&T departments/agencies was Rs 1,163.80 crores in 2005-06 (2007, Directory of Extramural Research & Development). There were 3,569 projects approved for funding during 2005-06. Biological sciences (682 projects) attracted the maximum number of projects. However, the maximum extramural expenditure was in medical sciences; its 565 projects incurred an expenditure of 372.84 crores. This was 49.16% of the total approved extramural grant during 2005-06. University Grant Commission (approved 758 projects), Department of Biotechnology (approved 422 projects), and Council of Scientific and Industrial Research (approved 247 projects); were the other prominent agencies involved.

Table 4-05.02: Number of Firms Involved in R&D in Different Years

	No. of firms	R&D expenditure(Rs. crores)	Sales (Rs. crores)	R&D* intensity
1990	44	74.57	152168.9	0.049
1995	853	1116.12	388437.9	0.287
2000	933	2219.33	748025.3	0.297
2001	930	2446.86	877662.4	0.279
2002	1068	3003.47	877667.13	0.342
2003	1099	3868.09	968885.39	0.399
2004	1070	5098.99	1139574.9	0.447
2005	980	6074.17	1358880	0.447
2006	966	7635.28	1608181	0.475
2007	918	8596.26	1837312.7	0.468

*R&D expenditure/sales
Source: *Constructed from Prowess database*

As outlined earlier R&D has never been a major concern for Indian industry. Liberalization and subsequent opening up of the Indian economy from 1991 onwards are beginning to make significant impacts. Lowering of custom duties, amendment of the patent act, foreign investment and entry of multinational companies with large R&D centers, corporate research centers and joint efforts with Indian partners are effecting the change.

Table 4-05.02 highlights the firms undertaking R&D investment (this is drawn from the population of 10,064 firms, in different periods of time). R&D intensity is defined as R&D expenditure divided by sales. Normalization of R&D by firm sales controls for the effect of firm size, which affects the return per unit of R&D effort. It shows significant positive growth in number of R&D firms from 1990 to 1995 (we define a firm as an R&D firm if it has undertaken R&D investment). The growth trend is slower after 1995 with minor negative fluctuations in some years also. However, absolute value of R&D investment has significantly increased over the years. There has been almost a 770% increase in R&D investment in 2007 from that in 1995; although the increase in number of firms undertaking R&D investment has been marginal. The number of R&D firms in 2000 was more than that in 2007. However, R&D investment in 2007 was 387% more than that in 2000. The R&D intensity does not show these high growth rates as sales have also increased significantly over the years. The proposition that R&D investment contributes to sales is supported by this empirical data.

Characteristics of Firms Undertaking R&D in 2006-2007: There were 1,055 firms from the population of approx. 10,000 firms that had made investment in R&D for the period 2006-07.

Key Findings

- Many of the firms were incorporated more than fifty years ago. It is however, not possible to ascertain when individual firms undertook first investment in R&D.
- Western region was found to be the major centre of location of the R&D firms.
- Chemical sector emerges as the dominent sector in which firms had made R&D investment. Automobile, Food & Beverages and Instrumentatation are the other sectors where firms had made R&D investment. In the later period there is emergence of software firms.
- Small firms (sales < 100 crore) were the key drivers of R&D activity. Firms in this category devoted almost 6% of their sales in R&D (this is on an agggregate) as compared to range of 0.45 to 1% for firms from other categories (sales above 100 crores).
- R&D intensity was high for pharmaceutical industry (6.7%) and Chemicals (2.42%). Textile (0.19%), Basic metals (0.15%) and Non-metallic (0.16%) were hardly contributing to R&D. Software sector had moderate investment intensity (1.15%).
- Foreign promoter share (FPS) acted as an inducement for R&D investment. Firms that had FPS > 75% had R&D intensity of 1.68% in comparison to firms with no FPS (0.63%).

We should be cautious in making generalized interpretations from the above findings. Firstly, these statistics emerge from a snapshot analysis of average activity in two year period 2006-2007. Secondly, the firms are restricted to only public limited entities.

FDI in R&D in India

R&D internationalization is not a new phenomenon. It is an activity for resource exploitation and augmentation through various channels beyond the national boundary. It is a global search for talented human resources, conducive research environment and low cost for R&D activities. The implications are global, national and at firm level. MNCs are expanding their domain of R&D activities overseas, in the following three ways: Joint venture, Greenfield, Mergers and Acquisitions.

The focus of this investigation is on the following issues:

- How and why R&D internationalization is taking place?

  Firms are decentralizing their R&D activities to different geographical regions as a part of their business strategy. Why firms are looking beyond their home country for R&D activities is an important issue for understanding global innovation networks.

- Patterns and trends in R&D internationalization (Global)

  Global firms are seeking the shores of emerging economies to have access to their S&T resources. More and more R&D centers of global firms are setting-up in India and China. This brings in a new dimension to the issue of R&D internationalization.

- Indian Scenario

  Presence of global firms in R&D activities is growing with more R&D investment coming in various sectors like IT, drugs and pharmaceuticals, biotechnology, automotive etc. The pattern of flow of FDI in R&D by various countries in different sectors in India is important here. It has resulted in R&D clusters by MNCs. The other dimension of it has been that many Indian firms have also expanded their R&D activities to other regions.

Internationalization of R&D

Internationalization of R&D is a phenomenon of the late eighties. Many MNCs set up production facilities in the growing markets overseas through their subsidiaries, or through collaborations with local companies. In many cases products have to be modified to suit local tastes, conditions, and also locally sourced materials or components. R&D facilities were created to address such needs for modification of the products and technologies. The present trend of internationalization of R&D, however, goes much beyond this practice. The present trend is more about attaining or retaining global competitiveness by having access to R&D infrastructure and capabilities from multiple sources; developing global networks.

New Trends in R&D Internationalization

Internationalization of R&D has entered a new phase, with MNCs' overseas investments increasing in the Asian region. China and India are emerging as the most preferred destinations for MNCs for setting-up their dedicated R&D centers. According to 'The Economists Intelligence Unit survey, 2007', India emerges as the most preferred destination for R&D location, followed by US and then China. Now, firms from India are also expanding their R&D, production and marketing activities. Main reasons behind this new trend are:

- Escalating Demand on S&T Infrastructure
- Prohibitive Cost of Highly Skilled Manpower
- Resource Scarcity in Developed Countries

According to Economist Intelligence Unit 2004, out of many reasons, India's R&D activities and highly skilled labor force have been the carrots for R&D FDI entering India. This gives a new perspective – emerging economies being sought by the global firms for augmenting their knowledge resources.

Indian Scenario

Foreign R&D Centers in India: Internationalization of R&D and innovation in the Indian context is the measure of FDI inflow and outflow in R&D (as a percentage of total R&D investment in India). MNCs, Indian firms, universities and the public research institutes together contribute to the process of internationalization. It is a measure of the nature and type of R&D activities undertaken by the MNCs in India and also of the R&D activities of Indian firms outside India. It is also a measure of the extent of Indian R&D and production system getting linked to the global R&D system, through MNCs R&D activities in India.

According to a TIFAC report, over 100 foreign organizations (mainly MNCs) have opened R&D centres in India over the last decade. The flow of foreign R&D is mainly concentrated in few areas like software development, auto design, drug design and pharmaceuticals, hardware and product design. Earlier, many MNCs had R&D set-ups as support structures to their production units. Latter entrants are however opening dedicated independent R&D centers for taking up R&D activities in new/emerging research and high tech areas. During 1996-2000, new countries established their R&D centers in India and countries that already had R&D centers have established more during the same period. This has been a phase when India became a centre for global R&D activities. There are 16 countries whose MNCs have established their R&D centers in India. US have the maximum number of R&D centers with maximum R&D workers employed.

Country-wise R&D investment: Firms from different countries have been setting up their R&D centers in India. USA has invested maximum of 860.88 million US $ in India followed by Korea, Germany, China, UK, France, Netherlands, etc. These countries also established R&D centers in different locations in India. USA was far ahead of all other countries (in 2003) with 53 R&D centers followed by UK, Japan and Germany, each having 7 R&D centers. USA also employed maximum manpower in India. It is also evident that more R&D centers were established during 1996-2000 when India was emerging as an R&D hub.

Sector-wise R&D units: Global firms have been setting up more R&D units in IT sector (71) followed by automotive (23), drugs and pharmaceuticals (13), biotechnology (8), aerospace (7) and agriculture (6). These firms have setup 128 R&D units in India.

Sector-wise foreign R&D investment by global firms: IT sector got maximum FDI investment in R&D followed by automotive, biotechnology, aerospace, drugs and pharmaceuticals and agriculture during 1998-2003.

Indian IT sector: Indian IT sector has attracted the maximum investment from global firms. This gives an important insight to the issue of R&D internationalization where most of the global IT giants have their R&D operations in India and have linkages with Indian R&D and production system.

It is seen that the top 7 globally spending IT firms have their R&D operations in India. They have set-up their dedicated R&D centers. Many of the top global IT firms established their R&D centers in India around

2000. Some of the new entrants after 2003 have again been firms from USA like HP, Microsoft etc. These firms are now expanding their R&D activities by setting up newer centers.

Indian IT firms' performance should be seen in the following context: total R & D expenditure for the year 2006-07 was Rs. 429.99 crore; 30 firms invested in R & D out of 296 companies as per CMIE Database on IT sector. The top 10 firms together have R&D expenditure to the tune of 87.8 percent of the total R&D expenditure by the Indian firms in this sector.

In 1997 the R&D expenditure was basically from the top 10 firms, but over a period of 10 years other firms also began spending on R&D.

Linkages with Indian Production and R&D System

The nature and type of linkages and also their extent have implications for the host country's R&D and production system. The spillover from MNC R&D to local entities might take place through setting-up of joint research labs with local universities. This has in turn triggered off similar joint research labs being set-up by some of the local large firms with the universities. There are studies, which are indicative of the possible benefits to the host country's innovation system, but not much is known about their impact.

Glimpses of linkage observed in India between foreign R&D centers and the Indian production and R&D system: One interesting observation is that the foreign R&D centers have not only linkages with some of Indian firms but they also have linkages with certain research institutions like Indian Institute of Science, IITs etc. This gives a new dimension to the issue of linkages where it indicates a search for knowledge resources by global firms in India. This is a departure from the earlier understanding where the global firms mostly sought emerging economies for marketing. This could be described as a reverse spill over.

R&D in Private Industry in Post liberalization Period (1990-91 to 2006-07)

Liberalized economic policies in post 1991 era have stimulated competition in the Indian industrial sector forcing private industry to improve product quality through increased investments in R & D. It is evident from the data in Table 4-07.01 that there has been consistent growth in R&D investments by the private industry in the post liberalization period (with some exceptions: 1997-98, 1999-2000). A sharp increase (132%) was observed in the initial period of liberalization which indicates that 'liberalization' has been taken as a signal by the industry to prepare for competition through technological advancements. In this period (1990-91 to 2006-07), an average 33% rate of growth in R&D investment by private sector is seen. A significant GDP growth has also been registered by private industrial sector with the increased R & D expenditure. But industrial GDP achieved per unit of R & D expenditure shows a decline over the years. However, no definitive trends were observed in case of R & D intensity (R & D Expenditure/Sales). Trends of increasing royalty payments reflect on industry's effort to acquire new technologies. Export of goods also

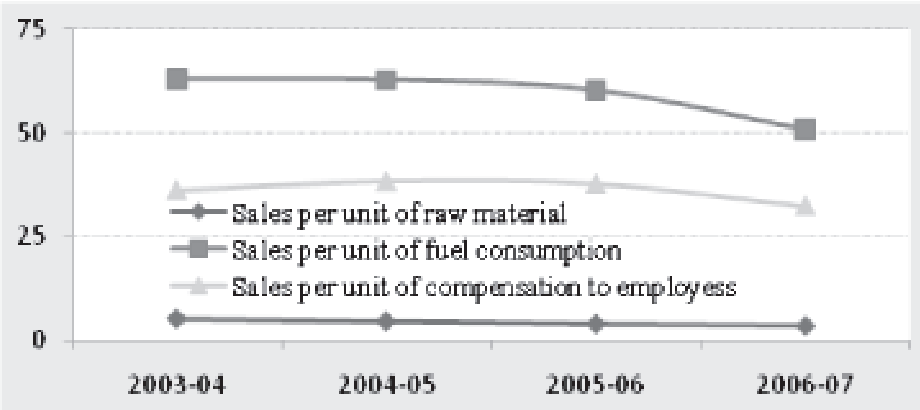


Fig 4-07.01: Sales per unit of compensation, money spent on power and raw material

shows a consistent growth in the earnings through exports of goods by the private industries. Rate of growth for export of goods is found to be appreciable in the past few years (2002-03 onwards). However, in terms of innovation, industry has shown a decreasing trend in terms of sales achieved per unit of compensation given to employees, money spent on power consumption and raw material (Fig 4-07.01). A further analysis in terms of geographical distribution for selected sectors i.e. cement, processed food and chemicals shows lowest concentration of firms in eastern region of the country.

Table 4-07.01: Trends in R & D expenditure for Indian Private Industry vis a vis other parameters of industrial growth

Year	R & D expenditure (Rs. millions)	% increase in expenditure over previous year	Industrial GDP at constant price (Rs. millions)	Industrial GDP per unit of R & D Expenditure	R&D Intensity (R&D Expenditure /Sales)	Expenses in Royalty Payment (Rs. millions)	Export of Goods earnings (Rs. millions)	Export of Services earnings (Rs. millions)
1990-91	1232.3	132	2145520	1741.07	0.000596	4157.7	84749.7	18971.7
1991-92	2863.3	82	2139250	747.13	0.001093	12280.5	120173.5	26451.4
1992-93	5212.2	24	2208800	423.77	0.001697	18746	158615.5	46571
1993-94	6458.1	49	2373760	367.56	0.00184	19528.9	214908.4	34701.1
1994-95	9620.7	53	2621640	272.5	0.002171	10090.2	271616.1	67334.2
1995-96	14672.8	35	2966640	202.19	0.002686	27672.1	350657.7	64344.9
1996-97	19810.8	-10	3202660	161.66	0.003203	51013.3	394941.8	74949.3
1997-98	17855.7	17	3267200	182.98	0.002679	54566.1	442032.3	82716.4
1998-99	20803.7	-4	3383690	162.65	0.002845	37123.8	456569.7	95865
1999-00	20036.6	22	3502330	174.8	0.002317	68191.7	509185	102236.2
2000-01	24397.3	8	3725990	152.72	0.002347	90989.1	754029.3	53235.2
2001-02	26388.7	35	3813660	144.52	0.002411	120187.9	719609.2	98427.1
2002-03	35719.4	31	4072760	114.02	0.002925	138328.8	893770.1	95932.3
2003-04	46660.5	16	4317240	92.52	0.003357	149901.5	1135266	86420.1
2004-05	54243.5	35	4684510	86.36	0.003296	170062.5	1546837	98866.8
2005-06	73115.4	9	5060160	69.21	0.003839	194620.6	1895607	157338.3

Source: *Prowess database of Centre for Monitoring Indian economy (CMIE) containing data about 10,000 large and medium size Indian firms.*

Expenditures in terms of R & D and Royalty; Sales, export of goods & export of services for top 10 sectors (of the sectors covered here) of private industry has been shown in Fig 4-07.02. Similarly expenditures in terms of R & D and Royalty, sales, export of goods & export of services for bottom 10 sectors of private industry have been shown in Table 4-07.02. Both the top and bottom 10 sectors have been chosen on the basis of sales during the period 1990-91 to 2006-07.

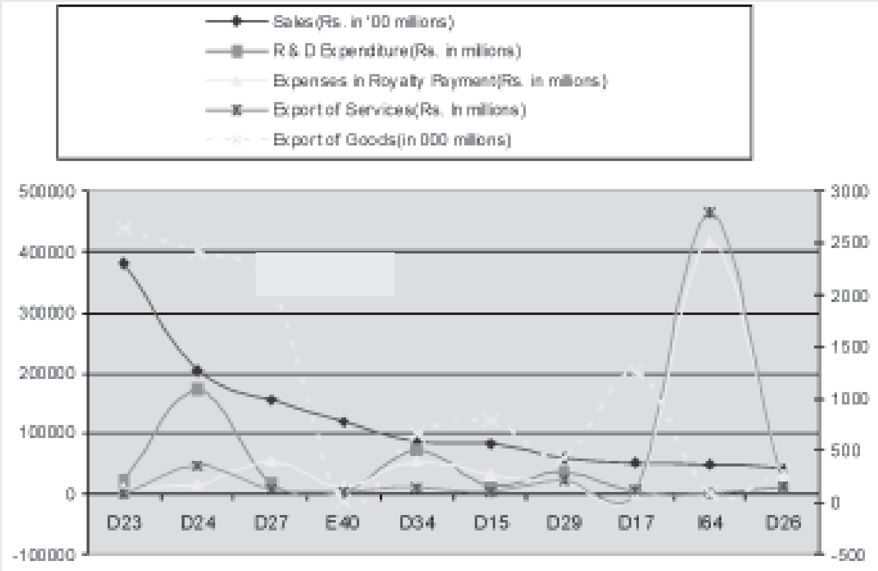


Fig 4-07.02: Expenditure done by top 10 sectors on different parameters for the period 1990-91 to 2006-07
Source: CMIE

Table 4-07.02: Expenditure done by bottom 10 sectors (in terms of sales) on different parameters and sales, export achieved for the period 1990-91 to 2006-07

NIC Code	Sales(Rs. millions)	R & D Expenditure(Rs. millions)	Expenses in Royalty Payment(Rs. millions)	Export of Goods(Rs. millions)	Export of Services(Rs. millions)
D28	1078273	1189.5	905.8	140589	28199.8
I61	971857		1575.9	145.2	320421
D30	694400	2003.1	9373.4	106700	4969.9
C13	653746	1486.7	9437.9	244365	339.2
D22	610650	19.1	4480.6	19110	4363.8
I60	483784	0.8	308.8	324.3	5396.1
D19	337305	390	1105.4	143652	18
D33	319770	822	814.8	20587	6928.7
N85	145899	1.2	49.7	187.8	2490.5

Fig 4-07.02 exhibits that there is very little or no correlation among different parameters. However, it can be seen that manufacture of chemicals and chemical products has incurred highest expenditure on R & D followed by manufacture of motor vehicles, trailers and semi-trailers. It can be seen that post and telecommunication sector has incurred highest expenditure on royalty payments and has achieved highest export in services. Highest sales and export of goods are achieved by manufacture of coke, refined petroleum products and nuclear fuel.

Pattern of Innovation and R&D in Select Sectors by Listed and Other Companies of India

Innovation behaviors of listed firms are likely to be different from business enterprises that are not listed, such as privately held family firms. The listing entitles a firm access to supposedly cheaper capital market. Listing also makes it obligatory on the part of companies to divulge performance and investment data beyond what accounting standards require. This probe is based on much of such data provided by listed companies as also by other companies and as provided by the Prowess database of the Centre for Monitoring Indian Economy (CMIE).

Most stock exchanges globally and Indian exchanges too have either proved indifferent to or sometimes even hostile to expenditure on R&D. Therefore, a company would choose between the following options: (1) report on R&D to gain in tax savings or the company perhaps does not require to raise money from capital market; (2) de-risk the listed company by hiving off the vehicle that would undertake R&D; (3) not report on R&D and forego tax gains but invest in developmental projects; or (4) not undertake R&D or no major developmental project.

Perhaps most important would be – what defines R&D expenditure? In fact very often firms abroad classify activities of a not strictly R&D type under this head in order to gain tax rebates or to secure strategic mileage. Most importantly a large number of firms are busy in innovative development, while not owning a formal R&D set up. In this section, therefore, we would look into reported cases of R&D without looking into issues of business strategies and the non-R&D elements of innovation.

Place of R&D and the Company Management Structure

Indian companies doing R&D generally locate the R&D unit only at one location, which is not necessarily the head office of the company. Each factory/division would most often not have respective product R&D. Size of a typical R&D unit is almost always very small and intra-company mobility across factories/divisions shop floor or marketing and the R&D unit is rarely institutionalized. The head of R&D almost never is on the board or often does not report to the chief of the company. In only a few cases has the chief taken a personal interest in R&D. To recall, legal institution such as Companies Law, Factories Act, Competition policies or similar others and other fiscal or capital market policies critically influence R&D behaviors/extent and in-company structure and function of the R&D.

Rather recluse, R&D by an Indian company rarely encourages its personnel mobility across companies or public R&D institutions/universities. Mobility is known in pharma and IT R&D. Nevertheless, many large companies have commissioned studies or projects to public laboratories, especially the CSIR and also sometimes to the universities. In few cases of large companies, one might discover competency centers.

Nature of Innovative Output

Development of new product, upgrading quality, adapting or improvising imported products or raising productivity, developing novel solutions including new molecules, and consequently claiming patents and other IPs are a few examples of the R&D output of a company. Rarely would company R&D personnel publish research papers. Often it would be difficult to establish causal linkage between investment in R&D and the innovative output. Measuring investment in R&D as reported in accounting report therefore, remains often the only mode to apprehend R&D by a company. In fact output measurement often fails to indicate investment.

Modes of Innovative Undertaking

Public-private partnership in R&D is rather old in India. The ARAI, textiles group such as the ATIRA, CITRA have been working for decades under several types of mixed modes of governance structures including sometimes under cooperative mode, involving private companies and public R&D. Perhaps lack of strong interests has often weakened such partnerships. A recent initiative by the CSIR in this regard has been the NMITLI; similarly the DBT and other ministries have also taken initiatives on partnerships in R&D. Over the last few years, a few companies have floated foundations of R&D who in turn have sometimes located respective R&D centers in universities / IITs and similar places. However, public-guided cooperative research between competing companies on advanced areas has not been undertaken in the manner of the USA, France or Japan. This appears to be an important aspect requiring attention.

In recent years some companies especially from the drugs and pharmaceuticals sector have begun business in outsourced R&D (CROs) or outsourced R&D based manufacturing (CRAMs) or even value-add services closer to R&D such as in analytics, solutions, clinical research, and similar others. In manufacturing, several companies especially from the automobile and auto components sector have shared facilities and competencies to undertake joint product development with firms from other countries.

Features of Innovation

A typical Indian company will often have low cost strategy. Hence moving down the cost ladder could be part of the innovation. The present data set provides information on dimensions like license fees paid, royalty paid, foreign exchange earned through services, and similar others. Such data would provide insights into the technology acquisition strategies of companies which in turn would provide boosters to innovation.

Table 4-08.01: No. of companies reporting R&D expenditure

Year	R&D doing firms (No.)	Share of total listed Firms (%)	Sales turnover of R&D doing firms (Crore)	% share of all firms sales turnover
1995	853	15.84	261595	49.44
1996	917	16.32	352591	54.24
1997	1000	18.46	425988	59.30
1998	960	17.07	4518245	58.11
1999	970	15.46	499202	56.86
2000	932	13.70	587294	57.22
2001	928	13.45	715867	58.42
2002	1068	14.64	764001	58.62
2003	1105	13.11	862977	59.28
2004	1073	12.42	970177	56.75
2005	985	11.91	1201531	59.63

The structural dimensions of innovative changes in the economy could be looked at in three modes: (1) innovative behaviors of individual companies, (2) innovation in specific sectors of the economy as reflected through mostly the listed firms, (3) changes in inter sector structure brought about by innovative value adding activities. These three modes, in turn would provide scope for designing of innovation policy. Prowess database, that has been used here, provides firm-level data of large and medium Indian firms. The companies covered account for around 75% of all corporate taxes and over 95% of excise duty collected by the Government of India.

Indian Companies and R&D

The investment/expenditure on R&D by a company is the most important indicator of innovation – providing an eyehole peep into future directed efforts on new products/processes, new designs, novel solutions/discovery, new packaging, etc. or on improving the quality of the services or goods. However, as discussed above, R&D reporting entitles a company to saved taxes and most importantly extent and conversely spread/focus of R&D is an important signal to competitors and in particular R&D acts as a deterrent to entry.

The cyclic increase and fall in number of companies reporting R&D activity is given in Table 4-08.01. It is apparent that companies reporting R&D have under them most part of the market, close to 60%. However, number of companies undertaking R&D constitute a small portion, currently only about 12% down from the 1998 share of 17%.

The percentage of listed companies having R&D expenditure was highest in 1997 (18.46%) and lowest in 2005 (11.91%). The annual percentage change in the number of companies doing R&D shows a highly negative trend (Fig 4-08.01) except during 1999 and 2002. While the percentage of the companies investing in R&D is decreasing, their corresponding share of the total sales turnover is almost continuously increasing.

R&D expenditure at current prices had steady growth, and even taking care of inflation, the expenditure had steady growth. The average percentage of own sales turnover spent on own R&D figure rose almost steadily from about 0.21% in 1995 to about 0.30% in 2005. Observing sectors reporting R&D, is very revealing. The drugs and pharmaceuticals sector tops the list, rising steadily from 93 companies in the year 1995 to 112 in 2005. Other sectors exhibiting considerable interest and participation in R&D are dyes & pigments, fertilizers, generators transformers & switchgears, general purpose machinery and few more.

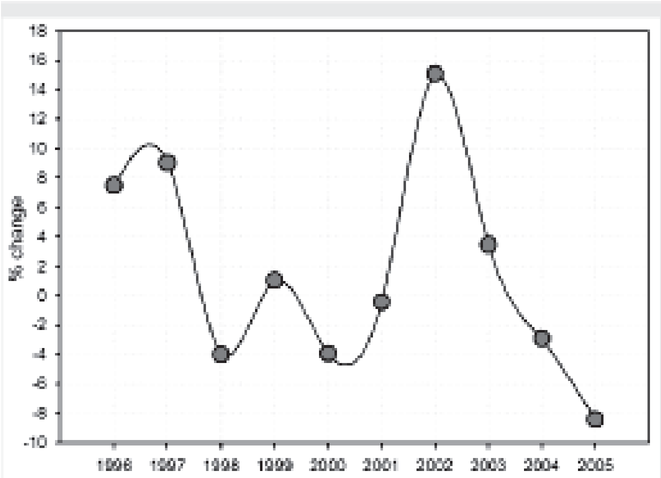


Fig 4-08.01: Trends in % change over previous year in numbers of companies doing R&D
Source: *Prowess database of the CMIE*

Knowledge acquisition, including licenses against payment, is an important dimension beyond R&D that needs a look. Among the R&D active companies, the percent increase in expenditure on R&D was much higher in the year 1998-99 than that in 2002. During the year in which there is a negative growth in R&D expenditure, there is corresponding increase in the expenditures in royalty, technical know-how and license fee paid (Fig 4-08.02). During 2000, R&D expenditure shows about 30% fall, while the expenditure in royalty, technical knowhow and license fee paid shows around 180%, 300% and 450% increase over the expenditure during 1999. There is a strong complementarity between knowhow import in both embedded and disembodied forms and R&D investment, the latter often follows the former.

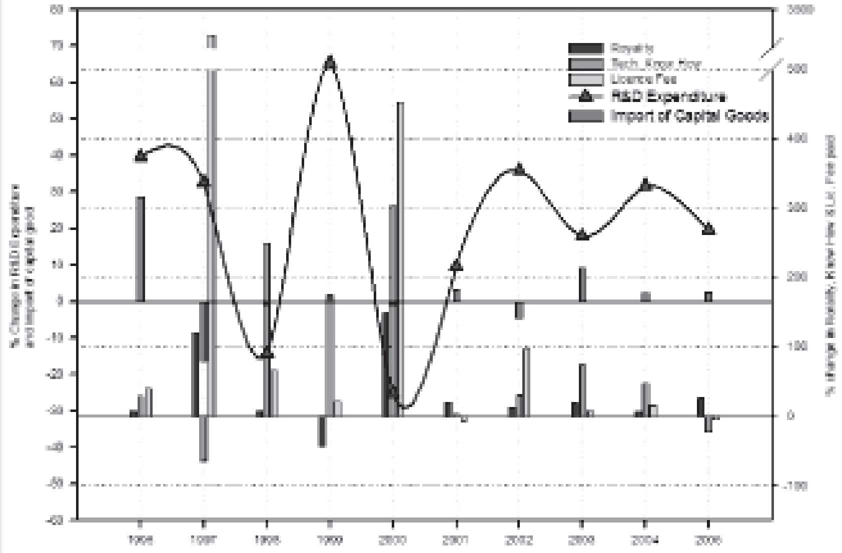


Fig 4-08.02: Trends in percentage changes in expenditure in non-R&D innovative parameters

Forex earning through export of goods would represent both capability to manufacture quality goods and the economy's global connectedness and both these are important aspects of a country's innovativeness. For both forex earning on services and goods the absolute values rose substantially in current prices. For a large number of companies and in particular drugs and pharmaceuticals, forex earning through services represent earning from contract research as well.

Inter-Sector Restructuring

A remarkable feature of innovation is that it is likely to lead to a structural shift both within a sector and among sectors. A very simple and non-robust method, adopted here, involves measuring the shift in a sector's share of sales in total sales (of all sectors under lens) over a ten year period. In terms of percentage share of total sales turn over the sectors: refinery, trading, steel and electricity generation remained the top four during 1995, as well as in 2005. The sectors which were among the top 10 contributing in 1995 but could not remain among the top 10 during 2005 are cement, diversified and cotton & blended yarn sectors (Table 4-08.02). The new entrants among the top 10 in 2005 are telecommunication services, computer software and automobile sectors.

Table 4-08.02: Best *(top 10)* industrial sectors in terms of % share of total sales turn over

Sector	1995 Share	Sector	2005 Share
Refinery	14.64	Refinery	20.97
Trading	8.59	Trading	9.32
Steel	6.47	Steel	6.03
Electricity generation	4.19	Electricity generation	4.58
Fertilizers	3.19	Telecom services	3.32
Crude oil & natural gas	2.76	Crude oil & natural gas	2.62
Cement	2.47	Computer software	2.32
Drugs & pharma	2.33	Drugs & pharma	2.05
Diversified	2.01	Fertilizers	1.99
Cotton & blended yarn	2.01	Automobile ancillaries	1.86

Source: *Prowess database of the CMIE*

Among the 10 least contributors of 1995, sectors like media broadcasting, ITES and media content have performed well and are out of the 'least 10' of 2005 and are replaced by the three sectors, namely other leather products, non-banking financial companies (NBFCs) and animation content provider (Table 4-08.03). It is worth mentioning here that sectors with reduced R&D expenditure (as % of sales turn over) have performed badly, a feature common to both top performing and least performing sectors.

Table 4-08.03: Least performing *(bottom 10)* sectors in terms of % share of total sales turn over

Sector	1995 Share	Sector	2005 Share
Tourism	0.011	Other leather products	0.021
Media-broadcasting	0.009	Railway transport	0.016
Irrigation	0.007	Tourism	0.015
Floriculture	0.005	Banking services	0.015
ITES	0.004	NBFCs	0.008
Brokers	0.001	Animation content	0.007
Media-content	0.001	Floriculture	0.003
Housing finance	0.001	Housing finance	0.002
Railway transport	0.000	Brokers	0.002
Banking services	0.000	Irrigation	0.001

Source: *Prowess database of the CMIE*

In terms of net difference in the percentage share of total sales turn over during 1995-2005, refinery sector retains the top position while the sector of electricity generation occupies the 10th position. This positioning is independent of the scale of contribution of a sector in the respective years. A quick review of the R&D expenditures of these sectors during these two periods partially confirms the hypothesis that sectors spending on R&D are likely to improve relative positions vis-à-vis other sectors.

Non-R&D Innovation and R&D in Select Industry Sectors based on Mostly Listed Companies

It makes sense to identify sectors that influence the trend of R&D expenditure in the overall industries. It was observed that the overall steep rise in industrial R&D expenditure during 1999 was largely due to the high expenditure in software R&D and the moderate growth in R&D expenditure during 2002 was largely contributed by the automobile sector (Fig 4-08.03).

All Manufacturing Industries: An overview of both R&D and non-R&D innovation by all listed companies cutting across sectors indicates that R&D spending as % of sales remained nearly indifferent over a decade and so have been all such payments as % of sales for knowledge, such as for royalty, licenses, knowhow (Fig 4-08.04). Though both forex earning as well as forex spending per unit of sales shows an increasing trend, the latter surpasses the former indicating increasing global dependence. Salaries per unit of sales are decreasing which indicates enhanced labor productivity as well as white collar productivity and a declining consumption of power per unit of sales implies improvement in energy efficiency.

Automobile industries: The most striking feature in this sector is the drastic increase in the number of companies paying royalty, license fee etc from mere four in 1995 to more than hundred during 2005. Consumption of power per unit of sales is decreasing indicating increasing energy efficiency. An increasing trend in both R&D expenses as well as royalty paid per unit of sales indicates emphasis on innovation.

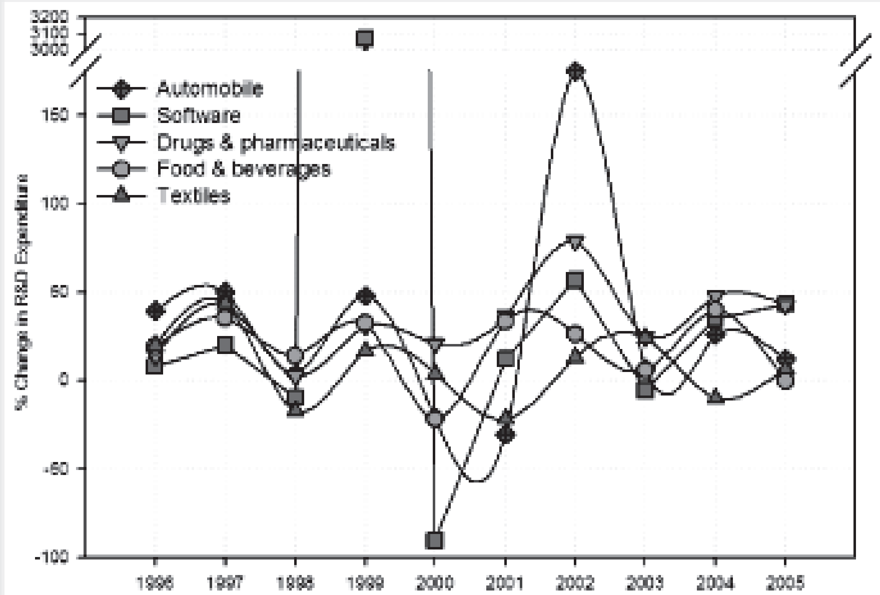


Fig 4-08.03: R&D expenditure by listed companies in selected sectors of manufacturing industries;
Source: *Prowess database of the CMIE*

The tough competition among the individual companies in the automobile sector is apparent from the highly fluctuating number of units in the top 10 per cent of turnover-based size, while the bottom 10 percent (though showing improvement) is almost steady.

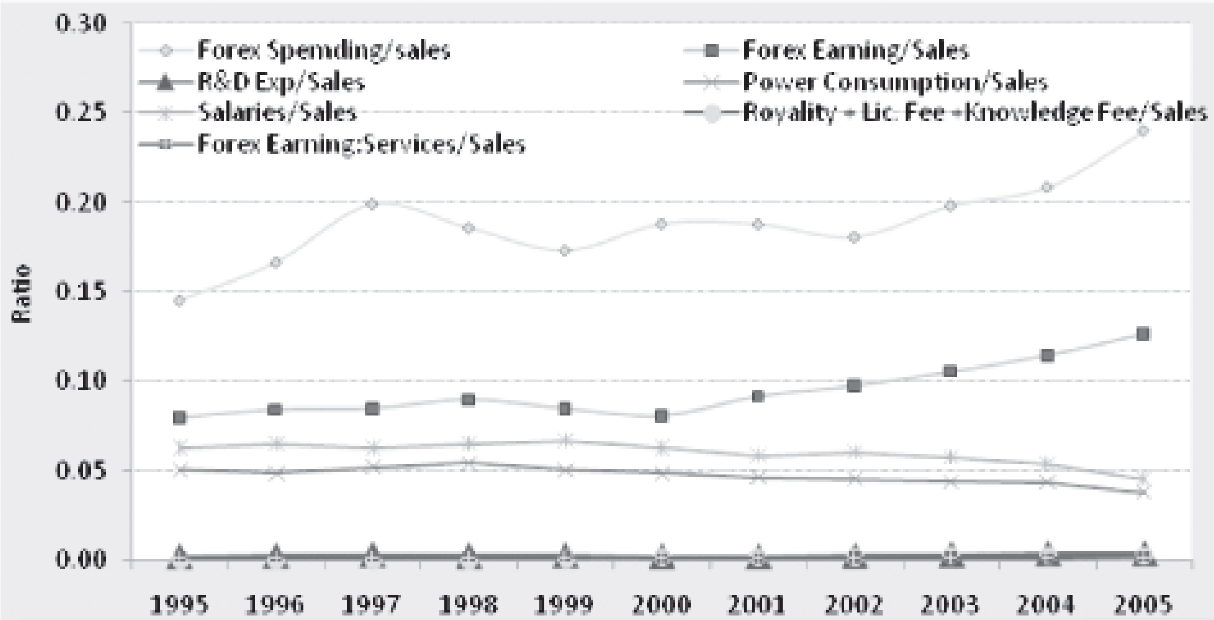


Fig 4-08.04: Indicators of innovation in the manufacturing industries in India
Source: *Prowess database of the CMIE*

Tool Manufacturing: Companies paying royalty, license fee etc show a drastic increase especially beginning 2000. And the number of companies earning from foreign exchange is also on the rise. Consumption of power per unit of sales is decreasing especially after 2001 indicating increased efficiency. This decreasing power consumption is accompanied by an increasing expenditure in R&D as well as in royalty, license fee etc.

Paper Industry: Till 1998 no paper company was paying royalty, license fee etc. Total forex expenditure per unit of sales has almost remained constant while forex earning per unit of sales is increasing, though it is slightly declining after 2003, indicating net increase in export. Power consumption per unit of sales is also declining which indicates improved efficiency. In this sector, R&D expenditure as well as royalty paid per unit of sales appears to be very negligible indicating lack of innovation.

Cement Sector: Number of companies paying royalty, license fee etc also shows an increasing trend. However, number of companies earning from foreign exchanges has slightly decreased over the same period. Consumption of power in the cement industry shows an increasing trend. There is no significant variation in R&D expenses per unit of sales. However, royalty paid per unit of sales shows a slight improvement especially after 1999.

Steel Sector: Only a few companies are involved in R&D. However, companies paying loyalty, license fee show an increasing trend. There is a declining trend in the consumption of power per unit of sales indicating more efficiency of the processes employed. There is no significant variation in the R&D expenditure per unit of sales.

Drug & Pharmaceutical Industries: Forex earnings in the drug and pharmaceutical sector have increased considerably while forex spending has remained almost constant during the period 1995-2005. However, in all the years, forex earning has been lower than forex spending. R&D expenditure is showing an increasing trend which indicates that the sector is investing in order to remain innovative.

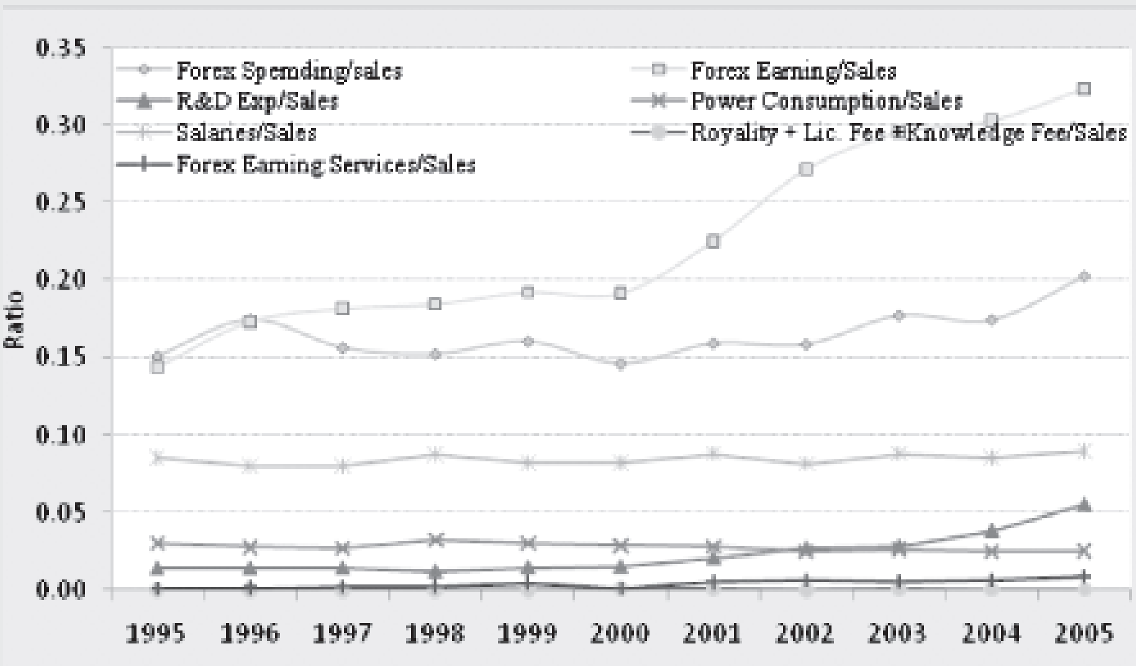


Fig 4-08.05: Indicators of innovation in the drug & pharma industries in India

Source: *Prowess database of the CMIE*

Forex earning indicates increasing outsourced R&D services to domestic firms. This therefore indicates enhanced R&D capability. Similarly, R&D expenses also exhibit an increasing trend from 2000 onwards. However, payment of royalty, license fee has remained almost negligible. Power consumption and salaries per unit of sales does not exhibit any significant variation over the period 1995-2005.

Trading Sector: In the trading sector, it is interesting to note that several companies are engaged in R&D though the number is showing a decreasing trend over the period 1995-2005. Even the number of companies paying royalty, license fee is also in the rise. In terms of per unit of sales, forex expenditure is comparatively higher than earning, though both exhibit an increasing trend. Power consumption per unit of sales is decreasing which indicates more efficiency. The declining trend of R&D expenses appears to be compensated by the steep rise in the amount of royalty paid per unit of sales especially beginning 2000.

Software Industries: Till 1998 very few companies in the software sector were into R&D related forex transactions. Beginning 1999 there is a sharp rise in their number which, however, again starts to decline from 2003. Nevertheless, the difference between the number of companies having forex earning and those having forex spending is very small. In fact, the trend is reversed since 2004; the number of companies spending on R&D is increasing. R&D expenditure and power consumption by software companies is almost constant.

Regional Performances: Sector-wise & based on Mostly Listed Companies

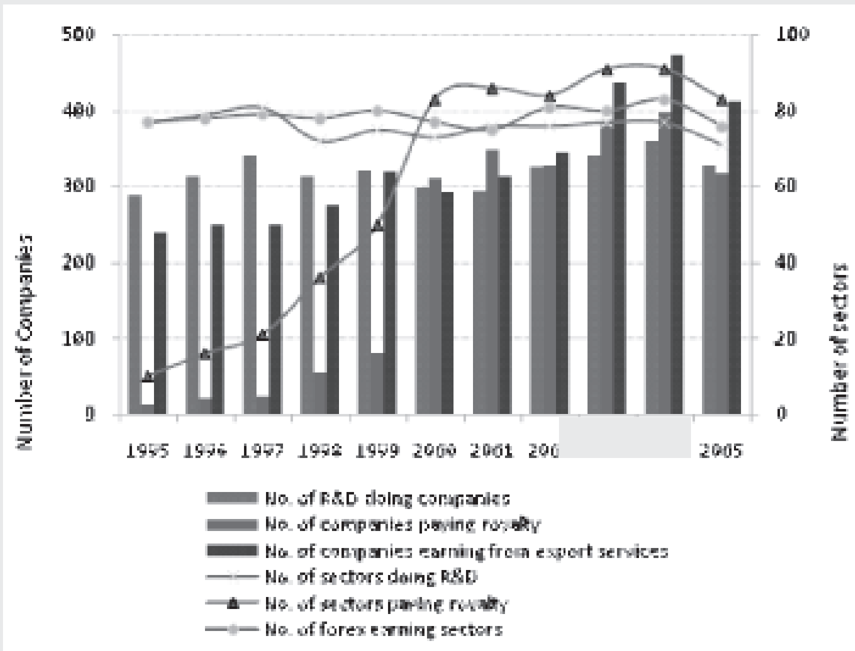


Fig 4-08.06: Status of the listed companies of Maharashtra in terms of R&D
Source: Prowess database of the CMIE

Regional, in particular, competition between several governance units of federal governmental set-up has proved strong influencing factor in many countries and competition between provincial states appears to be important in India as well. However, regional governments in countries such as China have exercised much higher degree of competitive autonomy resulting in both gains and perhaps distortions, especially in fiscal areas. Indian states enjoy relatively more restricted fiscal autonomy and little financial power.

Maharashtra: In Maharashtra, more and more companies are going for R&D and are increasingly paying royalty which probably led to a corresponding increase in the number of companies earning forex reserves from export services. The most spectacular increment is in the number of companies paying royalty (specially beginning 2000) and this is followed by the number of sectors covered by the above features. The point to be noticed here is that a downward trend in all the parameters is evident since 2004.

Maharashtra accounts for around 30% of the listed and other large companies in the country contributing about 39% of the national sales turn over from such companies and this share has been fairly constant throughout the period. The number of companies doing R&D has increased from 287 in 1995 to 327 in 2005, while the number of sectors covered by these companies has remained at 77 indicating more and more companies are opting for in-house R&D. The share of the R&D activity companies to total state companies, however, shows a declining trend but their share to total state sales turnover has increased from around 54% in 2005 to around 77% in 2005, which indicates increased productivity.

Tamil Nadu: In Tamil Nadu, the most spectacular improvement is in the areas of royalty payment. The number of enterprises has increased from mere 9 units in 1995 to 150 units 2005. The state is maintaining a constant share (11%) of the national companies and the state sales turn over accounts for around 7% of the

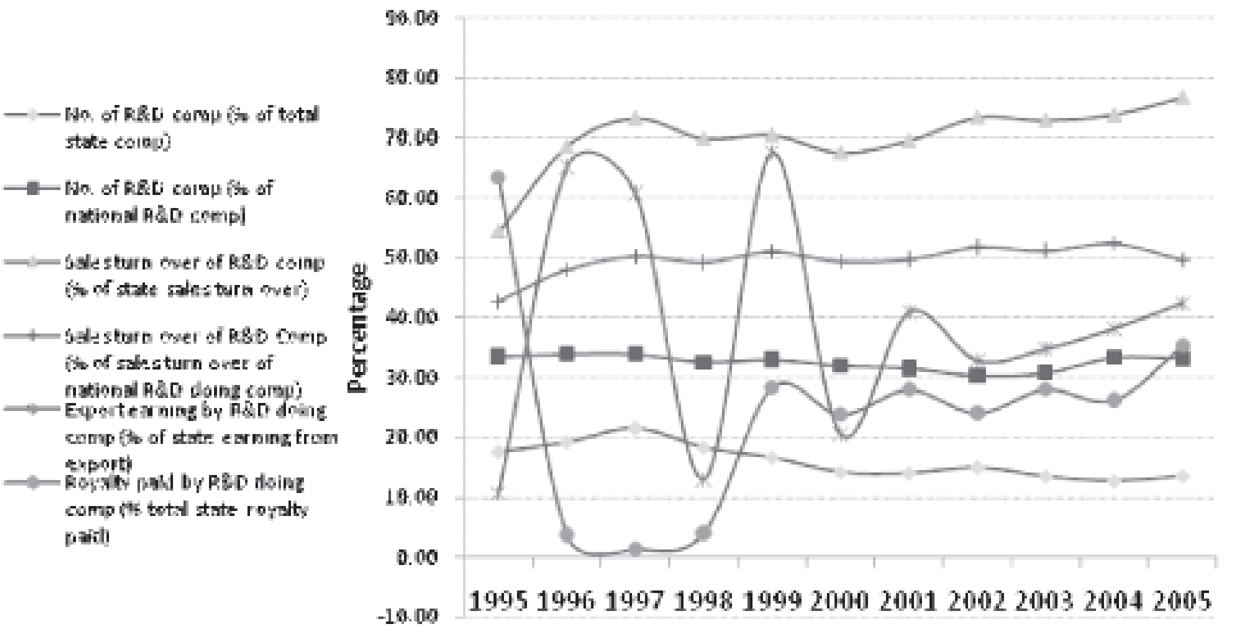


Fig 4-08.07: Trend of the R&D doing listed companies in Maharashtra

national sales turn over. Around 1.5% of the state's companies paid royalty during 1995 which increased to about 17% by 2005.

Gujarat: Strangely the number of companies engaging in R&D involved in Gujarat is decreasing. However, the number of companies earning from export services is showing an increasing trend, companies paying royalty show a sharp increase since 2000, that again started declining from 2004 but the number of sectors involved in royalty payment is declining. The share of companies paying royalty to total state companies paying royalty was only 0.35% during 1995 which increased drastically to as high as 8.75% during 2005.

Punjab: In Punjab, both the number of companies doing R&D as well as the number of companies earning from export of services is declining which is accompanied by corresponding decrease in the number of sectors covered under each parameter. However, the number of companies paying royalty has drastically increased from almost none in 1995 to more than 15 during 2005, accompanied by a corresponding increase in the number of sectors covered.

Micro, Small and Medium Enterprises of India: Innovation Status and State of Affairs

Overview

The Micro, Small and Medium Enterprises (MSMEs) segment of the Indian economy is vast, with largest number of enterprises, very large numbers employed, highly dynamic in terms of the entry of new entrepreneurs and the exit of a huge number of enterprises annually. Data from the Fourth Census is yet to be available. By 2001 this segment of Indian economy had employed 24.932 million persons in 10.521 million enterprises of which 5.808 million were rural and the rest urban, and mostly in non-metropolitan towns/peri-urban areas; and manufacturing sectors of the MSME enterprises were close to 40% of the total and the repairing and maintenance sector enterprises constituting another 16% with total MSME gross output for 2001-02 at Rs. 2,822 billion and export at Rs. 141.79 billion.

Industrial Organization in Tiny Sector

Despite the network linkages that an MSME unit enjoys often along value chains or despite the fact that a location has a mix of products, technologies and resources, there have been several locations of art genres or skill genres and sometimes of traditional product brands, such as the Chanderi. As for the registered clusters there are 1,223 clusters in 26 states covering 321 products with 16.99% of total gross output; Kerala had highest number of such clusters; and there are 819 clusters of unregistered units in 25 states covering 250 products and with a share of 34.63% of total gross output. Close to 95% of the output of this sector is for domestic consumption with one crucial constraint that only marginal amount of this 95% is consumed by the large enterprises in the factory sector. Only 2.98% of the units are ancillary to large enterprises and another small but unknown share would be fed into the logistics chains of large enterprises. However, as the NSSO data suggests, these units often survive on the network relations governed by traditional master skill persons or master traders. The large corporate sector is virtually absent in the governance of these MSME units.

Public Procurement for MSME

There is another potentially very large market – that of public procurement. The registered units enjoy, under the current system, the facility of bidding for public procurement under NSIC based registration that entitles them for DGS&D equivalence. However, the bids would be for standards set at DGSD where the NSIC registered units have little voice and the bids would be competing with imports and outputs from the large sector. This Third Census revealed that only 2.27% of units had registered for NSIC. Amongst the states Punjab, Haryana, Rajasthan, Uttar Pradesh, Gujarat, Andhra Pradesh (the largest number), Kerala and Tamil Nadu had each no less than 5,000 such units registered with the NSIC. Volume of public procurement through NSIC/DGS&D route has been meager, resulting in a weak and unattractive signal to MSME units, who mostly therefore cannot depend upon public procurement. In turn, perhaps the most important route of enforcing technological changes and innovation, through public procurement based upon standards, remained inoperative.

Rural inputs into MSME

Rising energy bill with decline in investment in machineries indicates decline in general technological changes in these sectors. General trend in MSME seems to indicate weakening of input ties with agriculture, strengthening of inputs from urban industries, however, strengthening of MSME output to rural areas along with continuation of dependence on traditional credit circuit. Weakened (as reflected in lower value of factor) inputs from agriculture might indicate general weakening of materials-flow network between the MSME and the agriculture and is a matter of serious concern. This might also indicate lowered relative prices of inputs from rural milieu, indicative of lower technological changes in agriculture and allied sectors. The agricultural input then might be drawn from local unorganized markets or from networks of input providing wholesalers/ large traders through non-price transactions. In parallel, the relative rise in values of several types of feedstock or inputs from industry reflects both advancing integration with the industrial system for inputs (in comparison with inputs from agricultural system) and relative technical stagnation vis-à-vis large industries. The other input, the financing, also appears to be drawn, as NSSO rounds suggest, mostly from the traditional circuit of master traders/wholesalers. The Third Census on MSME reports that about 7.39% of the units in the total SSI sector had outstanding loans as on 2002, with registered sector of the SSI's outstanding at 20.1% of all units and for unregistered sector at 5.48% only. Out of this outstanding loan, institutional loans constituted only about 4.55%. This Census also reported that the surveyed units reported acute problems in securing working capital. The rate of outstanding loan or of default therefore will be very close to the share of total units under MSME group availing of loans from institutional sources. This share therefore is unlikely to be more than 10% or 15%; the rest of the units would arrange capital from family sources or from the network of master traders/ wholesalers *et al.*

Sustainability of MSME Enterprise

A striking feature nonetheless of the MSME is the sustainability of business models – about 32.35% of units have survived for about two decades, 1.22% survived for five decades or more, about 11.21% of units for about twenty five years and similarly. However, the growth story is dismal. Even hundred years old firms exist at nearly the same volume of gross output as was a century back. There are only few cases of MSME becoming large and super large. It appears the institutional backup and also the backup from organized market of finance is missing. Very quick growth based on novel innovation and technology has remained extremely scarce. MSME appears to be the backyard; with plants and machineries often very old and nearly never replaced; the units survive on old technologies, skills, low wages and perhaps locked-up markets. There are close to 451 units with plants and machineries as old as 100 years, again about 4,100 units with about 80 years old, or about 8,588 units with about 60 years old, or 15,992 units with more than 40 years old machinery and plants. About 36% of the currently working plants and machinery were installed during the 1970s and 1980s; and 56.36% units installed machineries during the 1990s. However, given the fact that three out of four units had original value of plants and machineries at below Rs. 0.1 million, new entrants over the last one decade had fixed investment in plants and machineries as low as in the previous decades – it might be inferred that large number of newly installed plants and machineries were second hand or even old vintages.

Know-how and Knowledge Flows for MSME

Nevertheless, a large number of units procure assistance of knowledge and competence that adapt to old machines and methods, perhaps from outside sources. Through the traditional circuit the network aggregators such as the master traders or crafts-persons or wholesalers, provide both tangible and intangible (such as designs, colors, methods, products even skills in cases) resources at local market transaction rates. Maharashtra, Manipur, Sikkim and Dadra & Nagar Haveli exhibit fairly large number of registered SSI units securing technical know-how from domestic R&D units or from special agencies; while Uttar Pradesh, Rajasthan, Punjab, Bihar, West Bengal, Gujarat, Karnataka, Tamil Nadu et al exhibit very low percentages of units securing such know-how from the R&D/ special agencies. Such SSI units secure know-how from three sources: abroad (presumably the output market aggregator abroad); domestic collaborating company (presumably in the logistics chain or the parent aggregator); and the domestic R&D or special agency presumably under public sector.

Entrepreneurship in Non Hi-tech MSME

This is perhaps the only segment of economy with such huge population of risk taking entrepreneurs entering the fray annually; during 1980-84 period 0.1622 million or more entrepreneurs started up, during 1985-90 similarly 0.3247 million or more and during 1991-96 period 0.4215 million or more entrepreneurs started up new ventures. Most entrepreneurs started up on the existing lines of business perhaps more because the entrepreneurs did not have access to knowledge of any new business/ product/technology and less because these starters were risk averse. The 1990s experienced a departure from previous decades through continuous liberalization and de-reservation of the SSI sector, however, the structural pattern of MSME distribution over several NIC codes of enterprises during the two decades of 1980s and 1990s and all over India exhibit nearly no structural shift (especially) towards higher value adding or technology intensive sectors or occupations. Further, in a few states, such as in Tamil Nadu which otherwise experienced large growth of automobiles and related transports/components under the ASI-factory sectors in 1990s, experienced during the same period a structural shift in MSME towards services and away from metal fabrication or metal based products. Simultaneously, units exited business. Exiting old business happened from the same districts where new units appeared. But, exits failed to send strong signals of despair. Table 4-09.01 exhibits a few figures on annual exits in terms of percentage of incumbent units. No other segments of factory sector or large sector of Indian economy experienced this entrepreneurial phenomenon and at such large volumes. One might wonder how often locations/states with more advanced large factory sectors exhibited larger incidences of MSME exit or sickness. For example, Delhi rural has 56.76% and urban has 53.09% registered SSI units closed, or Punjab rural has 52.79% and urban has 57.45% of registered SSI units closed, or Tamil Nadu rural has 35.08% and urban has 43.67%, similarly Maharashtra rural has 37.06% and urban has 40.11% units closed; however, Bihar rural has 27.70% and urban has 28.65% units closed. Exception is Gujarat rural with only 15.37% and urban 24.62% units closed. The backyard of large-scale factory sector has in general experienced increased closure/exit, which however, could not deter willing entrepreneurs from setting up new enterprises.

Table 4-09.01 : Distribution of closed MSME units by the year of closure						
Year	**Up to 1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Percentage of closed units	12.97	4.27	3.20	4.25	7.99	8.85
Year	1997	1998	1999	2000	2001	Not recorded
Percentage of closed units	10.39	14.17	13.67	11.25	2.97	5.52
Source: *Final Results, as above*						

Innovation & Technological Change Agency: Governance and Monitoring

Based upon learning from this above on who could be the driver of innovation and technological changes and who could monitor, support and govern such changes - a summary of the above learning informs us that:

1. Large corporate or large factory sector has insignificant role in governance and large sector cannot perhaps be the driver of change.

2. Both input driven and output demanded routes of changes are important, however, current arms length relations between large factories and MSME segments render the factor prices of changed inputs or outputs prohibitively expensive, which in turn cause MSME exit and disallow governance and change-agency to the large segment (given no appreciable investment or induction of new technology in MSME through large sector).

3. Institutional/bank based governance including monitoring has been close to a non-starter and such monitoring has remained very costly; as a result and unless current modes of monitoring or disbursals are completely changed governance through this mode would appear in fructuous.

4. Traditional circuits/networks of input and output who have retained, notwithstanding de-recognition and de-legitimating policies, very pervasive yet no longer very-strong ties with large part of the MSME, have limited financial wherewithal and rather old knowledge on products, technological inputs, innovation and growth possibilities, and management skills. However, these traditional networks have the most intimate and low-cost access to information and can monitor intensively at the least cost, and more importantly they appear to be very entrepreneurial. All this would suggest that policy based input/output provisioning through this circuit along with the modernization of this circuit could be very promising; for example, no stock exchange for the MSME could function without the monitoring and rating functions being undertaken by them.

5. Bridge R&D and especially development organizations of several social sector ministries under both the central and state governments (whose numbers are in thousands), have often been relegated to being philanthropic suppliers of advanced inputs without being empowered to govern and monitor and without fund allocation jurisdiction. In fact, often bridge R&D organizations have been bypassed and funds are channeled through non-governmental organizations (NGO). Most importantly, inputs for innovation and technological change could flow from such bridge organizations through the traditional networks more effectively than currently prevailing. A model of innovation-governance that is only germinal now, informs us: a mixed executive & market mode of governance involving bridge R&D organizations as advanced inputs/standards provider and/along with the bank and traditional network as the monitor and/or input/output providers, could be the answer.

6. Local executives at both line ministry levels, especially the District Industry Centers, and the district magistrate/commissioners levels often have only partial/ truncated jurisdiction over one or a few dimensions of MSME governance. The MSMEs cater to both local and supra-local or global markets. A model of local-government based governance of MSME but with competition between local governments encouraged through empowering those governments by way of funds transfer, say through the Finance Commission, and through empowering them to issue bonds or charge taxes (lessons from China could be important here - the JNUURM has limited scope in this regard) could be another alternative (its germinal is present).

7. Cluster based approach has been adopted by several ministries and the UNIDO, and there are multiple definitions and counting of clusters. However, clusters approach negates local diversity, the channel of network, the random entrepreneurial distribution, skill pools and pools of other knowledge and resources among others; more importantly – cluster does not appear to be the unit of governance. Only a handful of cluster-inhabitants succeed and perhaps such successful entrepreneurs cannot provide leadership to others in the same product category and within the same cluster.

8. Several other modes of quasi-governance often in public-private modes, such as through Commodity Boards, Commissioners, trade associations or a group of regional MSME units along with public R&D agencies have been providing important knowledge inputs, sometimes even standards or best practices, to the MSME. However, very often there has been a delink between transactions in knowhow on the one hand and fund or other inputs provisioning or even of provisioning of market/aggregation on the other hand resulting in voluntary transactions of discrete kind.

Governance and monitoring provides teeth to leverage and thus technological changes happen (including improvements in quality/productivity). Innovations (including prototyping, etc.) are hastened under governance constraints.

MSMEs: Introduction

Small and Medium Enterprises (MSMEs) have a significant role in the Indian economy in terms of output, employment generation, export etc. If we compare the MSME industry with big industries some interesting facts could be found out. As per the third census of MSME, the employment-investment ratio is about seven times for MSMEs compared to big ones. And investment-output ratio is better for MSME industry.

However, 3rd MSME census was carried out using older definitions prevailing during 2001-02. Number of MSMEs, according to new definition gets enlarged to approximately 13 million. Out of the total labor force, 30 million are employed in this sector and it generates 40% of India's total export. Its share in GDP stands at 8-9%. Total annual credit flow to the Indian MSMEs adds up to $12.0 billion.

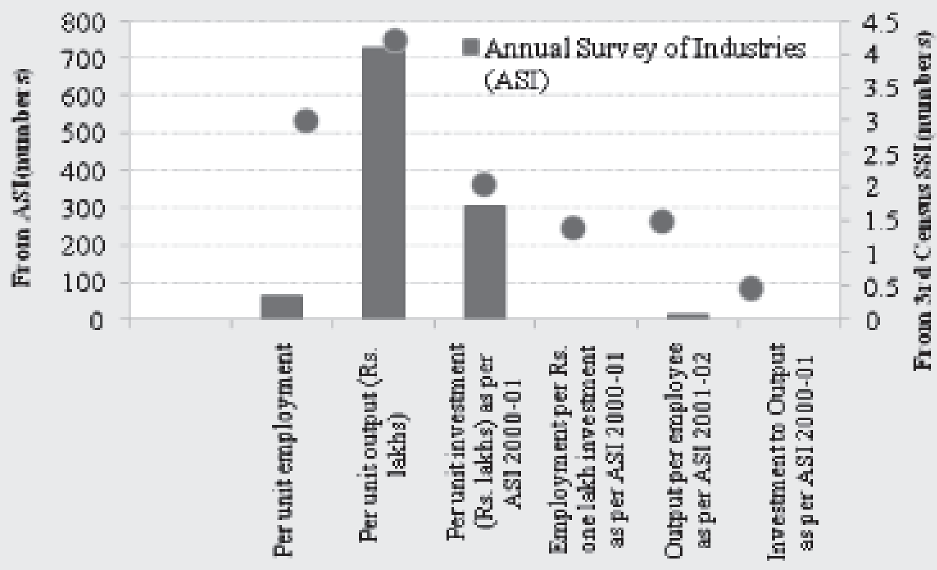


Fig 4-09.01: Comparison between MSME and ASI listed large industry
Source: *http://ssrn.com/abstract=1284892, working paper series*

Table 4-09.02: Classification of Enterprises into Different Categories (New Definitions) (effective from 2 October 2006)

Classification	Investment Ceiling (excluding land and building)	
	Manufacturing	*Service*
Micro	Up to Rs25 lakh	Up to Rs 10 lakh
Small	Between 25 lakh to Rs 5 crores	Between Rs 10 lakh to RS 2 crores
Medium	Between Rs 5 crores to 10 crores	Between Rs 2 crores to Rs 5 crores

Source: *DC(MSME)*

Table 4-09.03: Classification of Enterprises into Different Categories (Old Definitions)

Classification	Investment Ceiling (excluding land and building)	
	Manufacturing	*Service*
Micro	Up to 25 lakh	Up to Rs 10 lakh
Small	Between Rs 25 lakh to 1 Crore	
Medium	Not defined	Not Defined

Source: *DC(MSME)*

Entrepreneurship in MSME

Entrepreneurship is exhibited in the number of new units set up. A unit may introduce new products or services or may add value by copying old products or services. Table 4-09.02 exhibits the volume of setting up of new enterprises in MSME. Such new units indicate emergence often of new entrepreneurs. As per the MSME 3rd census the net of entry and exit, generation of new MSME units was positive during the years 1992-1996 whereas the trend became negative after 1996, the ratio of new units (according to initial year of production) to closed units was almost 3:2, whereas the reverse happened after 1996 and the ratio was also almost reciprocal. After economic liberalization in 1991 the entry of new entrepreneurs boomed. But after 1998 the rate slowed down due to industrial credit crunch. The industry wise trends for generation of new entrepreneurs in rural and urban India, for the pre and post economic liberalization periods are almost the same for service, manufacturing and repairing based industries.

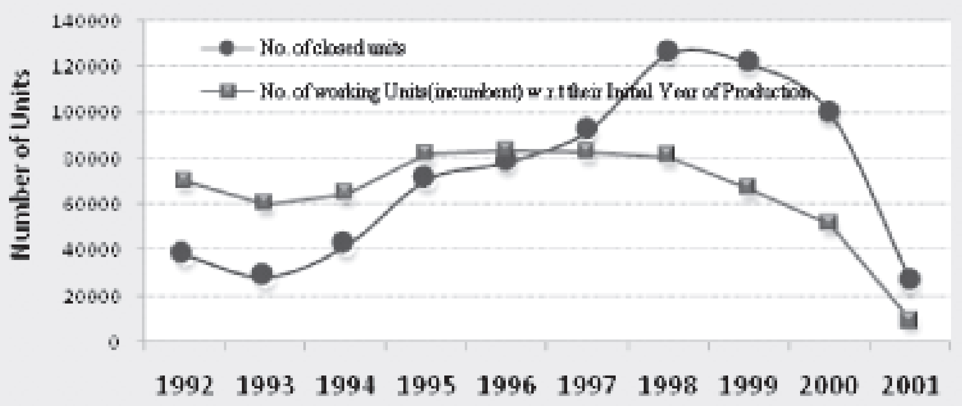


Fig 4-09.02: Generation of new entrepreneurs (Registered units)

Source: MSME third census

Ancillarization of MSME Units in India

About 98% of MSME units in India have almost no relation with big industries or channel partners. So, ancillarization part of Indian MSME is very small. The indicative figures show the share of number of units of different sector viz. manufacturing, repairing and services in MSME industry over pre and post liberalization periods for rural India.

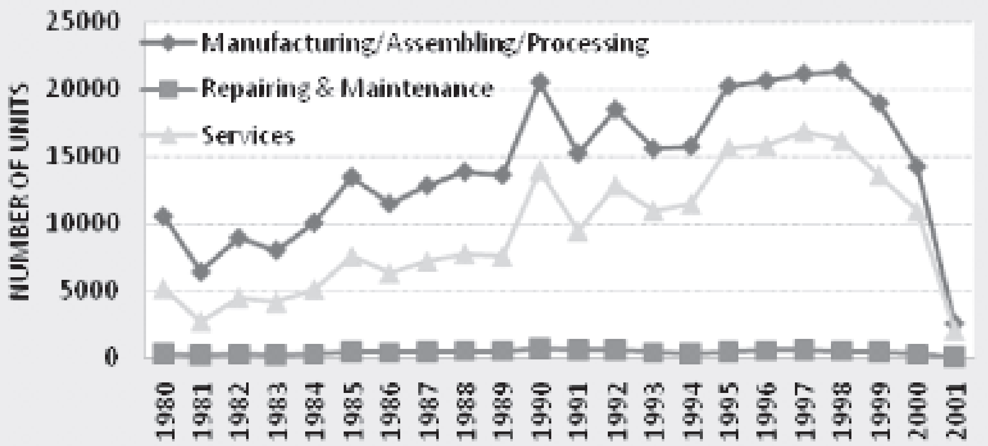


Fig 4-09.03: Non ancillary units (trend in rural India w.r.t initial year of production in terms of number of units)

Source: MSME 3rd Census

It is observed that almost the entire sector (85-86%) uses traditional knowledge in its production units, domestic R&D organizations have a meager share in provisioning of knowledge, only about 5-7% of the technical knowledge transactions are with public R&D.

Skill-pull in Indian MSME

Most MSME units appear to employ workers for the entire year, however, the seasonal MSME units resort to a skill pool. Those who are employed for year-long do not enjoy although job security. Such workers too join the pool. Workers in such a pool often enjoy multiple skills and job switch and occupation switch happens frequently. A skill pool indicates both low levels of skill requirement by MSME production system and presence of multi-skilled dexterous workers. The rural and urban skill pools appear to share similarities. Migration of workers is not reported to be very common.

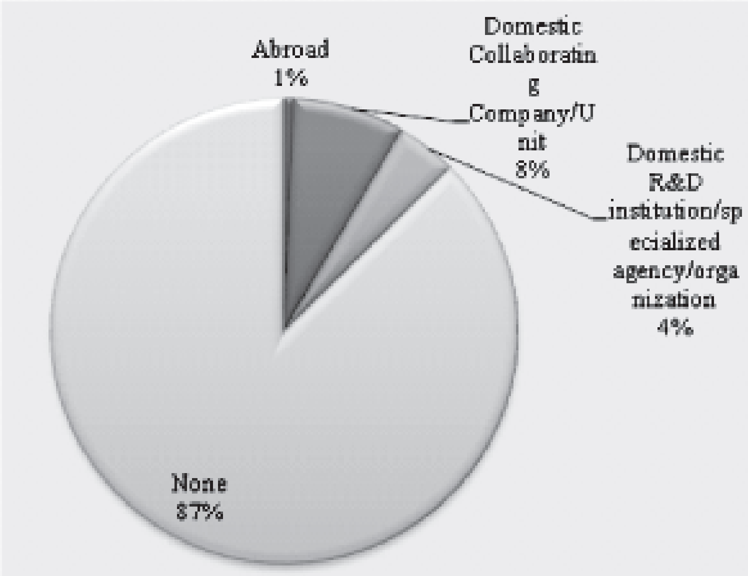


Fig 4-09.04: Preliberalization: Non ancillary manufacturing units
Source :MSME 3rd Census

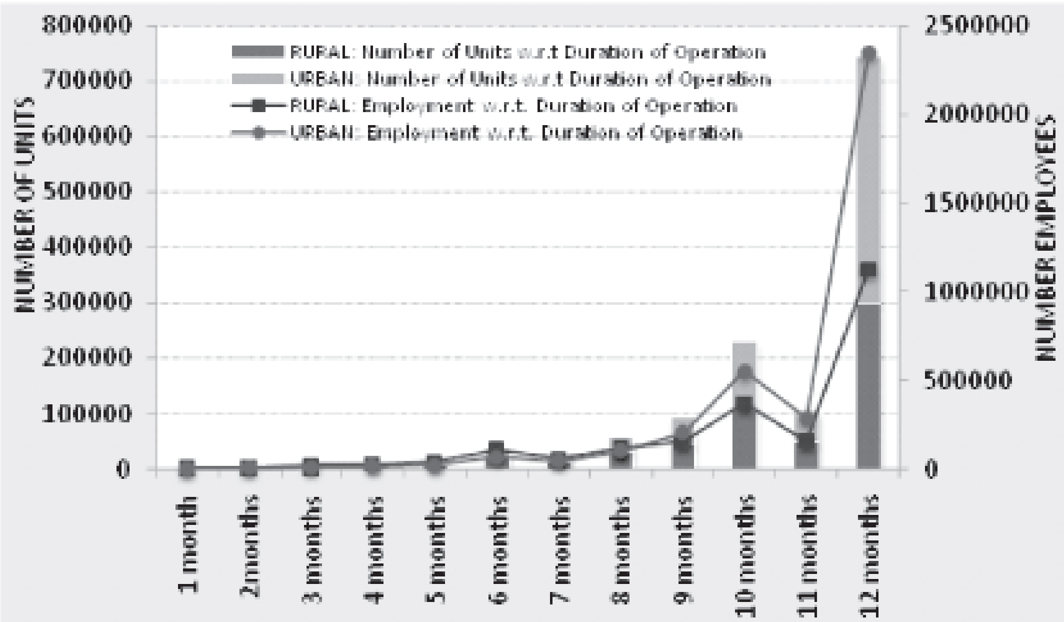


Fig 4-09.05: Skill Pull in India w.r.t operation duration of the unit through out the year
Source: MSME third census

MSME units are distributed over villages and small towns and over the large metropolitan cities. The spatial dimension of industrialization and competition as well as cooperation suggests the hypothesis that a city and the large industries there, would act as the magnet polarizing and catalyzing growth of mushrooming small units in the hinterland districts. Some of the cities selected for investigation into this hypothesis are Agra, Pune, Chennai, Gurgaon and Surat.

Manufacturing, repairing and service sector MSME units reportedly use traditional knowledge as their source of technological resource. The MSME census and other data from ASI suggests that in most cities, all industries e.g. manufacturing, repairing and service sector industries depend primarily on traditional knowledge as their technology source. The involvement of domestic R&D institution/ companies in transactions of knowledge and other factors has increased in post liberalization period.

In Agra there is an incremental change in food & beverage, textiles & apparel industries;

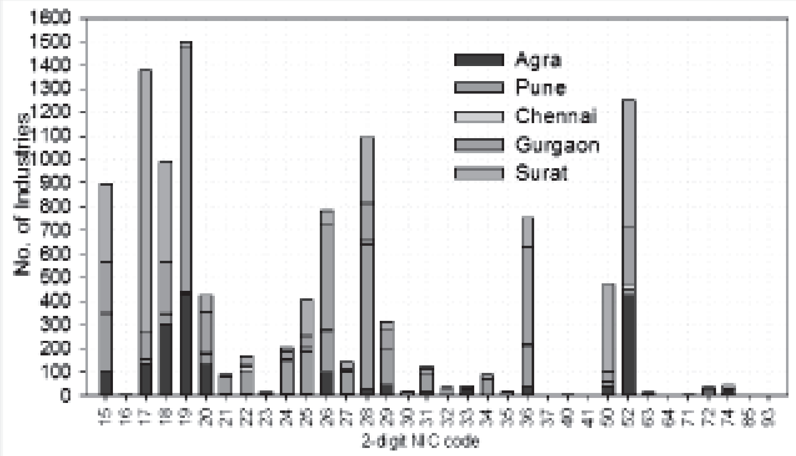


Fig 4-09.06: No. of different industries in selected cities
Source: *3rd Census MSME*

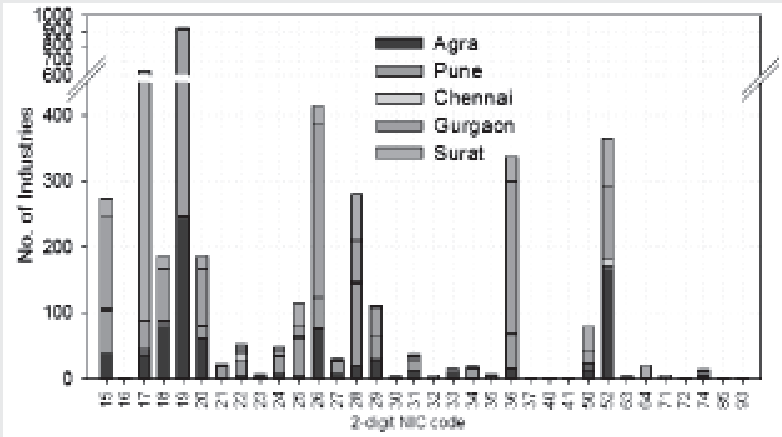


Fig 4-09.07: No. of different industries in selected cities in pre-liberalization period (1990-1990)
Source: *3rd Census MSME for small and micro industries and ASI data for large industries*

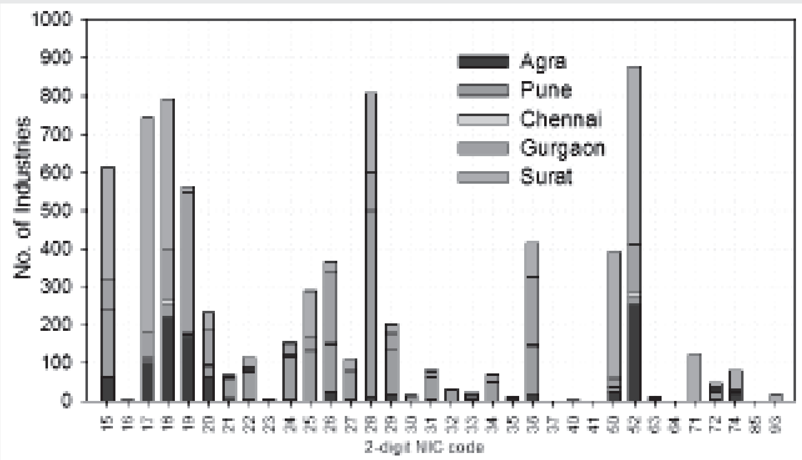


Fig 4-09.08: No. of different industries in selected cities in post liberalization period (1991-2001)
Source: *3rd Census MSME for small and micro industries and ASI data for large industries*

whereas negative growth has been witnessed in non-metallic mineral product and machine equipment manufacturing industries. MSME in Agra is dominated by 18, 26 and 52 NIC-codes while large industries in UP are dominated by 15, 17, 24, 26, 28, and 31 NIC-codes. There is a marginal structural change in MSME of Agra over pre and post-liberalization period. Pune is the prominent industrial city of India in the state of Maharashtra. It has advanced manufacturing industries. Number of repairing and service MSME industries increased in post liberalization period, while Pune is known for its large manufacturing enterprises. In Pune the supply-linkage between MSME units and large industries appears to be weak. For Chennai, incremental growth trend is observable in textiles, machine equipment and chemical industries. There is a stronger structural change in MSME in Chennai in post-liberalization period. At Gurgaon, there is a positive change in fabricated metal products, except for machinery and equipments and retail industry segments. There is little linkage between large scale industrial sector of Haryana and MSME of Gurgaon Huge growth in service sector and very moderate growth in the manufacturing industries in rural area of Surat is observed. Growth in all the sectors in Surat over the pre and post-economic liberalization periods is noticeable. In rural areas of Surat, the emerging sectors are food & beverage industries, wearing apparel and dressing material industries, industries based on rubber and plastic products, maintenance of motor-vehicles, and household-service sector in post-liberalization period. There appears to be little supply/manufacturing relation between the two segments, the MSME and the ASI-represented large factories in Surat.

From the above discussion it is clear that in the major industry-oriented cities, MSME units lacked knowledge support from the public/private R&D agencies/institutions and they do not have direct supply or support linkage with large industries.

Non-R&D Innovation in Indian Organized Factory Enterprises

Innovation in Organized Sector

The system of organized business enterprise is amongst the important actors of the national innovation system. Given the wide variations in ownership, size, nature of competition, there would be similar differences in the depth and types of innovative activities. The economic dynamics of this group of enterprises is very diverse, allowing investigation into changes happening beyond an individual enterprise. For instance, within the manufacturing group of relatively large enterprises, changes towards improved performances that could be described as innovative can be portrayed at three levels of (1) units (2) sector and (3) inter sector. All the 3 levels of innovation have dissimilar inputs and those at sector and inter sector levels are often macro in nature, flowing out of public policies.

Policy Targets for Innovation

Looking at and limiting innovations to the unit level would negate the scope for optimum achievement possible as a consequence of the innovation. Policies should therefore be designed for systemic changes, including system governance. Gains through policies could similarly be measured at the system i.e. sector or inter sector levels. Further, innovation in one enterprise/sector is influenced by plethora of economic policies and therefore we need to look beyond policies relating to promotion of R&D alone. Tax concessions on R&D expenses might incentivize enhanced reporting on R&D. Contrarily, non-R&D innovation when happening at enterprise level might not get reported. Typically policies relating to non-R&D innovation during pre-liberalization phase addressed exemptions in customs duty, depreciation and investment allowance and weighted tax deduction for using/commercializing technologies developed domestically. The post-liberalization phase extended benefits such as duty free imports or depreciation allowance for technologies developed in domestic entities.

Innovation Policy Types

In short, the governance mechanism during the later phase embraced two modes – the executive based and executive monitored instruments of taxation (and likes, broadly under fiscal category), and the second mode being fund based or bank based and bank monitored fund. Deployment of funds for promoting innovation or for creating markets for innovative products is also critical. Another related set of policies could be described under broadening and deepening of market. As much of R&D relates to corporate policies on barriers to entry and collusion, the competitive aspects of corporate non-R&D innovation assume larger significance especially for a country such as India facing both dumping and liberalized import. Other policies under market dimension, such as the Electricity Act or the recent Warehousing (Development & Regulation) Act 2007 – belong to non-fiscal often legal market development sets of pro-innovation instruments and institutions.

Both market related and bank related sets of policies appear to be more important for two robust reasons: (1) fiscal types of policies as experience shows could not often match expectations, and (2) fiscal related instruments might be more incumbent friendly hence less restructuring. A related but important issue is that a legal instrument frees governance structures and therefore helps generate non-executive modes of governance of innovation. Advantage of legal policies is that agency of innovation then shifts to institution.

Policy and Governance of Innovative Changes

Management of the process of change is the next important aspect. Governance of innovation can be classified in to three broad types: (a) executive based, (b) bank based, and (c) market based. Several countries have followed a mix of two types of policies. Governance of the innovative transition assumes crucial importance when we talk about normative policies/interventions especially by public agencies. Indian policies in the pre-liberalisation phase have been predominantly executive-based, while in the post-liberalization phase we observe minor influence of bank based policies although the dominance of executive based policies has continued. Market based governance appears to have insignificant influence on innovation outcome.

Further, several units and in a few cases respective associations of enterprises have been having transactions with public R&D systems and the university systems for knowledge and capacity building. Systemic knowledge, the social flow of skill and the abundance of skill pools are major factors in the system of innovation; but this is different from the agency of the executive. Therefore we can add a fourth type of governance - the social knowledge based governance.

Innovation Policy Schematic

We may for the convenience of description devise a simple schema of policy types. The first tier might be described in terms of governance as above. The second tier could be policies classified under fiscal, fund, infrastructure, managerial, legal, and asset-based. Fiscal includes tax and similar; fund includes bank based and similar; infrastructure includes cluster, S&T parks or public R&D lab/training; managerial includes handholding, VC manager; legal includes laws relating to company, patents, competition; and asset includes an item with future exchange value like a patent. There could be a third tier to indicate the target of the policy. This tier could have unit enterprise, sector, inter-sector, and finally institution.

Nature of Innovative Changes

Innovativeness of enterprises gets reflected through a range of parameters from cost containment to hastened import of embedded knowledge. This section looks at the larger picture of innovative improvements, mainly in terms of cost containments. Another dimension of the outcome of innovation is changes in inter sector input-output relations or structural balances, and such a picture presents us a broad picture of the directions of the economy. In this section, we will provide an indicative pointer towards the direction of innovation in the economy. A few sectors of crucial importance to higher value addition in the entire economy, such as machine tools, transport equipments, other machineries would be specially picked up to observe whether their intensive or larger use brought about inter sector restructuring towards higher value addition.

A description of this large group is best afforded by the data from the Annual Survey of Industries (ASI) series. The data is non-accounting and is on organized manufacturing factory sectors classified according to the NIC.

Innovation Patterns in Organized Factory-based Enterprises

Industrial sector is a major contributor to the growth of Indian economy which grew by more than 9% during 2005-08. Innovation has been one of the most important factors in growth of the Indian economy. However, over emphasis on R&D has somewhat shadowed the important gains in enterprise performances achieved through non-R&D investments or innovative activities. This scrutiny tries to realize the pattern of non-R&D based innovation in the organized manufacturing.

Innovation trends in select sectors of industry that are generic, technology intensive would hold higher promises than innovation in other sectors. Accordingly we captured the pattern of innovation in selected sectors – Manufacturing, Automobiles, Leather, Electronics and Computers, Small Electronics Equipment, Tools Manufacturing, and Processed Food Industries.

Cost containment is perhaps the principal feature of innovation in Indian industry. Other aspects like development of new products or entering new markets are important as well although from the present data we cannot infer anything about these other features. Following parameters were taken into consideration to study cost cutting innovation patterns in the industry: fixed capital, total emoluments, fuel consumed, material consumed, and total stock.

Ratio of these parameters with respect to 'value of output' and 'net value added' when calculated, exhibits several modes of cost cutting. A lower value of the ratio indicates consumption of fewer resources to achieve one unit of output or net value added. These ratios were calculated on aggregate basis for the selected sectors.

Innovation in Total Manufacturing Industries

In the post liberalization period, the number of unit enterprises increased from 1,10,179 in 1990-91 to 1,36,353 in 2004-05 with an Average Annual Growth Rate (AAGR) of 1.62 per cent. Fixed as well as the invested capital grew by around 11 per cent per annum, net income and gross capital formation by around 15 per cent or gross fixed capital formation by about 14 per cent. Overall, the intensity of capital use increased significantly. Labor productivity in the overall factory based manufacturing too grew. However the disconcerting aspect was very high growth of addition to stocks which would indicate higher gross delink; inter-sector or inter-factory.

There has been a drastic improvement in the performances of the Indian industries during the period 1990-91 to 2004-05. Parameters related to manpower such as workers per enterprise, employees per enterprise and total persons engaged per enterprise are showing a declining trend (Table 4-10.01) which actually is an indication of increase in labor productivity. Improvement in performance happens owing both to increased labor productivity and improvements in managerial functioning. The latter is evidenced further in the increased wages and increased emoluments per factory. In fact, this increase indicates that skill/knowledge level in use by a factory has increased significantly. Increase in gross fixed capital formation per factory exhibits increased use of advanced and recent machineries.

An increasing trend for material consumed with respect to 'Net value added' indicates more material is being consumed to achieve addition of value to one unit of output, a trend perhaps not welcome; however, it could contrarily indicate increased commodity prices and hence might not indicate increased consumption of material weights/quantities (Fig 4-10.01). However, the increase in stocks are perhaps owing to unsold stocks failing to add value In other words, stocks per value added could be considered a macro or systemic indicator of innovation. For fixed capital with respect to 'Value of output' and 'net value added', under the condition of enhanced capital stock - a declining trend in the ratio could represent increase in innovation because of enhanced capital productivity.

Table 4-10.01: Performances of industry between 1990-91 and 2004-05

Parameter	% change over 90-91
Number of factories	23.76
Workers per Factory	-15.45
Employees per Factory	-17.01
Persons engaged per Factory	-17.50
Wages to workers per Factory	106.02
Total Emoluments per Factory	152.80
Fixed capital per factory	210.21
Working Capital per factory	204.16
Invested Capital per factory	214.83
Fuels consumed per Factory	231.93
Material consumed per Factory	395.81
Total inputs per factory	426.98
Value of output per factory	399.51
Net value added per factory	307.68
Net fixed capital formation per factory	45.02
Gross fixed capital formation / factory	150.30
Gross capital formation per factory	173.18
Profits per factory	925.90
Addition of stocks per factory	240.39

Source: *Annual Survey of Industries, CSO, GoI*

Another Account of Innovation in Factory Sector

A simple approach to capture structural changes in the organized manufacturing sector over a rather short period of four years could be as follows: note the percentage share of a sector's value added to the total value added by all sectors for two periods; then note the change in relative share of each sector between the two periods; then observe the peculiarities including whether the overall economy has moved towards higher value adding sectors. This method is weak, however, it informs quickly on the structural changes in the output sectors vis-à-vis increased value addition.

The percentage share of value added in each industry sector to total value added by industries shows that iron and steel manufacturing industries recorded the maximum growth (8.8) followed by manufacture of refined petroleum products (6.2). Interestingly more than half of the industry sectors show a decline in the percentage share in net value added. Manufacture of basic chemicals lost most share preceded by spinning, weaving and finishing of textiles (Table 4-10.02). A significant loser is the drugs and pharmaceutical sector under the manufacture of other chemical products class. Perhaps several sectors that are mostly located in small urban areas and with relatively higher number of employees as well as with lower invested capital in machineries are the losers.

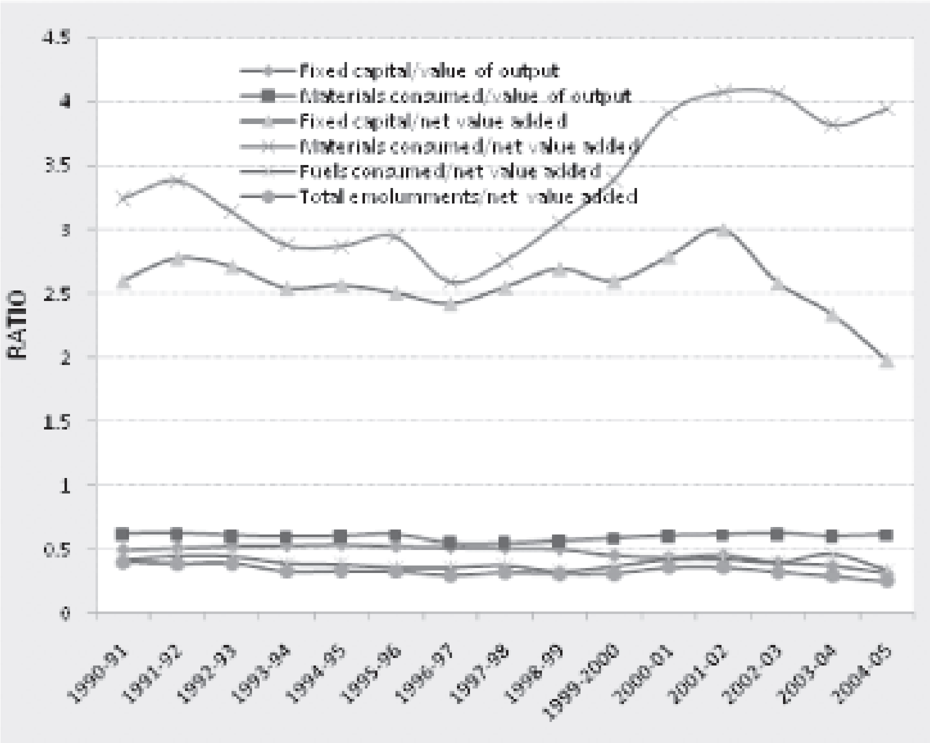


Fig 4-10.01: Selected indicators of industrial innovation
Source: Annual Survey of Industries

Innovation Across Different Types of Ownership

Four major types of ownership of manufacturing industries are prevalent in India: Government or publicly owned, Public Ltd companies, Private Ltd companies and Co-operative society owned. It is apparent from the trend of indicators that there is virtually no innovation in the government enterprises whereas in case of public limited and private limited companies, there is indication of the occurrence of innovation. The industries in the cooperative societies show a very fluctuating pattern for all the parameters, indicating inconsistency in the innovation process.

Table 4-10.02: Changes in the percentage share of value added for select industry sector with respect to the value added in the total industries

Industry type	% share in total value added by industry sector		Change in percentile points
	2000-01	04-05	
Basic Iron & Steel	6.3338	15.1778	8.844
Refined petroleum products	4.7406	10.9497	6.209
Basic precious & non-ferrous metals	2.4195	3.1556	0.736
Transport equipment	1.8863	2.5311	0.645
Coke oven products	0.1547	0.6702	0.515
Recycling of metal waste	0.0004	0.0027	0.002
Man-made fibers	1.2707	0.3488	-0.922
Paper and paper product	2.6097	1.3034	-1.306
Other food products	5.2507	3.0280	-2.223
Spinning, weaving & finishing of textiles	7.2894	4.3715	-2.918
Basic chemicals	10.2185	7.0328	-3.186

Source: *Annual Survey of Industries, CSO, GoI*

Location Based Innovation in Industries

Industries based in both rural as well as in the urban areas exhibit almost similar patterns of innovations during the period 1989-90 to 2004-05. Declining ratios like invested capital per gross output, wages per gross output and invested capital per net value added indicate innovation in manufacturing; but the decrease in wages per gross output is very small indicating little gains in labour productivity and the recorded innovation is perhaps due to the use of advanced or efficient technologies.

An increasing input to output ratio in both the rural and urban industries is an indication of overall low productivity. However, the degree of increase of the input to output ratio is higher in the urban industries (0.79 to 0.82) indicating that the urban industries are comparatively less productive than their rural counterparts whose input to output ratio has increased from 0.79 to 0.81 during the same period.

Inter-state Comparison of Industrial Innovation

Two patterns of innovation trend can be observed among the states. Some states such as Andhra Pradesh, Uttar Pradesh, Gujarat, and Karnataka exhibit almost continuous decreasing trend of indicators like capital intensity of output and of net value added, and emoluments intensity of output and net value added (Fig 4-10.03). This clearly indicates that the innovation process in the industries of these states is a nearly continuous one excepting a few kinks. The remaining states exhibit fluctuating pattern of the ratios, increasing first and then decreasing which indicates these states are also at last becoming innovative. These states are West Bengal, Bihar, Tamil Nadu, Punjab, Maharashtra and Madhya Pradesh.

However, if we consider states having lower values of the ratios as more innovative, then in general Maharashtra and Punjab go neck-in-neck to top the list of most innovative states. Rest of the states in descending order of innovativeness or more efficient use of capital and white collar employees or the organizational processes – would be like Uttar Pradesh > Karnataka > Gujarat > Andhra Pradesh > West Bengal > Tamil Nadu > Bihar > Madhya Pradesh.

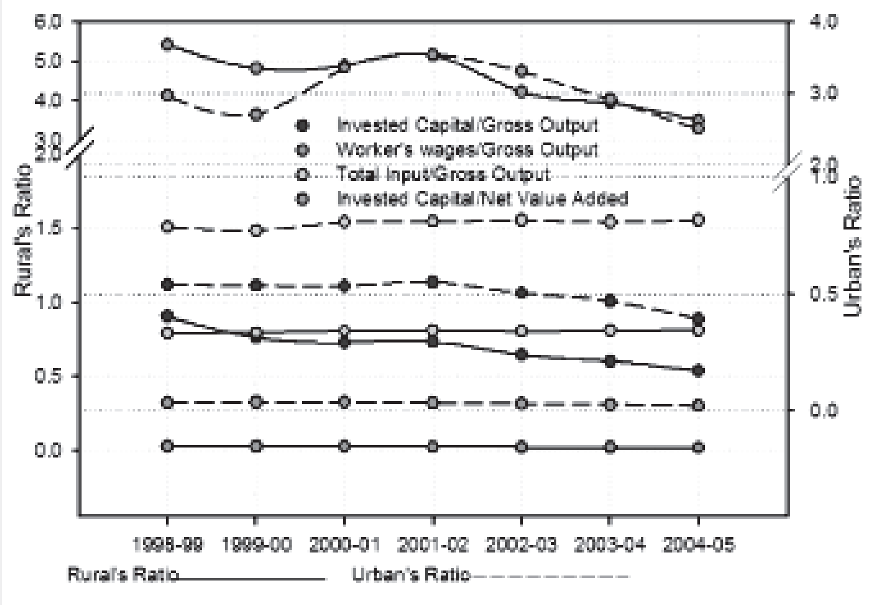


Fig 4-10.02: Indicators of innovation in urban vs rural industries

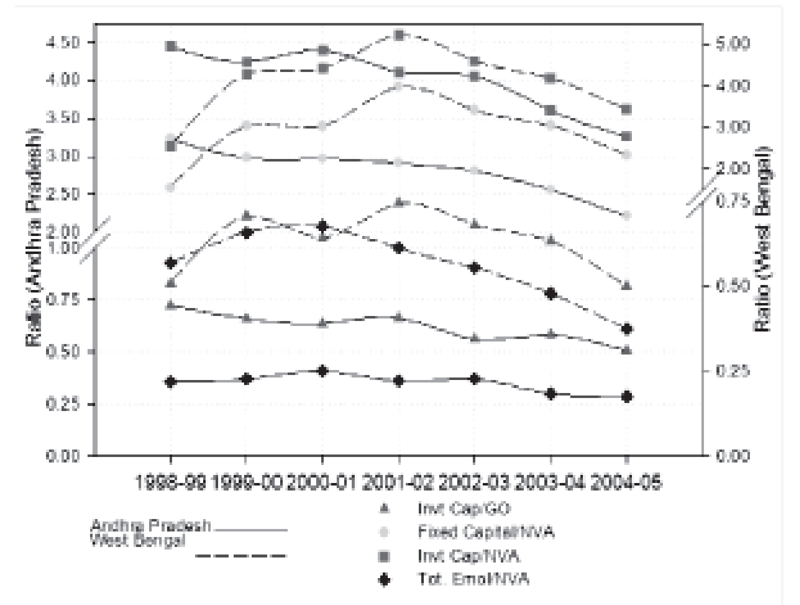


Fig 4-10.03: Indicators of innovation of representative states

Innovations in Sectors – Non R&D Aspects

Innovations across several sectors can be appreciated from decreasing per unit consumption of materials, fuels, emoluments, fixed capital, and stock-held for every value added or every value of output. The period of data is very small, only for 5 years 2000-01 onwards. A secular decrease, in particular a steep fall would indicate that the corresponding factory sector has done remarkably well in innovation. We should note that value added includes wages or emoluments and additionally also the capability of that sector to price its output, and also the capability to manage cash and intangibles.

Most importantly, investments in innovation are not captured in data on R&D expenditure. The fact that sectors undertake innovation and incur expenditure on R&D aspects is pointer to this often ignored dimension of innovation. Tax gains as policy may not have influenced the undertakers of the innovation, neither do these undertakers use innovation as signals to the capital market. In contrast such innovations appear to have been influenced by the sector's competition landscape and inter-sector competition landscapes. Policies that are targeted to competition and other legal dimensions including a few non-R&D aspects of fiscal policies have together influenced sector innovation outcomes. Input prices including of commodity, for example, might have been more influential than gains through tax deductions on R&D expenses to invest in innovation.

Automobile Industries: In the automobile sector, there were 4,412 industries in 2000-01 which increased to 4,957 during 2004-05. In this sector, material consumption is decreasing in terms of value of output and net value added to the product (Fig 4-10.04). The sharp fall evidences significant innovation in automobiles. Great gain in the productivity of capital signifies another dimension of innovation. The ratio of emoluments paid to the employee (Worker/Supervisor) to both output value and net value added, however, shows indifference. Another important dimension of innovation that relates more to inter sector than to the sector is about the stock held. High value of stock to per unit value add is therefore a drag on the company and the automobile sector exhibits a near indifference to this ratio over this five year period.

Leather Industries: In leather manufacturing, material consumption per unit value of output as well as per net value added shows fluctuations or an increasing trend, exhibiting poor state of innovation in materials efficiency. However, innovation in capital employed especially fixed capital per value of output has shown slight improvement. Emoluments trend exhibits indifference to innovation. The total number of enterprises in this sector was 2,378 in 2000-01 which decreased to 2,293 in 2004-05. In this sector there appears to be insignificant innovation in terms of fuel consumption as well as in terms of addition of stocks.

Electronic/Computer Industries: This sector exhibits poorer show on innovation front compared to the previous two sectors especially compared to automobiles. In the electronics and computer sector, material consumption in terms of value of output as well as net value added is increasing indicating inefficiency in material consumption. Whereas fixed capital invested in terms of net value added or value of output is decreasing over the period 2001-05. Wages per value of output or net value added is almost constant exhibiting indifference to innovation. There is no significant innovation in fuel consumption also. In this sector, the number of industries increased marginally from 3,742 in 2000-01 to 3,797 in 2004-05.

Small Electronic Equipment Industries: Similar to the sector above, the small electronic equipment industries sector exhibits a poor show in innovative activities with negative or indifferent trends of innovation. In this sector material consumption in terms of value of output as well as net value added shows upward trend over the period 2001-05 indicating material consumption inefficiency. Fixed capital invested per value of output as well as net value added is almost constant. On other aspects, such as stock held or on emoluments related business innovation, this sector remained indifferent. In this sector, the number of industries has reduced from 2,167 in 2000-01 to 1,993 in 2004-05.

Tools Manufacturing: Perhaps the poorest show of innovation is evidenced in this sector. Material consumption in terms of value of output as well as net value added shows a continuous increase over the period 2001-05. The stocks held too show upward trend. Materials consumption could be reduced per value

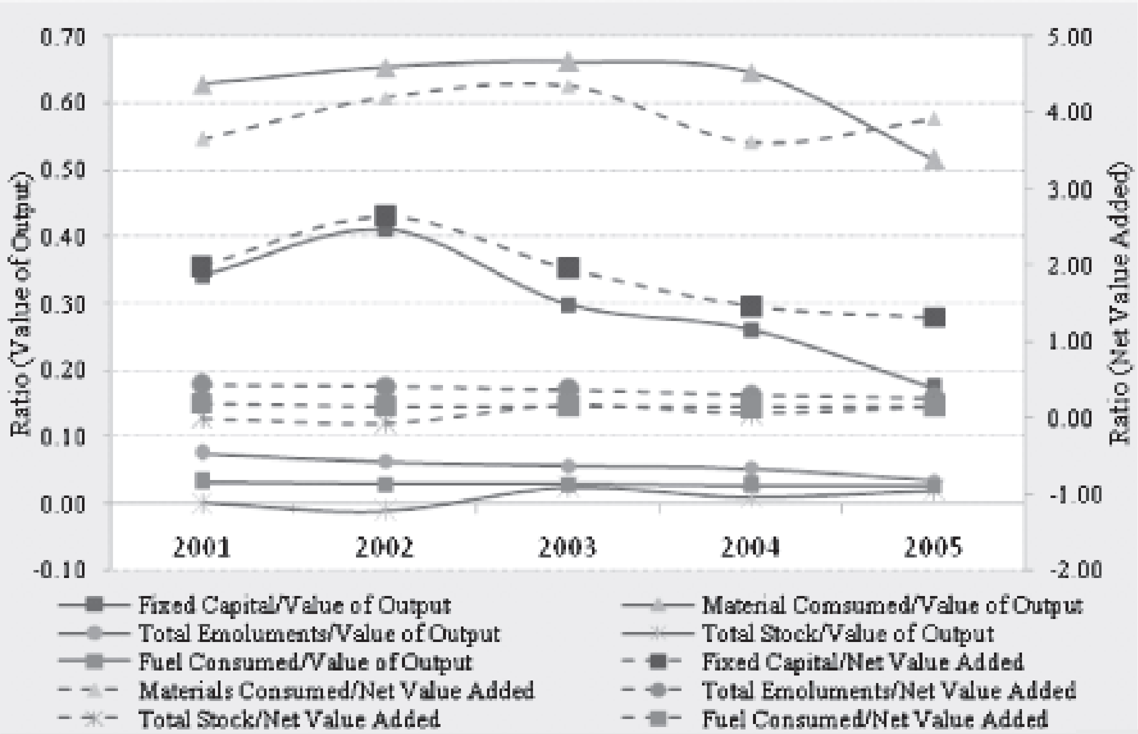


Fig 4-10.04: Indicators of innovation in Automobile industries

add through innovations within the enterprise while innovations in stock held would require improvements in cross-sector linkages of systemic nature. But fixed capital invested per value of output as well as net value added is showing a decreasing trend, exhibiting marginal innovative gains along this aspect alone. Number of units was 8,600 and 8,681 in 2000-01 and 2004-05 respectively.

Processed Food Industries: This is another sector with negative or indifferent state of affairs in innovative activities with marginal improvements only in stock held aspect of innovation and that too only in the later part of the period. In the processed food sector, material consumption in terms of value of output as well as net value added is increasing or indifferent. Fixed capital investment per value of as well as net value added is also indifferent. This sector is having the highest number of industries among the sectors under consideration. During 2000-01, the number of industries in this sector was 22,171 which has increased to 23,216 during 2004-05.

Textiles: Another poor show of innovative activity or absence of non-R&D innovation is evidenced in the textiles sector enterprises. In the industries involved in textiles material consumption in terms of value of output as well as net value added is almost constant over the period 2001-05. Fixed capital investment per value of output as well as net value added is also almost constant, however, with marginal improvements exhibiting better utilization of capital. This sector has the second highest number of enterprises after those in the processed food sector. The number of industries was 16,914 and 16,906 during 2000-01 and 2004-05 respectively.

Inter Sector Comparative Innovation in Some Select Sectors of Factories

This section describes patterns in innovations in different sectors of industries at factory level. The sectors are classified as per NIC Classifications. Innovation parameters are defined in terms of net value added per unit of materials consumed, total emoluments, fuel consumed and number of workers; whereas materials consumed represents expenditure incurred on material consumed for producing the desired products; total emoluments represents expenditure incurred on the salaries of the manpower involved in the production process, for the entire sector; fuel consumed represents expenditure incurred on fuel consumption during the production process, for the entire sector; number of workers represents number of the workers involved in the production process for the entire sector and net value added is calculated by deducting total input and depreciation from total output. Innovation parameters are calculated for the period 2000-01 to 2004-05. These values are calculated based on the data collected from annual survey of industries (ASI). Sectors selected are transport, machine tools, paper & leather products, and electrical & electronics equipments.

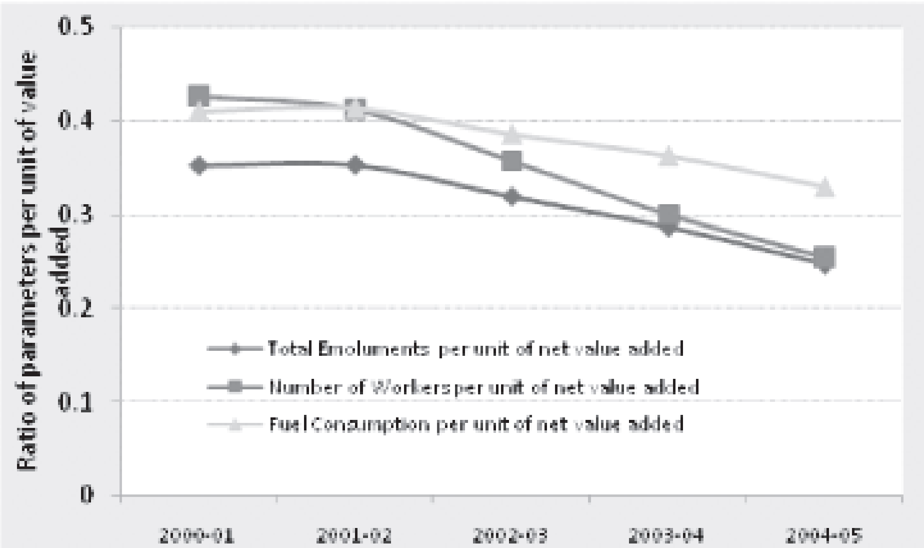


Fig 4-11.01: Ratio of different parameters per unit of net value added

Features of Non-R&D Innovation

It can be seen from the Fig 4-11.01 that at the aggregate level the industry has been saving in terms of total emoluments, number of workers and fuel consumption to achieve the same amount of 'net value added', in these sectors. However, no definite patterns are observed in terms of material consumed.

It can be seen that paper and paper products sector is more innovative than leather product sector, as far as material consumed, number of workers and total emoluments is concerned. But in case of fuel consumed, leather products seems to be adding more of 'net value' per unit of fuel consumed than paper & paper products Fig 4-11.02 to 4-11.05.

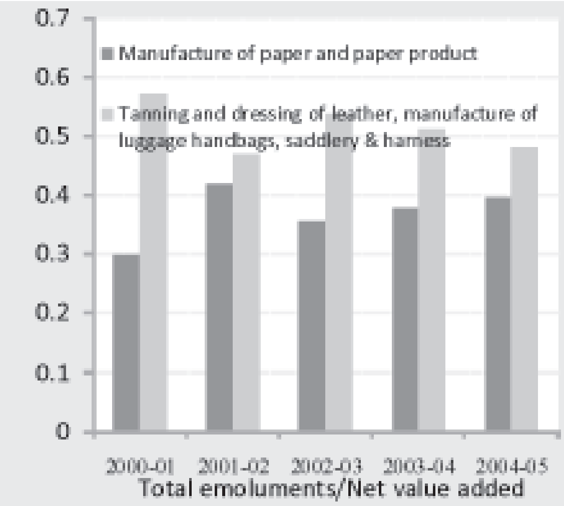


Fig 4-11.02: Total emoluments/net value added

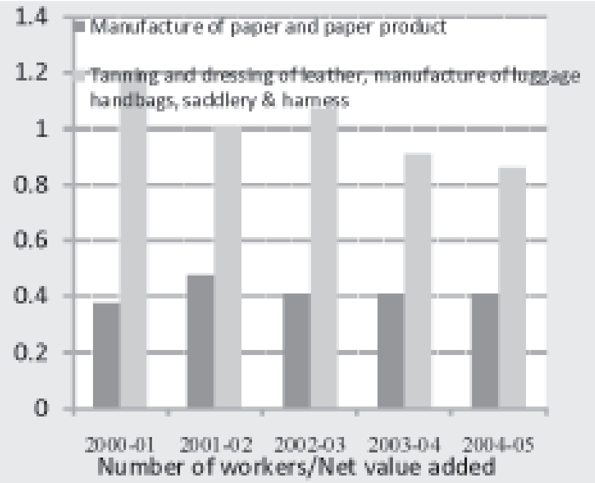


Fig 4-11.03: Number of workers/net value added

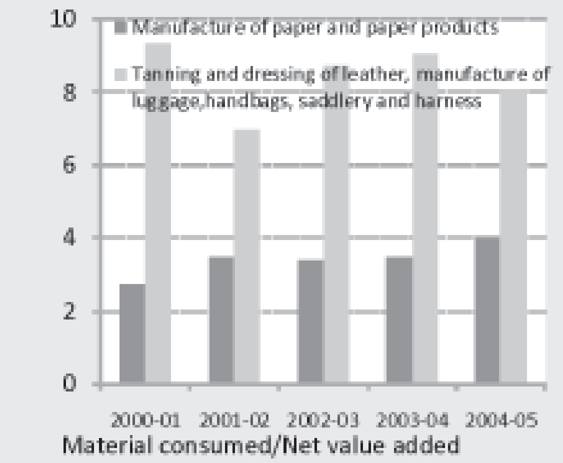


Fig 4-11.04: Material consumed/Net value added

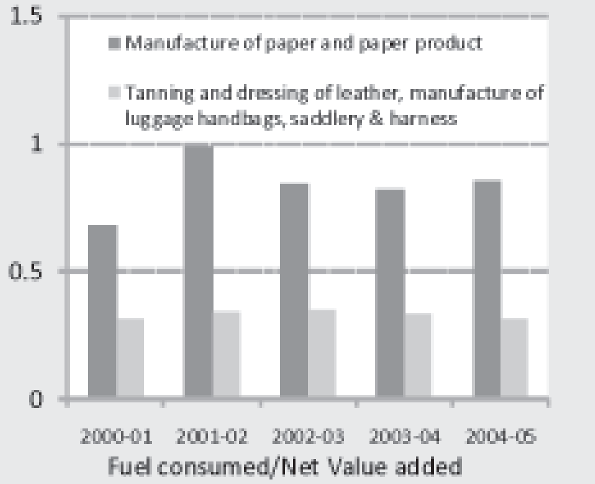


Fig 4-11.05: Fuel consumed/net value added

Trends in innovation parameters for transport sector have been shown in Table 4-11.01 and 4-11.02. It can be seen that manufacture of transport equipment has emerged as most innovative in terms of fuel consumption, while manufacture of motor vehicles has emerged as most innovative in terms of number of workers. Manufacture of parts and accessories for motor vehicles and their engines has emerged as most innovative in terms of material consumption.

Electrical & electronics equipments covered following sub-sectors:

Manufacture of office, accounting and computing machinery; Manufacture of accumulators, primary cells and primary batteries; Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy; Manufacture of electric motors, generators and transformers; Manufacture of electric lamps and lighting equipment; Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods; Manufacture of electricity distribution and control apparatus; Manufacture of other electrical equipment; Manufacture of insulated wire and cable; Manufacture of electronic valves and tubes and other electronic components

Table 4-11.01: Trends in innovation parameters for transport sector

	Manufacture of bodies (coach work) for motor vehicles; manufacture of trailers and semi-trailers				Manufacture of railway and tramway locomotives and rolling stock				Manufacture of parts and accessories for motor vehicles and their engines			
Year	Material consumed/Net value added	Total emoluments/Net value added	Number of workers/Net value added	Fuel consumed/Net value added	Material consumed/Net value added	Total emoluments/Net value added	Number of workers/Net value added	Fuel consumed/Net value added	Material consumed/Net value added	Total emoluments/Net value added	Number of workers/Net value value	Fuel consumed/Net value added
2000-01	5.1	1.0	1.5	0.3	2.4	0.7	0.7	0.2	2.7	0.4	0.3	0.1
2001-02	3.2	0.7	1.1	0.3	2.1	0.5	0.4	0.1	2.6	0.4	0.3	0.2
2002-03	8.4	1.8	2.8	0.5	2	0.4	0.3	0.1	2.8	0.4	0.3	0.1
2003-04	5.0	0.6	1.0	0.2	2.2	0.3	0.3	0.1	2.9	0.3	0.2	0.1
2004-05	4.8	0.5	0.7	0.1	2.2	0.3	0.3	0.1	3.2	0.3	0.2	0.1

Table 4-11.02: Trends in innovation parameters for transport sector

	Building and repair of ships & boats				Manufacture of motor vehicles				Manufacture of transport equipment			
Year	Material consumed/Net value added	Total emoluments/Net value added	Number of workers/Net value added	Fuel consumed/Net value added	Material consumed/Net value added	Total emoluments/Net value added	Number of workers/Net value added	Fuel consumed/Net value added	Material consumed/Net value added	Total emoluments/Net value added	Number of workers/Net value added	Fuel consumed/Net value added
2000-01	7.5	0.8	0.7	0.00021	7.9	0.5	0.2	0.2	4.6	0.3	0.3	0.1
2001-02	5.9	0.4	0.3	7.54E-05	7.7	0.4	0.1	0.1	3.6	0.2	0.2	0.1
2002-03	4.4	0.5	0.4	0.000132	4.5	0.2	0.1	0.1	3.5	0.2	0.2	0.1
2003-04	5.6	0.7	0.6	0.000154	4.5	0.1	0.1	0.1	3.3	0.2	0.1	0.1
2004-05	3.0	0.5	0.4	0.000109	7.9	0.5	0.2	0.2	4.0	0.2	0.1	0.1

In terms of total emoluments per unit of net value added, sectors like manufacture of accumulators, primary cells and primary batteries, manufacture of office, accounting and computing machinery and manufacture of electric motors, generators and transformers emerged as most innovative.

In terms of numbers of workers, manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods, manufacture of electric motors, generators and transformers, manufacture of office, accounting and computing machinery emerged as top three sectors.

In terms of innovation achieved in fuel consumption, the top three sectors are manufacture of electric motors, generators and transformers; manufacture of office, accounting and computing machinery and manufacture of electricity distribution and control apparatus.

In case of material consumption, following sectors emerged as most prominent

- Manufacture of office, accounting and computing machinery
- Manufacture of accumulators, primary cells and primary batteries
- Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy

Machine tool sector was further divided into 'manufacture of special purpose machinery' and 'manufacture of general purpose machinery' for observing trends in innovations. However it was found that both the sectors showed a decline in innovation in terms of material consumed, showing an improvement in terms of number of workers involved in the production process from year 2002 onwards.

Recent Trend in Technology Up-gradation in the Indian Textile Industry : Need for S&T Intervention

The importance of textile industry in the national economy can be found in its substantial contribution to employment, value addition and export earnings. In 2005-06 textile sector contributed 17.4 per cent in total exports of the country. The following summary account of the sector exhibits a few features of importance, and these are: (1) industry structure with significant presence of small sub-sectors; (2) under-capitalized units and low labor productivity holding up; (3) skill sets in need of improvement – and all this calls for technological intervention.

The textiles and clothing industry can be broadly divided into five stages of production, namely, ginning, spinning (yarn), weaving (fabrics), made-ups, and garments. According to the Handbook of Statistics on Textile Industry (HBSTI) (2008), non-SSI textile mills including spinning employed 8.53 lakh workers in 2007 with the average size of employment per mill being 472 and the SSI spinning mills employed 42,270 workers with average employment per mill being 32 workers. Bedi's (2008) estimates indicate that approximately 52.5 lakh textile and clothing units existed in India in 2000–2001 and around 99.9 per cent of these units operated with gross value of plant and machinery (GVP&M) less than or equal to Rs 1 crore. Total value-addition by this sector amounts to Rs 37,127 crore of which ginning, cleaning and bailing shared 0.1 percentage, spinning 28.9 per cent, weaving 19.4 percent and the finishing, made-up and garment 7 per cent, 16.2 per cent and 28.5 per cent respectively. It employed around 124 lakh people and the share of ginning, cleaning and bailing was 0.2 percent, spinning 7.6 percent, weaving 26.3 percent, finishing 3.8 per cent, made-ups 22.9 per cent and garments 39.2 per cent. Value added per worker turns out to be only Rs 24 thousand.

Gross Fixed Capital Formation (GFCF) indicative of addition of new plants and machinery embodying new or improved technology followed a cyclical pattern as per ASI data (at 1993-94 prices) - it first increased rapidly during 1991-1996, then started declining and reached the trough of the cycle in 2002 and thereafter it started moving upward and continued till 2005 (for which latest data are available). Average annual investment was Rs 3,129 crore during 1991-94, which rose to Rs 5,769 crore during 1995-98 and then declined substantially to Rs 3,815 crore during 1999-2003 and it again rose to Rs 4,358 crore during 2003-05. Disaggregated data indicate that the three segments namely spinning, weaving and finishing of textiles received the major share of the investments. Steady and a sizeable growth of investment in the periods 1999 onwards however took place in made-up textiles, knitted and crocheted fabrics and articles, and wearing apparel. The rapid growth of the investment in textile machines reflect to an extent the effect of Technology Uprradation Fund Scheme (TUFS) which started in 1999 in order to compensate for the global disadvantages faced by the Indian textile industry in the field of power, transaction costs and additional costs borne by the industry due to poor infrastructure.

There are various subventions under TUFS for different forms of capital subsidy/interest subsidy. But on an average Government outflow under the scheme has been around 5% of the amount disbursed (by the banks and financial institutions in the form of loans/advances, etc). It was initially launched for five years only, but later on it was further extended and modified several times and the latest extension is up to March 31, 2012. TUF scheme has been an important contributor to investment and modernization of the textiles and clothing industry since the inception of the scheme. Till March 31, 2008 a total of Rs. 54,229 crore had been sanctioned and Rs 44,917 crore had been disbursed under TUFS to various textiles and garment units. Spinning mills availed the maximum benefit from TUFS with disbursement of Rs. 14,841 crore (i.e.33.04% of the total disbursed amount). Other major beneficiaries are units of processing of textiles and garments, weaving, garment manufacturing, viscose filament yarn manufacturing, synthetic filament yarn, texturising, crimping & twisting and knitting. However there has been a gradual shift in relative importance of different segments - for instance, share of composite mills decreased from 30.74% as on March 31, 2002 to 18.88% on March 31, 2008; the share of weaving units increased from 6% to 8.58 %; 'others' including cotton ginning and pressing, CPP on stand-alone basis, fabric embroidery, jute industry, silk reeling and twisting, wool scouring and combing, etc increased from 2.37% to 14.27%. This indicates the beneficiaries of TUFS are becoming more and broader based. Loans availed through TUFS make a significant contribution of project costs of the units that had applied for TUFS - in the spinning segment it covered 47-57% of the project cost, in composite mills 37-45% and in garments 45-56% during 1999-2008.

A major drawback with TUFS is that it does not take into account the textile machinery manufacturing sector which could have been a leading and thriving sector given the rapid growth in domestic demand for textile machinery. This sector is stagnating with little investment in capacity building or modernization. Existing capacity is largely underutilized. Thus with growing demand the textile industry has been importing larger and larger share of its total machinery requirement. Imports of even conditioned (second hand) machinery are also quite substantial at present. In this context extending TUFS to machinery manufacturing sector and allotting a percentage of that for R&D would in the long run raise its scale of operation and make it globally competitive as may be seen in the case of a similar policy in China. This would also save the textile sector from the problems of currency fluctuation for importing machines as it is happening at present.

Table 4-12.01: Investment in Textile Machinery (Rs Crore)

Year	Investment in machinery	Share of import in total purchase of machinery (%)	Installed capacity of domestic textile machinery manufacturing industry	Capacity utilization of domestic textile machinery manufacturing industry (%)
1995-96	3411	62		
1996-97	2650	63	3000	43
1997-98	2911	60	3300	45
1998-99	2286	62	3600	32
1999-00	1866	56	3600	31
2000-01	2023	57	3600	36
2001-02	1877	66	3800	28
2002-03	2603	70	3800	31
2003-04	2986	73	3050	44
2004-05	4508	73	3050	55
2005-06	8503	80	3200	69

Source: *TMMA*

In summary, Indian textile industry is in need of technology up-gradation so as to make it globally competitive. Although this up-gradation process is going on, particularly after the introduction of TUFS, it is rather slow and too much dependent on imports of machinery. In view of the large demand for textile products a large variety of machinery is being imported. Keeping in view this huge domestic demand for machinery, suitable machine tools industry can be developed and that can also achieve scale economy. Along with this substantial amount of R&D would be needed to develop state of the art technology. Because of inappropriate technology, the existing Indian textile machinery manufacturing industry is not merely facing severe underutilization of capacity, most of its produce is not used by the Indian textile manufacturers. It is suggestive that a part of the TUFS money can be earmarked for R&D in the machine tools industry segment that is engaged in developing textiles machinery.

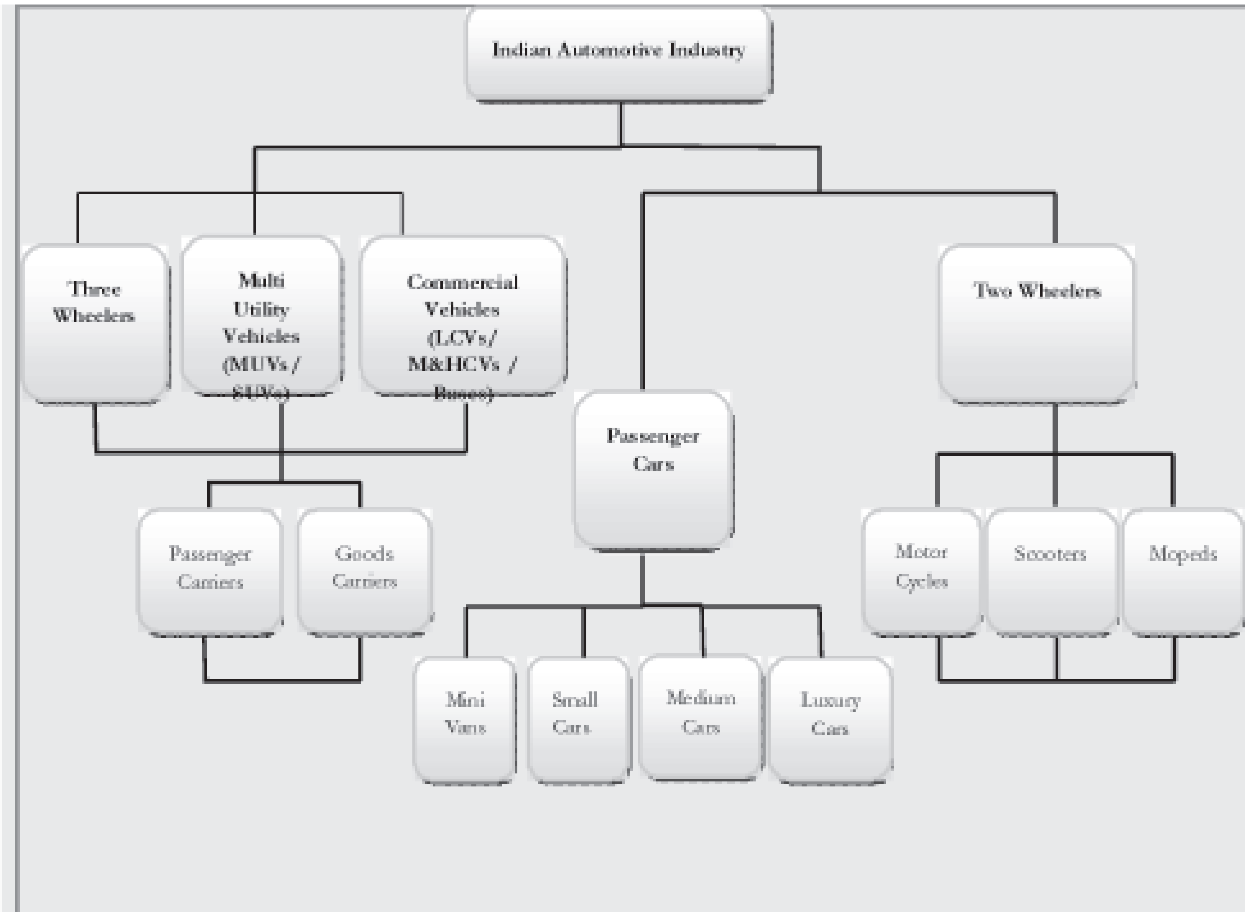
Table 4-12.02: Imports of Various Textile Machinery and Accessories (Rs crores)

Description of machines	2003-04	2004-05	2005-06	2006-07
Extruding machines	54 (2.3)	118 (3.3)	96 (1.4)	100 (1.3)
Preparatory textile fibres, spinning, twisting, etc	550 (23.1)	923 (26.0)	2126 (29.9)	2230 (29.7)
Weaving machines	604 (25.4)	807 (22.7)	1528 (21.5)	1610 (21.5)
Knitting, stitching and binding machines	445 (18.7)	619 (17.4)	1391 (19.6)	1460 (19.5)
Auxiliary machinery & accessories / spares	456 (19.2)	587 (16.5)	844 (11.9)	900 (12.0)
Manufacture of felt or non-woven in piece	13 (0.5)	13 (0.4)	25 (0.4)	30 (0.4)
Other accessories and parts	211 (8.9)	417 (11.7)	982 (13.8)	1040 (13.9)
Household/ laundry type washing machines/ parts	46 (1.9)	70 (2.0)	108 (1.5)	130 (1.7)
Grand Total	2379 (100)	3552 (100)	7100 (100)	7500 (100)

Note: Parenthesis indicates percentage share in total.
Source: *DGCIS, Kolkata.*

Chronology and typology of India's automotive growth

The growth of Indian automotive industry from the pre-independence period till date shows distinct phases. It all started in 1940s: the embryonic automotive industry emerged in pre-independent India. Despite the sluggish growth of the economy during 1950-1980, the automotive industry began to witness a relatively fast growth during 1970-1980 mainly due to the leading production role of Telco, Ashok Leyland, Mahindra & Mahindra, Hindustan Motors, Premier Automobiles, and Bajaj Auto. The growing demand for more cars since 1980s has changed the whole growth scenario. During 1980-1985 the first major change was sighted as Japanese manufacturers began to build car and commercial vehicle factories in India in partnership with Indian firms. At the same time, component manufacturers also entered the joint-venture scenario with European and US firms. Between the years 1985-1990 a noticeable change took place in the Indian automotive industry. The industry marked the entry of Maruti Udyog into the production of passenger cars: persistent high import tariffs were relaxed to a great extent, and with lesser import cost adding to the overhead production cost, higher productions were possible leading to the start of growing exports.



Source: ACMA, India.

Fig 4-13.01: Genre of Indian Automotive Industry

Growth Dynamics of Automotive Segment

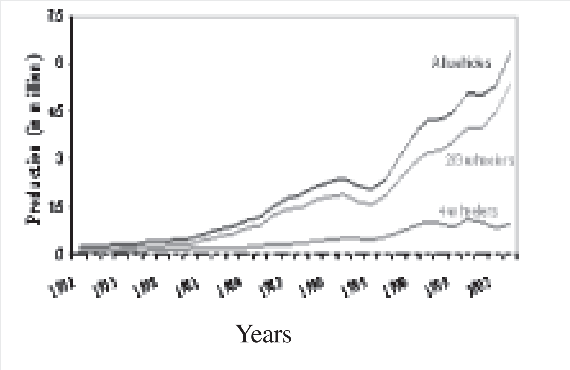


Fig 4-13.02: Automobile Production in India

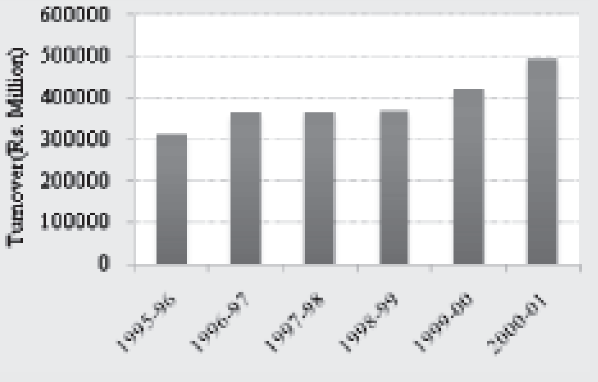


Fig 4-13.03: Vehicle Production: Industry Gross

There has been a considerable growth in the passenger car segment in comparison to the MUVs/jeeps during the same period as shown in Fig 4-13.04. It is evident that the major contribution to the growth of the total volume is from the car segment.

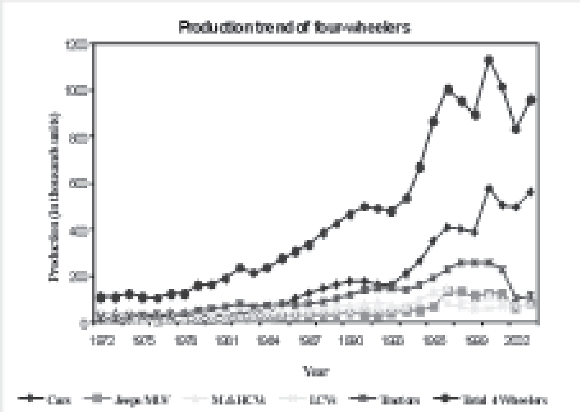


Fig 4-13.04: Vehicle Production: The 4-wheeler Segment

Source: Own construction using SIAM and ACMA data

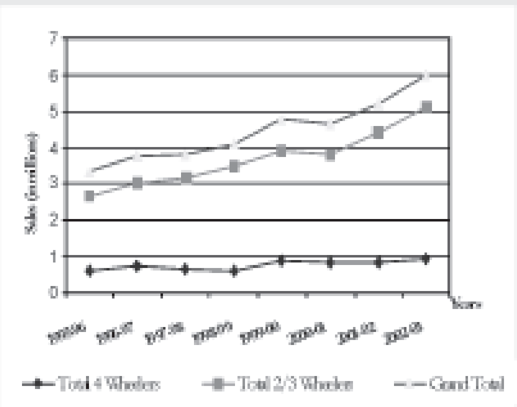


Fig 4-13.05: Domestic Vehicle Sales After 1991 (In Numbers)

Source: Own construction using SIAM and ACMA data

Automotive industry of India also started exporting slowly after the liberalization. Here again, MUL and TELCO have been the leading exporters, accounting for 95 percent and 86 per cent of passenger cars and commercial vehicle exports respectively in late 1990s. The automobile industry, along with the component industry, has significantly raised exports only in more recent years. In fact, the volume of exports was very small and had shown a downward trend in the later part of 90%. Afterwards, the trend started to reverse, however. For example, during the year 2002-03 the export of automobile industry had registered a growth rate of 65.35 per cent. Technological sophistication of the industry has also picked up after India adhered to the global environmental norms regarding emission standards as well as quality certifications. The upward trend in exports also reflects the changing nature of technological sophistication of the Indian automotive sector. Structural and technological changes in the automotive industry also have multiple trickle-down effects on its allied components segment as the latter is inextricably linked to the former in the value chain. The intricate nature of automotive industry's intra-sector relationships due to its tiered structure, and the

Table 4-13.01: Production Trend of Automotive Segments (millions)

Categories of vehicles/ Years	Cars	Jeeps/ MUV	M & HCVs	LCVs	Tractors	Total 4 Wheelers	Total 2/3 Wheelers	All vehicles
1971-72	--	--	--	--	--	--	--	--
1972-73	0.040	0.011	0.033	0.008	0.018	0.109	0.136	0.245
1973-74	0.037	0.013	0.031	0.009	0.022	0.111	0.151	0.263
1974-75	0.042	0.012	0.034	0.011	0.023	0.123	0.162	0.285
1975-76	0.031	0.010	0.035	0.006	0.031	0.112	0.194	0.307
1976-77	0.022	0.007	0.037	0.007	0.033	0.106	0.227	0.332
1977-78	0.036	0.008	0.039	0.008	0.033	0.125	0.284	0.408
1978-79	0.034	0.009	0.033	0.008	0.041	0.126	0.282	0.408
1979-80	0.033	0.012	0.047	0.013	0.055	0.159	0.321	0.480
1980-81	0.033	0.013	0.043	0.016	0.062	0.167	0.337	0.504
1981-82	0.031	0.016	0.054	0.020	0.070	0.191	0.467	0.659
1982-83	0.042	0.018	0.066	0.027	0.082	0.236	0.572	0.808
1983-84	0.044	0.020	0.061	0.027	0.063	0.214	0.664	0.878
1984-85	0.047	0.022	0.061	0.029	0.074	0.233	0.818	1.051
1985-86	0.076	0.023	0.063	0.033	0.082	0.277	0.941	1.219
1986-87	0.103	0.028	0.064	0.037	0.073	0.305	1.241	1.546
1987-88	0.126	0.029	0.060	0.039	0.079	0.333	1.449	1.782
1988-89	0.152	0.032	0.065	0.045	0.089	0.383	1.498	1.881
1989-90	0.166	0.036	0.070	0.046	0.107	0.425	1.716	2.141
1990-91	0.179	0.044	0.077	0.048	0.118	0.466	1.815	2.282
1991-92	0.182	0.037	0.087	0.058	0.139	0.502	1.910	2.412
1992-93	0.166	0.032	0.090	0.054	0.148	0.489	1.683	2.172
1993-94	0.163	0.039	0.075	0.053	0.148	0.479	1.569	2.047
1994-95	0.208	0.049	0.066	0.075	0.138	0.536	1.847	2.383
1995-96	0.264	0.050	0.102	0.093	0.163	0.672	2.324	2.996
1996-97	0.348	0.068	0.130	0.129	0.191	0.866	2.820	3.686
1997-98	0.408	0.135	0.152	0.085	0.226	1.005	3.202	4.207
1998-99	0.401	0.135	0.096	0.065	0.256	0.953	3.308	4.260
1999-00	0.390	0.113	0.080	0.055	0.254	0.893	3.584	4.477
2000-01	0.574	0.124	0.114	0.061	0.257	1.131	3.984	5.115
2001-02	0.507	0.126	0.088	0.064	0.231	1.017	3.961	4.978
2002-03	0.500	0.066	0.097	0.066	0.106	0.834	4.484	5.318
Compound Annual Growth Rates, CAGR (%)								
1972-81	-2.33	3.39	4.99	10.37	14.74	5.77	13.15	10.39
1982-91	15.65	7.66	2.72	7.91	5.34	7.84	12.82	11.56
1992-2001	11.79	14.85	-0.15	1.76	4.56	7.59	8.94	8.65
Total period	8.91	6.66	4.25	8.02	6.20	7.26	12.60	11.06

Source: Constructed from "Facts and Figures: 2000-2001", ACMA, India.

dynamics of international automotive market developments make it hard to disentangle the effects of the changes in both the sectors.

Auto Component Industry – Recent Performance Indicators

Trends in production: To cater to existing and new vehicle manufacturers' requirements a continuous expansion of the automotive components sector has been occurring after 1980s. With the opening up of the economy, a renewed optimism of market growth prospects inspired higher investment and output in this sector. In 1996-97, the investment in the component sector marked a little above 1,500 million dollars, but in 2001-2002, the investment rose to 2,300 million dollars which is a remarkable growth of 30 per cent in over five years (Fig 4-13.09), notwithstanding the existing structural bottlenecks like poor road infrastructure.

The total production of auto components has been increasing at about 19 per cent per annum since 1960s. However, the gross output in value terms was quite miniscule till mid 70's and picked up only after 80's. As can be gleaned from Fig 4-13.10, the volume of production was almost negligible in the 1960s. It is only after

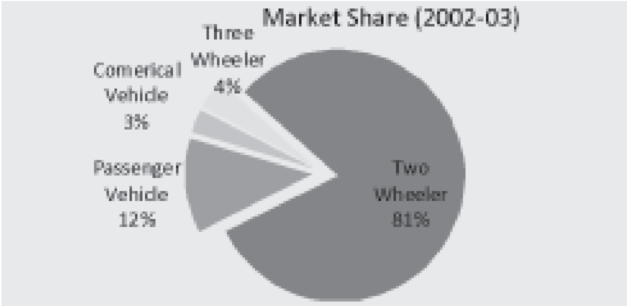


Fig 4-13.06: Market Share of Various Segments of Automobiles

Source: Own construction based on SIAM data

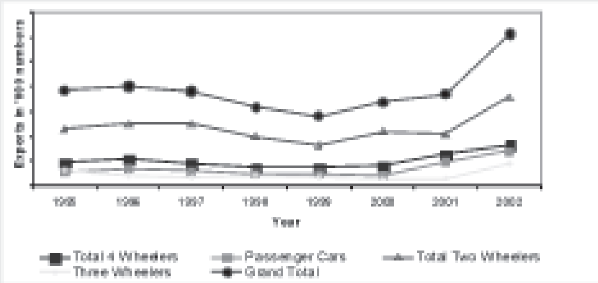


Fig 4-13.07: Automotive Export Trends

Source: *Own construction based on ACMA data*

Table 4-13.02: Share of Segments in Total Vehicle Production (millions)

	Commercial Vehicles	Passenger Vehicles	Two Wheelers	Three Wheelers	Grand Total
2000-01	0.16	0.64	3.76	0.20	4.76
2001-02	0.16	0.67	4.27	0.21	5.32
2002-03	0.20	0.72	5.08	0.28	6.28
2003-04	0.28	0.99	5.62	0.36	7.24
2004-05	0.35	1.21	6.53	0.37	8.46

Source: *Compiled from SIAM data*

1975 that some respectable production started (Fig 4-13.10), and in the subsequent years total auto component production has grown almost exponentially. Following the high growth of total production is the growth of engine parts and drive transmission and steering parts. All through the period, engine parts, being high value-added in nature, have been contributing the most to total production.

The direction of component export of the developing countries, i.e., whether they are exporting more to the developed or developing nations, is an important indicator of the competitiveness of the industry in the world market. Generally, exports of components mainly to the OECD countries would indicate technologically superior products, which cope up with international competition. India's auto component exports have marked a global presence in recent years. For instance, before 1993, the share of exports going to the non-OECD countries was higher than that for the OECD block (Fig 4-13.12). But as the impact of liberalization started

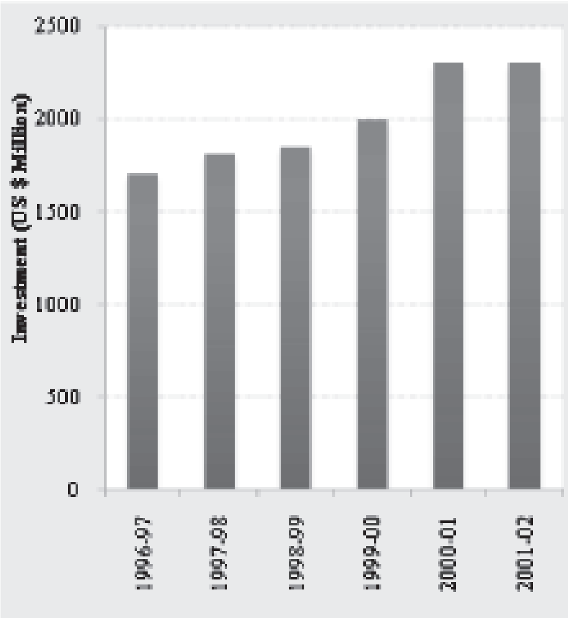


Fig 4-13.09: Investment in Auto Components Industry
Source: *Own construction from ACMA data*

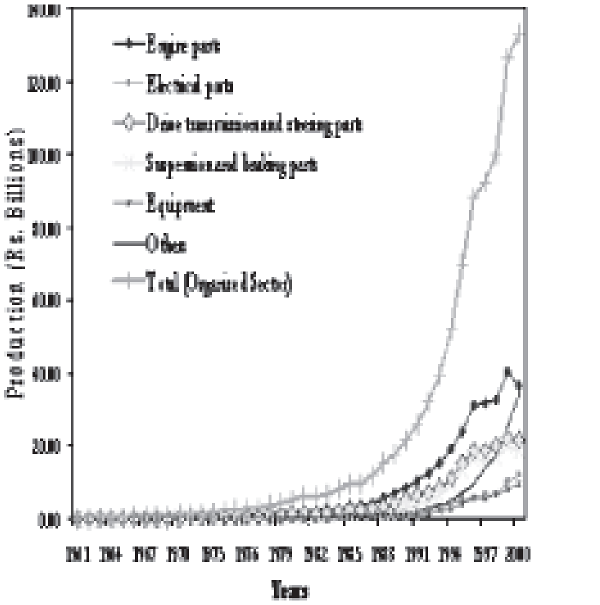


Fig 4-13.10: Component-wise Production Trend
Source: *Own construction from ACMA Data*

Table 4-13.03: Growth of Auto Components production in India (in millions)

Components Years	Engine Parts	Drive & Transmission Parts	Suspension & Braking Parts	Electrical Parts	Equipment	Total
1991-92	20.73	11.30	22.16	19.76	13.00	19.02
1992-93	19.01	14.31	8.10	35.99	18.06	20.52
1993-94	18.20	21.12	14.91	17.69	53.25	20.84
1994-95	22.94	28.91	26.02	44.13	21.29	27.19
1995-96	22.19	25.32	31.95	32.07	44.45	29.75
1996-97	27.26	7.77	21.20	20.36	28.93	23.65
1997-98	0.70	11.13	-0.18	-3.79	-1.05	4.73
1998-99	2.75	2.61	6.37	4.33	17.59	7.72
1999-00	21.43	43.06	9.04	18.50	18.57	22.99
2000-01	-9.79	15.04	-2.43	-7.07	15.61	5.30
CAGR (1961-2001)	***16.97***	***21.23***	***21.92***	***17.32***	***19.89***	***18.47***
CAGR (1991-2001)	***14.86***	***20.69***	***13.63***	***19.75***	***27.22***	***19.81***

Source: *Own calculation based on ACMA data* to flourish, the direction of the exports reversed after 1994; exports to OECD countries have been growing significantly. Currently, of the total auto component exports, developed markets such as the US and Europe together account for about 56 percent, Asia accounts for 27 percent and Africa accounts for 11 percent of the export earnings. The rise of exports in India was also partly led by the overcapacity in the domestic market that resulted from the sudden influx of FDI in 1990s. However, the focus on export markets opened up many avenues and challenges alike. While with growing exports, Indian companies gained increasing stakes in the global sourcing, at the same time they became aware of their technological capabilities in the 'global industry'.

Table 4-13.04: Growth Rate of Expo
Imports

	Exports		Imports
Years	OECD	Non-OECD	World
1989	-0.91	26.44	8.82
1990	24.10	9.01	17.86
1991	8.96	16.91	12.00
1992	17.82	35.10	24.72
1993	-15.03	10.92	-3.81
1994	-10.37	33.06	11.28
1995	28.02	27.96	27.99
1996	-5.44	17.50	8.23
1997	12.34	1.94	5.61
1998	-15.25	-1.43	-6.62
1999	6.51	16.96	13.40
2000	37.00	62.80	54.54
2001	10.62	-3.87	0.24
2002	15.46	24.26	21.51
Average annual growth rate	6.78	17.15	12.29

Source: *Own calculation from UN COMTRADE*
http://unstats.un.org/unsd/comtrade/.

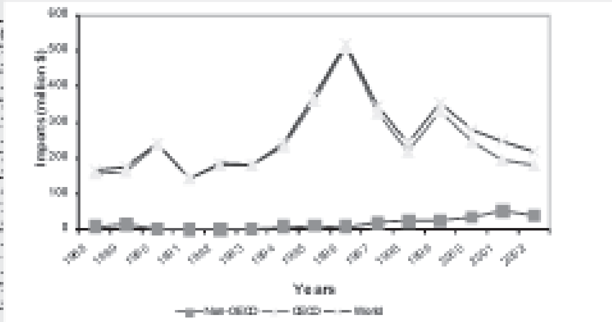


Fig 4-13.11: Export- Import Trends
Source: Own calculation from UN COMTRADE database

Inflow of foreign direct investment (FDI) and rise in foreign collaborations: Endowed with the potential of low-cost manufacturing along with a high engineering skills workforce, India edges over other developing countries with respect to component manufacturing. Many international component manufacturers such as

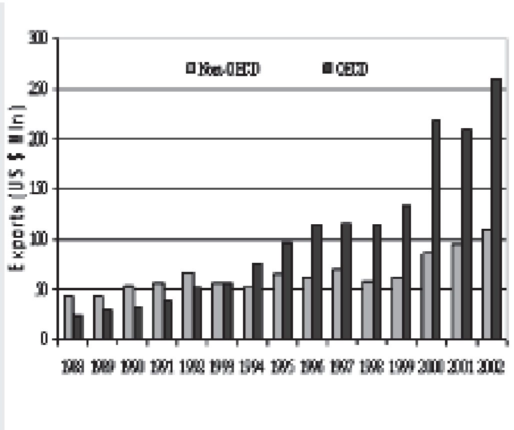


Fig 4-13.12: Direction of Exports
Source: *Own calculation from UN COMTRADE database*

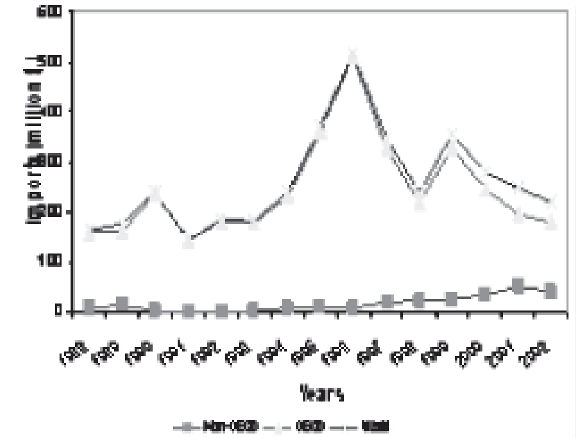


Fig 4-13.13: Imports of Automotive Parts: OECD vs. Non-OECD
Source: *Own calculation from UN COMTRADE database*

Delphi, Lucas-TVS, and Denso followed their customers (global car manufacturers) and started their manufacturing in India. This brought about a large inflow of FDI into the sector. This was primarily due to the 'follow sourcing' strategies of the global manufacturers present in India who encouraged their group companies or suppliers to create manufacturing bases in India, often in the form of joint ventures with Indian suppliers.

At present, there are over 450 collaborations with foreign partners from around the world (Table 4-13.05). Of this, about 64 percent are technical collaborations and another 11 percent are both technical and financial tie-ups. Many substantive component manufacturers have endeavored to secure international quality standards. A majority of ACMA members have already secured ISO 9001 certifications and a sizeable portion have got QS 9000 certification. Some of the auto components firms in India have achieved a great deal of success in terms of engineering capabilities and adaptation to the local requirements through local design.

Table 4-13.05: Foreign Collaborations of Indian Auto Component Companies

Nature of Collaboration	No. of Collaborations	% of the total
Technical	299	63.75
Financial	105	22.39
Technical and Financial	50	10.66
Joint Venture	14	2.99
Total	469	100

Note: Total number of firms is 365

Source*: Own calculation from ACMA's "Facts and Figures 2000-2001".*

Automobile Sector: Innovative Changes in Factory Sector over 2000-04

The automobile industry is one of the largest industries in India and has a strong multiplier effect on the economy through its forward and backward linkages with other sectors in the economy. This industry provided direct and indirect employment to more than 13 million people in 2006–2007. Moreover, there is a large unorganized sector also that contributes 30 per cent to total employment. Automobile industry plays a significant role in export from India. Production of motor vehicles grew at a faster rate during the first half of the present decade, but unevenly across the states in India. In terms of the number of factory units, Maharashtra has led the industry followed by Tamil Nadu and Delhi.

Parts and accessories experienced sharp growth especially since 2001 and motor vehicles too grew fast while the segment of bodies had flat and marginal growth. Productivity growth expressed in terms of materials consumed per output and also fuel consumed per output was very high for the integrated production system of motor vehicles while for bodies the productivity in fact dropped for the materials consumed per output, and strangely the productivity dropped on both two measures for parts and accessories production, done mostly under SME segment. The data for five years indicate organizational and process as well as system innovation had helped very significantly the motor vehicles producing large sector, however, small organizations could not achieve such innovations.

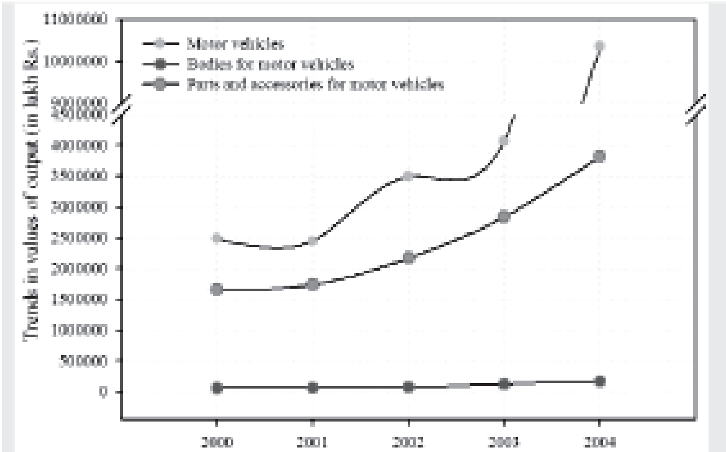


Fig. 4-14.01: Trends in values of output (in lakh Rs.)

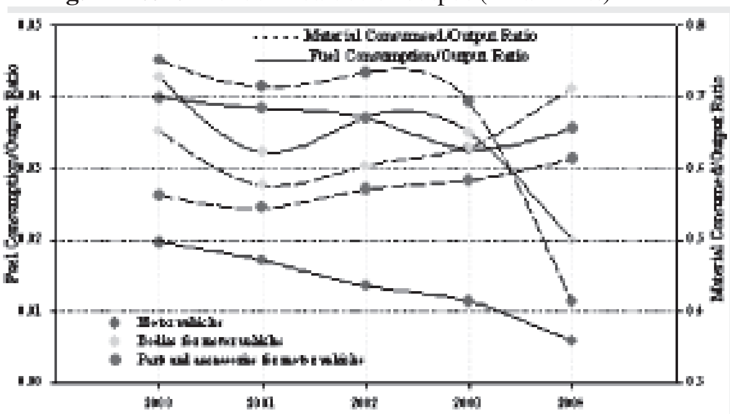


Fig 4-14.02: Fuel and Material Consumed per unit of output

Data from unit factory level suggest that organizational and systemic innovation played crucial role in shaping productivity and competitiveness outcomes. Wages remained higher during the four years 2001-04 in the states of Maharashtra followed by Jharkhand than in Haryana, Tamil Nadu; in West Bengal wages decreased, however, remained higher compared to wages in small units in Delhi, Gujarat, Rajasthan. Delhi with a fall in wage offered the lowest of all.

Value added per worker was the highest in Jharkhand where in fact it grew sharply during these four years, followed by Haryana and followed by Rajasthan and then Maharashtra. Worker productivity grew slowly in Rajasthan, then Haryana and at even lower pace in Maharashtra. West Bengal exhibits abnormally low and the lowest labour productivity. The fabulous gain in labour productivity in Jharkhand is not attributable to huge additional investment in capital machineries. In fact states with larger investment in capital machineries such as Uttar Pradesh, Andhra Pradesh, or Gujarat (even Maharashtra) experienced often very low labour productivity or gains in such productivity. Jharkhand's gain appears to be systemic and organizational.

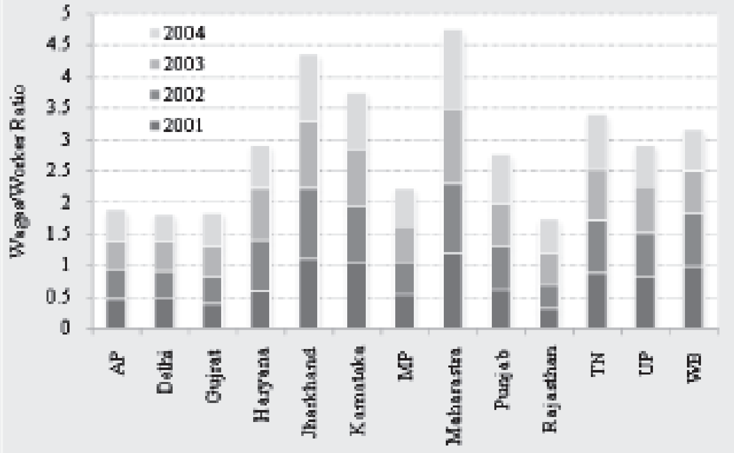


Fig 4-14.03: Wages per worker state wise

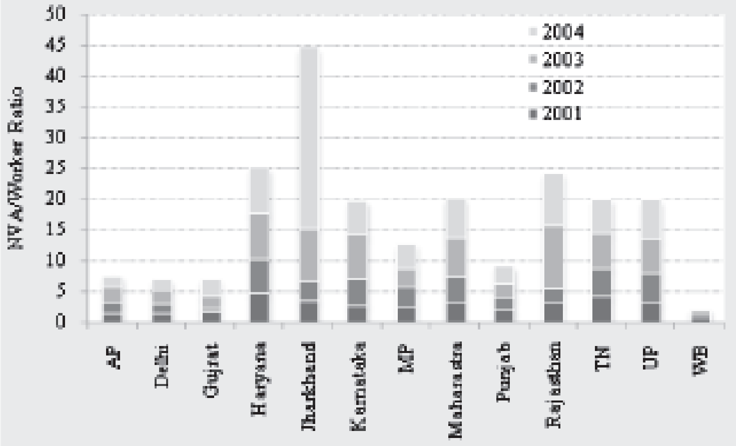


Fig 4-14.04: Net Value Added per worker

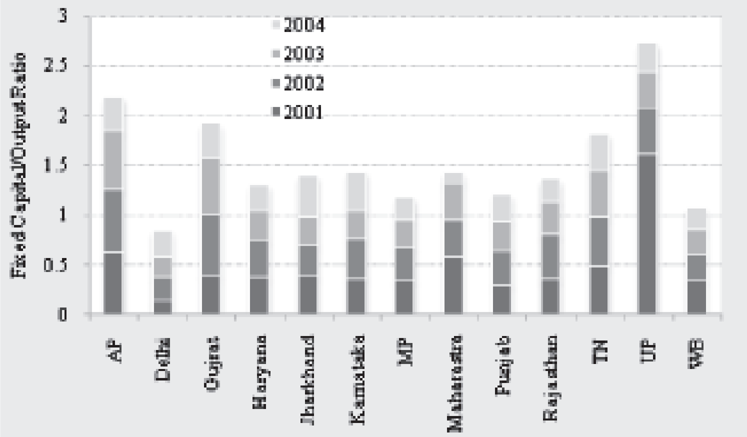


Fig 4-14.05: Fixed capital per output

Technology generation in the Indian tyre industry has witnessed a fair amount of expertise and versatility to absorb, adapt and modify international technology to suit Indian conditions. This is reflected in the swift technology progression from cotton (reinforcement) carcass to high-performance radial tyres in a span of four decades.

KEY FEATURES

Major players: At present there are 40 listed companies in the tyre sector in India. Major players are MRF, JK Tyres, Apollo Tyres and CEAT, which together account for 63 per cent of the organized tyre market. The other key players include Modi Rubber, Kesoram Industries and Goodyear India, with 11 per cent, 7 per cent and 6 per cent share respectively. Dunlop, Falcon, Tyre Corporation of India Limited (TCIL), TVS-Srichakra, Metro Tyres and Balkrishna Tyres are some of the other significant players in the industry. While the tyre industry is largely dominated by the organized sector, the unorganized sector is predominant with respect to bicycle tyres

Raw Material Intensive: The sector is raw-material intensive, with raw materials accounting for 70% of the total costs of production The industry is a major consumer of the domestic rubber market. Natural rubber constitutes 80% while synthetic rubber constitutes only 20% of the material content in Indian tyres. Interestingly, world-wide, the proportion of natural to synthetic rubber in tyres is 30:70

Production: Total tyre production figures in tonnage is 11.35 lakh M.T and total production (in nos.) of tyres in all categories is 811 lakh (2007-08)

Radialisation: Current level of radialisation includes 95% for all passenger car tyres, 12% for light commercial vehicles and 3% for heavy vehicles (truck and bus)

Import related trends: Restrictions have been placed on import of used /retreaded tyres since April 2006. Import of new tyres & tubes are freely allowed except for radial tyres in the truck/bus segment which has been placed in the restricted list since November 2008

Export: Total value of tyre exports in India is approximately Rs 3000 Crore (2007-08)

Demand: Some major factors affecting demand for tyres include level of industrial activity, availability and cost of credit, transportation volumes and network of roads, execution of vehicle loading rules, radialisation and retreading.

Source: *CMIE & ATMA*

R&D Efforts, Exports & Sales

A significant proportion of R&D effort is being carried out by the top ten companies. The proportion of raw material expenditure in relation to sales has been relatively stable for top ten companies while in the case of sectoral aggregates, it has witnessed a sharp spurt in 2007. The proportion of exports to total sales continues to be negligible.

Technology Generation

Technology generation is geared towards developmental research, involving the changing of tread design, reinforcement material etc. Most of the major players do not engage in basic research due to high costs. The source of technology for the domestic firms has been through reverse engineering, joint ventures and collaborations. The emphasis on applied research, setting up of well equipped in-house R&D centers by the companies, manned by experts have all helped in technology upgradation. Indian tyre industry has exhibited versatility in maintaining inflow of technology through foreign collaborations and tailoring the same to domestic needs. R&D is essentially business or market driven. However, raw material suppliers could also help in conceiving new projects. Tackling compound development and in-process problems has been main thrust of in-house R&D.

Table4-15.01: Evolutionary Phases of Tyre industry in India.

Phases	Period	Characteristics	Policy Regime
Phase-I	1920-35	No domestic production. Demand met through imports. Key players included Dunlop (U.K), Firestone & Goodyear (USA)	Liberal imports
Phase-II	1936-60	Domestic production begins by erstwhile trading companies: Dunlop, Firestone, Goodyear and India Tyre & Rubber Company	Imposition of tariff & non-tariff barriers on imports
Phase-III	1961-74	Indian companies - MRF, Premier & In check- enter manufacturing sector with foreign technology; licensing of additional production capacity	Regulation on capacity expansion and repatriation of profits of foreign companies; enforcement of export obligation on MNC; protection from external competition
Phase-IV	1975-91	Entry of large Indian business houses like Singhania & Modi & technical collaborations with MNCs, introduction of radial tyres, vertical integration and exponential growth in tyre production & exports	De-licensing of production, placing of imports under OGL with tariff & non-tariff barriers
Phase-V	1992 onwards	External trade liberalization & reduction in import duty; re-entry of MNCs either independently or in collaboration with Indian capital	Progressive reduction in import duty; liberalized imports

Source: *Mohanakumar & Tharian (2001)*

Automation

Tyre production traditionally, is multi-stage, with significant inter-stage differences in the intensity of labour requirement and a highly complex process involving the use of around 37 different materials, including rubber, steel, fabrics and vulcanizing materials. The production system has been traditionally very labour intensive. The automation of manufacturing processes has increased gradually, which has slashed the size of the workforce to a considerable degree and has effected a change in its composition. The degree of automation has been greater in the area of radial technology, while cross-ply technology is still labour intensive. Firms have been resorting to automation to tackle the problems related to labour unionization and indiscipline in the sector. The rationale provided by the firms for automation has been that high quality and standardization cannot be guaranteed with a labour intensive process.

Recent Initiatives

The tyre industry in India has had to grapple with raw material price volatility, rupee appreciation and cheap Chinese imports. In this connection, some recent initiatives by the government to facilitate the growth of the sector include no restrictions on the importing of all categories of new tyres except truck/bus (radial tyres), which has been placed in the restricted list from November 2008, no WTO bound rates for tyres and tubes, no restrictions on the import of all raw materials required for tyre manufacture except carbon black and increasing thrust on development of road infrastructure.

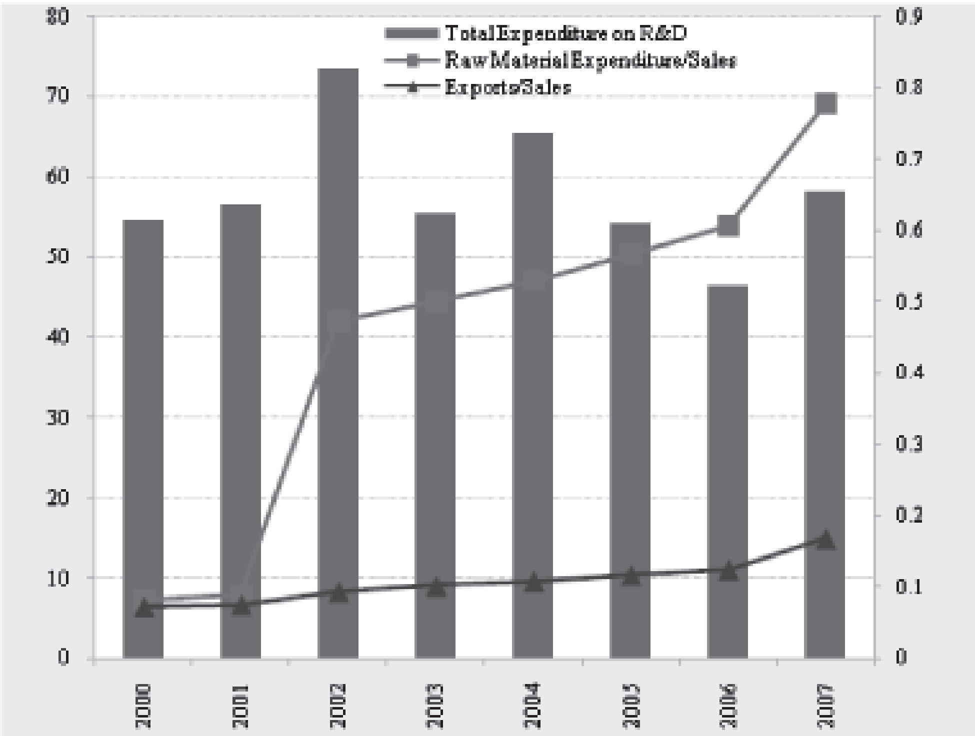


Fig 4-15.01: Comparison of R&D Expenditure, Exports, Sales & Raw Material Expenditure among all Companies (2000-07)

Note: The primary vertical axis depicts expenditure on R&D (at current prices) in Rs (crores),while the secondary vertical axis depicts the percentage of exports and raw material expenses in relation to sales. There are 40 listed players in the sector. Very few of these firms engage in R&D efforts.

Data Source: CMIE

The Indian tyre industry is expected to show a healthy growth rate of 9-10 per cent over the next five years, according to a recent study by Credit Analysis and Research Limited (CARE). While the truck and bus tyres are set to register a compounded annual growth rate (CAGR) of 8%, the light commercial vehicles (LCV) segment is expected to show a CAGR of about 14 %. The growth of the sector is closely linked to the expansion plans of the automobile companies, the government's thrust on development of road infrastructure and the sourcing of auto parts by the global Original Equipment Manufacturers (OEMs), exploring newer markets, increasing degree of radialisation, innovation and emphasis on product differentiation.

India's Telecommunications Industry

The phenomenal growth of the IT industry in India has brought to the fore the growing importance of India as a knowledge powerhouse. But this competitiveness is restricted to the services sector. In fact the service sector in general has come to occupy pre-eminent position in India's economy in terms of its contribution to overall GDP, exports and as a destination for Foreign Direct Investments. An interesting dimension of high technology production in India is that this capability is largely in the realm of services, rather than in manufacturing. And an industry where it is very clearly visible is in the area of telecommunication where a revolution of sorts is taking place.

Contribution of Telecommunications Sector to India's Economy

The sector accounts for about 4 per cent of GDP and with its rather high rate of growth contributes about 11 per cent of the growth in overall GDP of the country. Of the Information and Communications Technology (ICT) sector of the economy, it is again the communications sector that is more important. Around 63 per cent spending on ICT was done in communications (Figure 4-16.01).

The communication sector is composed of both services and equipment manufacturing although in the above characterization the data refers only to the services segment. The domestic production of telecom equipments has shown some impressive increases during the period since 2001, but even now (2006), it accounts for only about 15 per cent of the total telecom industry. Even then with some fluctuations the equipment sector is slowly decreasing its share in the total revenues of the telecommuni-cations industry.

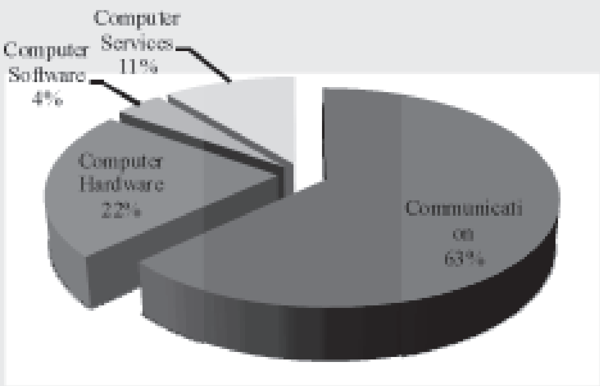


Figure 4-16.01: Distribution of total ICT spending in India, 2001-2006
Source: World Information Technology and Services Alliance (2006)

Dimensions of the Growth Performance of Telecommuni-cations Services

In India, the number of telephone subscribers has increased from 5 million in 1991 to 385 million by the end of 2008 showing an average annual growth rate of over 27 per cent. No other country in the world, other than China, has shown such high rates of growth. Tele-density which was below 1 telephone per 100 persons has now risen sharply to about 33 (Table 4-16.01). Among the infrastructure industries, telecommunications is the only industry that has shown significant improvements over the reform period. There are at least, seven dimensions of this growth performance that merit attention:

i) *Dominance of wireless technology than wire-line*: Almost the entire increase in the availability of telephones has been contributed by wireless technologies. India has one of the highest ratios of wireless to wire-line technologies, which is now almost 9. This rather heavy reliance on wireless technologies, while extremely positive from the availability point of view, has some implications for the diffusion of internet in the country.

ii) *Monthly addition to mobile subscribers and the growing market for telecom handsets*: There has been a steady increase in the average number of mobile subscribers per month since 2003. In 2003, on an average 1.5 million new subscribers were added to the existing stock. This has since increased to approximately 9 million per month in 2008. However, the very sharp reduction in the number of subscribers in March 2007 was due to a governmental security regulation. Consequently, a huge domestic market for telecom equipments has suddenly emerged in the country spawning the creation

Table 4-16.01: Trends in the number of telecom subscribers and Tele-density, 1991-2008
(in million numbers; Tele-density is number of telephones per 100 persons)

Year	Fixed	G. Rate	Mobile	G. Rate	Total	G. Rate	Tele-density	Rate of mobile to fixed
1991	5.07				5.07		0.6	
1992	5.81	14.6			5.81	14.60	0.67	
1993	6.8	17.04			6.8	17.04	0.77	
1994	8.03	18.19			8.03	18.09	0.89	
1995	9.8	22.04			9.8	22.04	1.07	
1996	11.98	22.24			11.98	22.24	1.26	
1997	14.54	21.37	0.34		14.88	24.21	1.56	0.02
1998	17.8	22.42	0.88	158.82	18.68	25.54	1.94	0.05
1999	21.59	21.29	1.2	36.36	22.79	22.00	2.33	0.06
2000	26.51	22.79	1.88	56.67	28.39	24.57	2.86	0.07
2001	32.44	22.37	3.58	90.43	36.02	26.88	3.58	0.11
2002	41.48	27.87	13	263.13	54.48	51.25	4.3	0.31
2003	42.58	2.65	33.58	158.31	76.16	39.79	5.1	0.79
2004	45	5.68	50	48.90	95	24.74	7.04	1.11
2005	49	8.89	76	52.00	125	31.58	10.66	1.55
2006	40.43	-17.49	149.5	96.71	189.93	51.94	17.16	3.7
2007	39.25	-2.92	233.63	56.27	272.88	43.67	25	5.95
2008	37.9	-3.44	346.89	48.48	384.79	41.01	33.23	9.15

Source: *Department of Telecommunications (2007) and Telecommunications Regulatory Authority of India (various issues)* of a significant manufacturing base. The South Indian city of Chennai has become a thriving cluster for mobile handsets manufacturing and this has important implications for the downstream industries such as the semi-conductor industry.

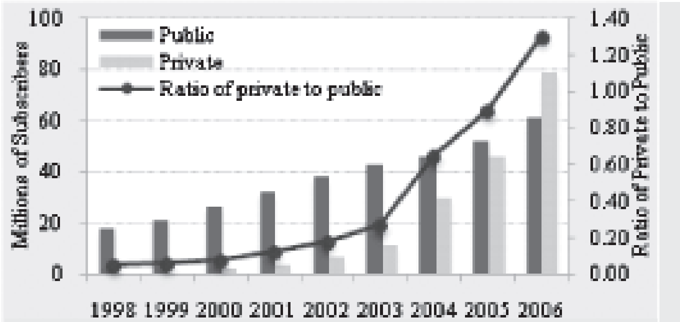


Fig 4-16.02: The rising privatisation of the Telecommunications services sector, 1995-2006

Source: *Department of Telecommunication (2007)*

iii) *Increasing privatization of the telecom services industry*: The distribution of telecom services in the country was entirely in the hands of the public sector for a very long time until the middle of the 1990s. The new telecom policy of 1994 changed all this. The share of the private sector in the overall telecoms industry has been rising (Fig 4-16.02) and the ratio of private to public has actually crossed unity in 2006. This again is due to the fact that the public sector is more dominant in wire-line (or fixed) and the private sector is dominant in the wireless (mobile) segment.

iv) *Competition in the provision of telecom services: (Fixed vs. Mobile and within Mobile GSM vs. CDMA)*: An interesting feature of the industry is that after a very long time, it has suddenly become very competitive. There are three dimensions to this competition. First, it is a competition between two standards or technologies, namely Global System for Mobile Communications (GSM) vs Code Division Multiple Access (CDMA) standards. Second, it is a competition between various service providers. Still another dimension is the type of market - Local telephone market; Long distance or national telecom services; and Foreign or the overseas market.

A. *Competition in Fixed and Mobile technologies:* The markets for mobile services are much more competitive than the one for fixed line services. In the latter the incumbent service provider, BSNL continues to have a lion's share of the market. However, the existence of mobile communication services have made the market for fixed line services contestable and as a result despite high concentration, prices of fixed telecom services kept falling or were kept under check over the last five years or so.

a) *Competition in fixed telephone services*: The market for fixed telephone services is much more concentrated than the one for mobile services (the Herfindahl Index for fixed services for the nation as a whole works out to 0.6899 while the one for mobile services work out to 0.1592). This national level picture hides the level of competition that exists at the sub national level. In order to gauge this, the structure of the market for fixed telecom services in each of the 28 telecom circles that the country is divided into, have been computed. As can be seen from Table 4-16.02, the market for fixed telecom services is highly concentrated in all the telecom circles, although in some of them, namely Delhi-NCR, Chennai, Madhya Pradesh, Mumbai, Punjab and Karnataka, the H Index has a value less

Table 4-16.02: Degree of competition in the market for fixed telephone services (as on December 31, 2008)

Telecom Circle	Fixed	Mobile
	H Index (Number of service providers)	H Index (Number of service providers)
Andaman & Nicobar	1.00(1)	1.00(1)
Andhra Pradesh	0.78(4)	0.19(6)
Assam	1.00(1)	0.25(6)
Bihar	0.98(3)	0.28(7)
Chennai	0.57(4)	0.20(6)
Chhatisgarh	0.67(2)	1.00(1)
Delhi	0.48(4)	0.18(6)
Gujarat	0.84(4)	0.21(6)
Himachal Pradesh	0.98(3)	0.26(7)
Haryana	0.92(4)	0.17(6)
Jammu & Kashmir	1.00(2)	0.37(5)
Jharkhand	1.00(1)	1.00(1)
Karnataka	0.64(4)	0.26(6)
Kerala	0.94(4)	0.19(6)
Kolkata	0.81(4)	0.20(6)
Madhya Pradesh	0.68(4)	0.24(6)
Maharashtra	0.86(4)	0.18(6)
Mumbai	0.55(4)	0.17(7)
North East-I	1.00(1)	0.28(6)
North East-II	1.00(1)	1.00(1)
Orissa	0.98(3)	0.24(6)
Punjab	0.69(5)	0.18(7)
Rajasthan	0.79(5)	0.20(7)
Tamil Nadu	0.86(4)	0.21(6)
UP (EAST)	0.90(4)	0.20(6)
UP (WEST)	0.93(4)	0.18(6)
Uttaranchal	1.00(1)	1.00(1)
West Bengal	0.99(3)	0.21(6)

Source: *Telecommunications Regulatory Authority of India (various issues)*

than 0.8000. There are two dimensions to this level of competition for fixed services. First, as has been argued earlier, the consumers are increasingly substituting mobile for fixed services, so the fixed service providers face intense competition from mobile services. Second, the existence of a telecom regulator too has acted as a check on the dominant service provider, BSNL from charging high prices.

b) *Competition in the mobile services industry*: If one computes the H-Index for the industry, at the national level (which is not exactly meaningful as some of the providers are only at specific telecom circles), it shows a mild increase: the H-Index for the industry increased from 0.1370 in 2002 to 0.1593 in 2007. However, this increase hides considerable variations at the circle level. Most of the service providers have focused on specific regional markets, with the exception of Bharti (the largest mobile service provider). In fact there are only four service providers who have a presence in at least 20 of the 29 circles. It is also interesting to see that the circles where BSNL has a monopoly position are also those with very low revenue potential. In other words, the private sector providers have positioned themselves in the most revenue earning circles. Also it is seen that it is in the circles with high revenue earning potential that one sees an increase in the intensity of competition- the metros of Delhi, Mumbai and Chennai for instance.

B. *Competition between mobile standards:* Since the introduction of mobile phones towards the latter half of the 1990s and until the end of 2002, the market was dominated by just one technology, the GSM. But in December 2002, a firm called Reliance Infocomm Ltd. launched CDMA services across 17 circles on a countrywide basis. Most Indian consumers are unaware of the nitty-gritty of the two technologies. So the deciding factor between the two technologies is often based on price and other conditions of offer. Given this sort of a possibility of perfect substitution between the two types of technologies, the existence of the two standards have made both the markets for GSM and CDMA services very competitive. What is being argued here is that despite being highly concentrated CDMA service providers have to compete with GSM service providers and this has prevented the CDMA service providers wielding any excessive market power.

One of the most important institutional requirements for competition to emerge and sustain is the introduction of number portability. TRAI had recommended in March 2006 to the Department of Telecommunications (DoT) that mobile number portability be introduced by April 2007. It appears that DoT has not accepted this recommendation citing technical reasons such as non-availability of dual technology handsets that can handle both GSM and CDMA handsets. It is generally held that major opposition to number portability came from GSM service providers while the CDMA providers were welcoming it with the hope that it would allow them to expand their market share.

v) *Price of telecom services*: Before the deregulation of the telecom services industry and indeed the entry of mobile service providers, the telecom consumers were periodically subjected to increase in the tariff. Based on estimates made by TRAI (2006), the minimum effective charge derived out of an outgoing usage of 250 minutes per month per quarter during 2003 through 2005 has been plotted for both fixed and mobile services. Although charges for both the calls have come down, a higher reduction is noticed in the case of mobile services.

The two state-owned service providers, BSNL and MTNL have launched “One India Plan” with effect from 01.03.2006. Under this plan a three minute local call and a one minute national long distance call (referred to as STD call) will cost only Re. 1. The “One India” plan, also, for the first time, takes away the distinction between the fixed line tariff and the cellular tariff and thus, makes the tariff “technology independent”. A similar plan has also been introduced for the customers of post paid and pre-paid mobile services of BSNL and MTNL.

vi) *Institutional support*: An interesting feature of the growth of telecommunications industry in the 1990s and beyond, compared to the earlier period, is the strong public policy support that the industry has received. It manifested in the form of the following acts/policies.

National Telecom Policy of 1994:

- Telecom Regulatory Authority Act of 1997
- New Telecom Policy of 1999
- Broadband Policy of 2004

Other policies having an indirect effect are: FDI policy, the Electronic Hardware Policy of 2003, and the Semiconductor Policy of 2007. Among these four main policies, the most important piece of legislation that is determining the growth performance of the industry is the establishment of a regulatory agency in the name of Telecom Regulatory Authority of India (TRAI).

ii) *Growing R&D outsourcing:* It is generally held that India has emerged as a major R&D hub. The total receipt on R&D services have doubled itself from US $ 221 million in 2004-05 to US $ 519 million in 2005-06. Telecom along with the pharmaceutical industry is a major recipient of these investments. The innovative performance of this segment can be gauged from the fact the number of US patents issued to inventors from India (including MNCs having operations in India) in the area of telecom technologies has increased from just 1 in 2001 to 13 in 2005 (Table 4-16.03).

Table 4-16.03: Patents issued to Indian inventors in the US, 2001-2005 (Number of patents)

Year	Multiplexing	Pulse or Digital	Telephonic	Telecommunication	Total
2001	0	1	0	0	1
2002	2	1	0	1	4
2003	3	1	0	1	5
2004	6	2	1	0	9
2005	7	2	1	3	13

Source: *Compiled from USPTO*

Growth Performance of Technology Oriented Industries in India: Case – Biotechnology

Biotechnology (BT) can be defined in at least two ways. It can mean any technique which uses living organisms or parts thereof to make or modify products, improve plant or animal productivity or to develop micro-organisms for specific use. This definition encompasses new biological tools as well as ancient uses. A second and narrower definition refers to new "high-end" biotechnology, involving recombinant DNA, cell fusion and novel bio-process engineering techniques such as gene transfer, embryo-manipulation monoclonal anti-bodies and so on. In India earlier the first definition was used, but it is being replaced gradually by the second one in the last few years.

Biotechnology Industry in India

At the industry level, the Indian biotechnology industry is still at a nascent stage. There are some success stories but still a lot needs to be done to make the industry move from being generic-focused to an innovative research-oriented one. Traditionally, India has a strong presence in generic drugs market and this has helped many Indian companies enter the market for biogenerics – generic therapeutic products. Agro-biotech is another important area where a number of products have been introduced in the market/fields. India's strong skills in the IT sector have played an important role for some Indian companies to diversify into bioinformatics. Many Indian companies are also offering attractive cost benefits to foreign companies through outsourcing, including contract R&D activities. However, there is still a lack of interest from the venture capitalists to pump in money in this sector (so far, some US$ 20 million). The main reasons cited for this lackadaisical attitude are: long gestation time in product commercialization, present small size of the domestic market for biotech products, inadequate protection for IPRs, and prevailing controversies over consumption/use of GM products.

Biotech industry ideally is not a homogenous sector like pharma or agro-industry. It has medical, agricultural and industrial biotechnology. Variations in the estimates of number of companies working in biotechnology gives an idea of the variety of products/activities included under it. The estimates range from 170 companies to 800 companies. While this confusion exists, the products based on BT have already reached the market under various categories and projections are that the industry is poised to grow at 20% annually. The increase in the number of companies in modern biotechnology is a post-1998 phenomenon. It is also observed that most of these new companies are involved in service sector, namely contract research, clinical research or bioinformation.

Like any other country which has succeeded in commercializing biotechnology, Indian biotech industry also could be observed to have three types of players:

- Startup companies with major focus on BT
- Established local companies who diversified to BT operations
- Multinationals

The first category is outcome of public spending on R&D, as happened in the US. There are two possible models. One like the US, the academic scientists enter businesses of their research results, by their own efforts. Some of the examples are: Avesthagengraine technologies, Strand genomics, Metabelix, Biomakso, Bhat Biotech, Shantibiotec, Preocentis, Mascon, Sudarshan Biotech, Virchow biotelch. Companies under the category 'Established local companies' are companies who have sufficient revenues from other business to try and enter BT area through investing in R&D initially. Some companies in this category are: Rallis, Biocon, Dr. Reddys Lab, Dabur, Bharat Serums etc. Monsanto, Pfizer, Astra Zeneca, Unilever, Dupont, Bayer, Eli Lilly, Hoechst Roussel Vet, Millipore, Novozymes etc. provide examples of MNCs' BT operations.

R&D intensiveness, long gestation periods, high investment, high value addition, heavy risk, stringent & evolving regulatory norms, uncertain levels of acceptance of BT products, ethical concerns etc. make BT very distinct from other technologies and especially from the point of view of investing in the field at research or commercialization level. The cost of product development in the bio-industries is high. Taking a new diagnostic kit from R&D to market might cost from \$2 to \$30 million and take up to 5 years. A new pharma product or crop variety might take 12-15 years and over \$ 200 million to reach the market.

A look at the allocations & expenditure by the Department of Biotechnology and other public bodies over the years gives evidence of the importance assigned by the Government and the commitment to make India one of the advanced countries in BT in the developing world. The government initiatives involve establishment of infrastructure for research in universities and public funded R&D institutions. The efforts included generation of manpower for research and also for absorption by industries in Biotechnology area. Department of

Biotechnology which played a pivotal role in these efforts has also created mechanisms for technology transfer and guidelines for regulation of GMOs and GMO based products.

Indian Biotechnology industry started after the research capabilities and infrastructure were developed. Most of BT commercialization occurred basically in two phases. First in the late 1980s in the form of low end biotech ventures, in the form of tissue culture companies and ELISA or other formats of in vitro diagnostics. But most of the companies which were active in these areas slowly disappeared by mid 90s. The second phase had companies which are mostly diversified pharma companies which expanded their operations in the area of biotechnology. The new Biotech companies started as dedicated units which were small and had narrow focus with a couple of products. The other breed of small companies mostly took a service role of doing research at the basic level or generating clinical data or bioinformatics.

Structure of Biotech Industry

There are about 130 companies which are privately owned, another 75 by public, 13 MNCs and around 10 companies about which information is not known. Out of the 300 odd companies 56% are small, ~15% are medium and 28% companies are large in size.

These companies do differ in their activities. Some of them undertake research, production and marketing, while some do only research or marketing. Some companies are involved in production and marketing. Distribution of these companies according to the product segments shows that they are spread over a wide range (from aquafeed to biotherapeutics). They are also spread over 10 States in India, though there is a higher concentration in southern and western states.

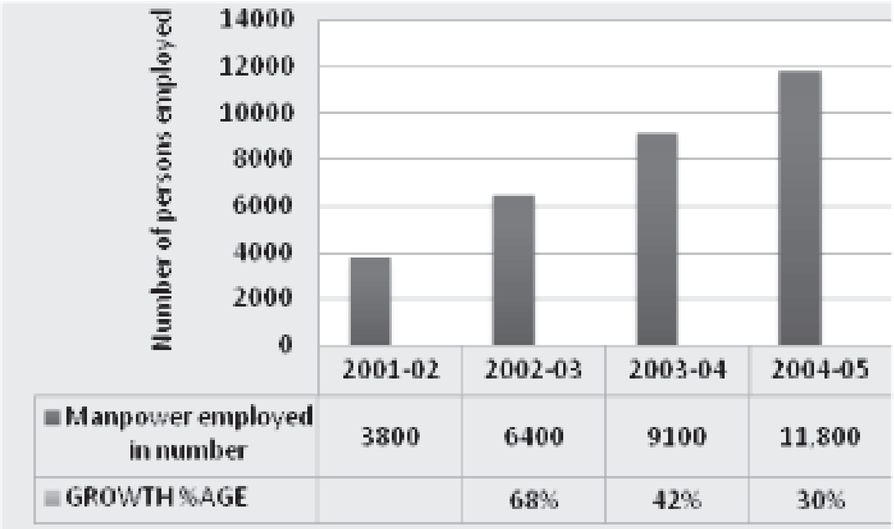
Manpower involved in the biotech industry has increased over the years. But still there is widespread dissatisfaction about the quality of manpower available to the industry in India.

Table 4-17.01: Area of activities of Biotechnology Companies in India

Area	No. of Companies	Percentage of Companies
Agriculture	61+2	28.38
Healthcare	96+1	43.69
Industrial enzyme	10	4.50
Bioinformatics	10	4.50
Environment	3	1.35
Instrumentation	2	0.90
Research biologicals	2	0.90
BT education	3	1.35
Contract research organization	3	1.35
Clinical research org.	7	3.15
Others	21	9.46
Services	1	0.45
Probiotics	2	0.90

Biotech Market in India

World market for biotech products is more than $100 billion and this is expected to grow to $170 billion by the year 2005. India's share in global biotech market is just 2%. The market for biotech products in India has increased five-fold from its size in 1997 and is at present valued at $2.5 billion



	2001-02	2002-03	2003-04	2004-05
Manpower employed in number	3800	6400	9100	11,800
GROWTH %AGE		68%	42%	30%

Fig 4-17.01: Manpower employed in BT Industry in India
***Source**: Behera (2006)*

Currently, there are some 220 companies engaged in biotechnology field and out of these some 50-60 companies are in modern biotechnology. According to a study made by the Confederation of Indian Industry (CII) of 52 Indian companies in the modern biotechnology segment, the total projected investment by these companies was over US $100 million in the last decade, and 32 were incorporated after 1998, showing increased interest in the industry. As per industry analysts, the domestic market for biotechnology products

Table 4-17.02: Contribution of BT Industry to GDP (2002-03 to 2005-06)

Year	GDP Current Prices*	Production Value	% of GDP
2002-03	2248614	2345	0.104
2003-04	2531168	3475	0.137
2004-05	2833558	4745	0.167
2005-06	3225963	8541	0.264
2006-07	Not Available	10272.9	

***Source:** Ministry of Finance Website*

in India was about US $2 billion in 2001. An EU study estimated the Indian biotech market worth US $1.5 billion in 2000, with human health-biotechnology, agri-biotechnology and veterinary-biotechnology products dominating the market (85 % share) and industrial products, R&D, supplies etc. accounting for the remaining share (15 %).

The biotechnology sector still has a minuscule share (< 1%) in the country's GDP. However, given the current growth potential (Table 4-17.02), this sector is certainly going to play a better role in India's economy.

Presently, foreign trade data for biotech products is not available separately (it is clubbed with the related areas, e.g. pharma products, seeds). The import and export data for pharmaceutical products (ITC/HS Chapter 30) and seed-sowing (ITC/HS Code 1209) are briefly mentioned below in Table 4-17.03:

The industry analysts have projected the consumption of biotech products in India at a level of US $4.27 billion by 2010, with sub-sector forecast for human and animal healthcare products ~ US $1.7 billion; agriculture products including seeds ~ US $1.4 billion; industrial products ~ US $978 million; and other products ~ US $145 million approximately. India is expected to have a market share of about 8% in the world market for biotech products by 2010. Importantly, the market segment for modern biotechnology products and services, i.e. products involving recombinant processes, is rather small at the moment, but this segment is expected to grow at a comparatively higher average annual rate of 35-40%. The Indian government has already granted marketing licenses for about 25 recombinant protein therapeutics. The present market for diagnostic/vaccines is valued at US $200 to US $500 million (depending upon how a biotech product is defined). Currently, 50%

Table 4-17.03: Import and export of pharmaceutical products and seeds for Fiscal year 2001-02

Business sector	% of imports	Change from previous year	Value in USD m	Main countries of origin
Imports				
Pharmaceutical products	0.32	+10.61%	166.56	Germany, Switzerland, USA
Seeds	0.028	+ 2.58%	14.28	South Korea, USA, Japan
Exports				
Pharmaceutical products	2.40	+11.7%	1055.80	Russia, Brazil, South Asian
Seeds	0.03	-8.38%	13.54	USA, Japan, Netherlands

Source: *Department of Commerce, Indian Ministry of Commerce and Industry*

of diagnostic products in India are imported, and as the healthcare market is expanding, there is a big potential to be tapped by foreign companies. In the agriculture segment, India, being one of the largest food producers, offers a huge market for agri-biotechnology products. Indian scientists have traditionally been introducing hybrid seeds using tissue culture techniques. However, the genetically engineered seed market is very small at the moment, worth an estimated $2.5 million out of a total seed market (worth US $450-500 million), but is expected to expand once controversies over GM products settle down. Furthermore, there are good market/R&D prospects for bio-pesticides and bio-fertilizers, bio-remediation products/processes, bio-fuels, bio-indicators, and bio-sensors.

Performance of Biotech Industry in India

The performance of the industry at the level of the economy can be evaluated in terms of – contribution to GDP, export, quantum of sales etc. It could also be evaluated at the level of technology in terms of – capability to innovate, nurture innovation and compete locally and globally through introduction of products.

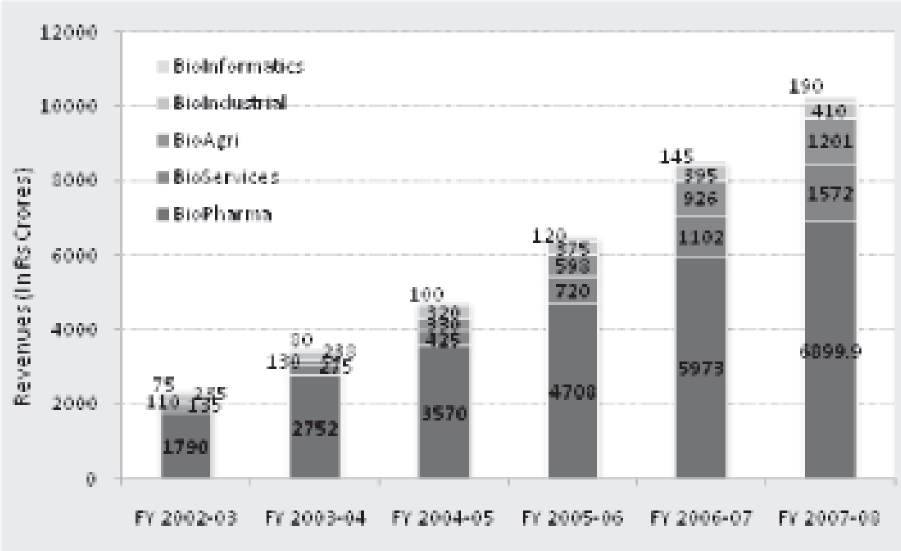


Fig 4-17.02: Growth of Revenue of Indian Biotech Industry 2002 2007

Apart from the products and processes for making products, the biotech companies also came out with public outputs in the form of publications and patents. There are 13 companies who have published 1,211 papers in different journals during 1990-2008. Of these Wockhardt has published 850 papers and Ranbaxy 250 papers.

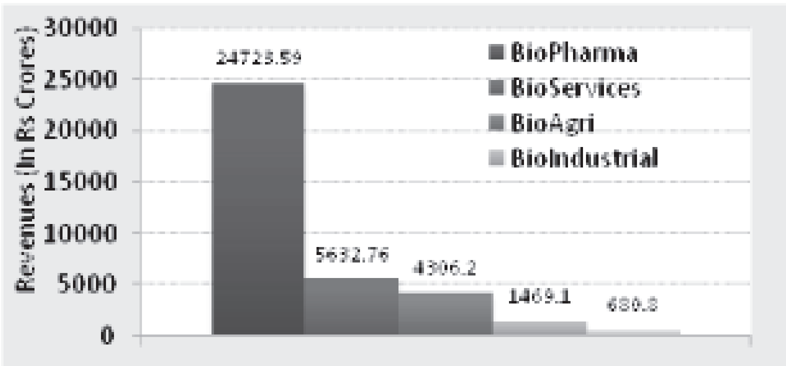


Fig 4-17.03: Forecast for 2015

The number of patents by Indian companies with interest in Biotechnology has increased significantly since 2004. This is partially due to the fact that the companies have realized the need to patent in the post-WTO era and also the data need to be looked into for patents which may not be in the area of Biotechnology.(as some of the companies in the list also have products by chemical/synthetic methods).

In addition to producing products and patenting/publishing they are reaching out to research organizations in the country as well as outside India for improving their competitive quality. This is done through alliances

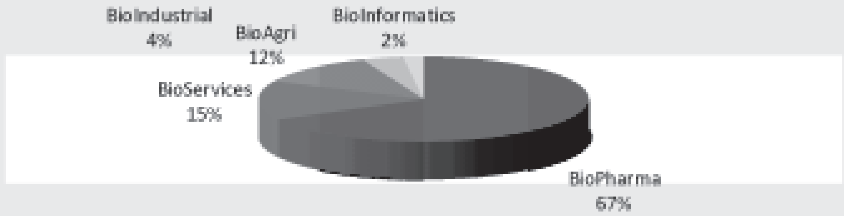


Fig 4-17.04: Revenue Share of Biotech Sectors 2007-08

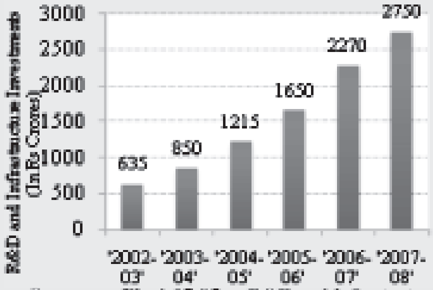


Fig 4-17.05: R&D and Infrastucture Investments

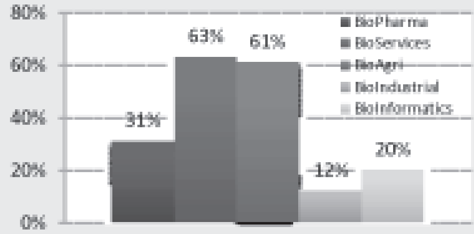


Fig 4-17.06: Compounded Annual Growth since 2003

Table 4-17.04: Biotech Industry Revenues from Exports and Domestic Sales

Sub Sectors	Exports		Domestic		Total
	Value (in crores)	%age	Value (in crores)	% age	Value (in crores)
BioPharma	3999.9	58	2900	42	6866.90
BioServices	1502	96	70	4	1572
BioAgri	51.78	4	1150	96	1201.78
BioIndustrial	30	7	380	93	410
BioInformatics	150	79	40	21	190

Source: *ABLE Survey - Biospectrum*

Table 4-17.05: Past Sales of Biotech Products in India and Future Sales Estimates (Rs. In Millions)

	Particulars of Biotech Sub-sectors	Actual Sales 2005	Future Sales Estimate 2010
1	Human & Animal Health care Products	35320**(37.6)**	93540 **(38.5)**
2	Agriculture (including traded varieties & hybrid seeds & other planting materials)	28880 **(30.7)**	78720 **(32.4)**
3	Industrial Products	28500 **(30.3)**	53590 **(22.1)**
4	Other Biotech Products	1300 **(1.4)**	17000 **(7.0)**
	Total	94000 **(100)**	242850 **(100)**
	In million US Dollars	**2186**	**5782**

Source: *P K Ghosh (2008)*

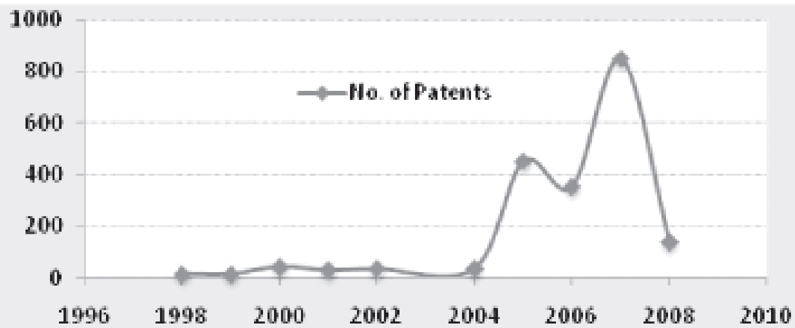


Fig 4-17.07: No. of Patents published by Indian BT companies (1998-2008), Note : Data for 2008 is incomplete.
Source: *Indian Patent Office site & Bhaswa C*

Table 4-17.06: Modern biotech products currently (2006-07) being produced in India

Sector	Major companies involved in production
Health Care Products	
Hepatitis B surface antigen	Transgene Biotech, Hyderabad ,Shantha Biotechnics, Hyderabad, Wockhardt Ltd, Aurangabad, Bharat Biotech International Ltd, Biological E Ltd Hyderabad, Panacea Biotech Ltd Delhi Serum Institute of India Ltd Pune.
Granulocyte Colony Stimulating Factor (GCSF)	Dr. Reddy's Laboratory Intas Ltd. Ahmedabad
Recombinant Erythropoietin alpha	Wockhardt Ltd. Aurangabad Intas India Ltd. Ahmedabad
Interferon alpha 2B & pegylated product	Shantha Biotehcnics Ltd. Hyderabad in *E. coli* strain.
Epidermal Growth Factor	Bharat Biotech Ltd. Hyderabad developed the product in E. coli.
Streptokinase	Shantha Biotechnics, Hyderabad; Bharat Biotech Hyderabad, developed this technology in *E. coli.*
Recombinant Human Insulin	Wockhardt India Ltd. Biocon India Ltd. .
Analogues CETUXIMAB	Biocon Ltd. Bangalore
RITUXIMAB	Dr. Reddy's Laboratory, Hyderabad
Several New Products & BioGenerics	Many companies are working on different compounds with/without collaborations to develop the technologies to market them. It is anticipated that several new products would be introduced during the next one decade. Concurrently, imports of many such products would continue.
Agriculture	
Bt Cotton	Mahyco – Monsanto Hybrid Seeds Pvt. Ltd. Mumbai Rasi Seeds Company Ltd., Nath Seeds Ltd. Aurangabad Syngenta India Ltd., Pune Ankur Seeds Ltd., Nagpur, Krishidhan Seeds Ltd., Jalna Ajeet Seeds Ltd., Aurangabad , JK Seeds, Secunderabad, Nuziveedu Seeds Co. Ltd., Hyderabad
Rice	Mahyco, Mahyco Research Foundation, Hyderabad Hybrid Rice International, Gurgaon
Tomato	Indo-American Hybrid Seeds, Bangalore , Proagro PGS (India) Ltd, Gurgaon
Corn/Maize	MAHYCO, Mumbai Syngenta India Ltd, Pune
Brinjal/Eggplant	Proagro PGS (India) Ltd, Gurgaon
Mustard	MAHYCO, Mumbai Proagro PGS (India) Ltd, Gurgaon .
Pigeonpea	MAHYCO, Mumbai
Cauliflower & Cabbage	Proagro PGS (India) Ltd, Gurgaon

Source: *Modified from Ghosh (2008)*

and also through patenting in other countries where they believe they have markets. Some of the major players in this respect are Dr. Reddy's, Ranbaxy, Wockhardt and Panacea Biotech. Major collaborating companies with Indian public research system have been Cadila, Bharat Biotech, Biological E and Shantha Biotechnics.

Apart from their activities in production, marketing and collaboration, the biotech industry in India also engages actively in participation in shaping policies for development of Biotechnology. They had been associated with resource allocation and prioritization by taking part in committees and task forces for these purposes. Through the Association of Biotech Led Enterprises (ABLE), they have been able to communicate the problems faced by the industry and have helped in the formulation of the new Biotechnology Policy. The industry's influence has led to the formation of new financing mechanisms like SBIRI and a new single window regulatory body NBRA. Their active involvement has led to the coming up with a type of Bayh Dole Act for India. Their vocal expression of the quality of the manpower developed has been taken seriously and made as one of the priority items in the new Biotechnology Policy.

Pharmaceutical Industry

Indian pharmaceuticals industry (IPI) is one of the largest and most advanced among the developing countries. It has over the years made significant progress in infrastructure development, technological capability and hence produced a wide range of products. The industry now produces bulk drugs under all major therapeutic groups. It has a sizable technically skilled manpower with prowess in process development and downstream processing. With a capital investment of about Rs. 2,150 crores it produced bulk drugs of value of Rs. 3,777 crores and formulations worth Rs. 15,860 crores in 1999-2000. It is estimated that the figures for the above could rise up to Rs. 4,344 and 17,843 crores respectively. The balance of trade in the pharma sector, which was Rs. 16.05 crores in 1960-61 and Rs. 650.6 crores in 1990-91, has grown to an imposing Rs. 5129.0 crores. There is an increasing interest and investments in R&D. Bulk drugs have grown at a rate of approximately 15%, formulations by 20% in the nineties. It provides employment for over 28,00,0000 persons both directly and indirectly (employment in ancillary industries and distribution trade). The industry is highly fragmented. It has about 250 large units and around 2,500 small units in operation. At present 70% of the requirement of the country in bulk drugs and all the demands for formulations are met by the domestic industry.

Structure

Data from CMIE on 597 listed companies were found and after deleting companies in Ayurvedic medicines 591 companies remained. A total of 46 companies (7.78%), of the 591 listed companies, are foreign companies and 200 companies have gone through some type of merger and acquisition activity in the past 12 years.

FDI inflow in the pharmaceutical sector for the years 1991-2008 exhibit a significant decrease in number of financial cases since 2004 and a similar drop in technical cases from 1999.

Performance

Both imports and exports grew at a significant rate over the past 7 years.

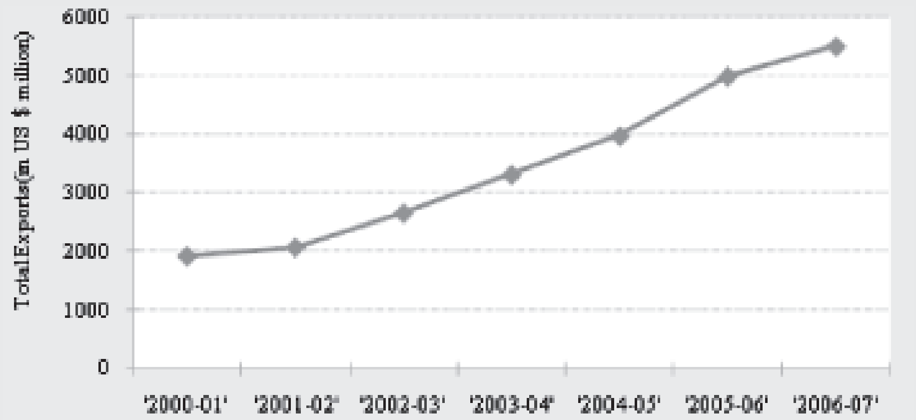


Fig 4-18.01: Total Exports by Pharma Companies during 2000-2007
Source: *Foreign Trade and Balance of Payments, CMIE, 2007*

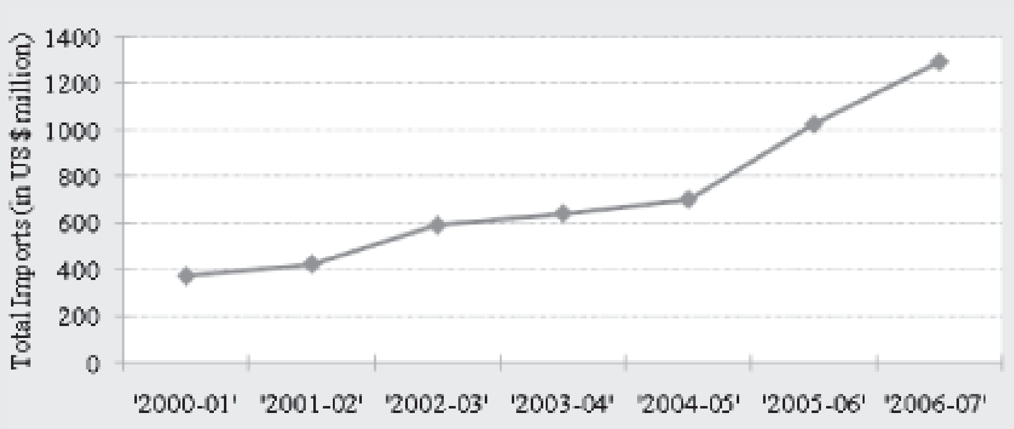


Fig 4-18.02: Trend in Total Imports by Indian Pharma Industry during 2000-2007
Source: Foreign Trade and Balance of Payments, CMIE, 2007

Figure 4-18.03 gives the market share of Indian and foreign companies from 1999 to 2003. It clearly shows that the market share of Indian companies has risen in this period.

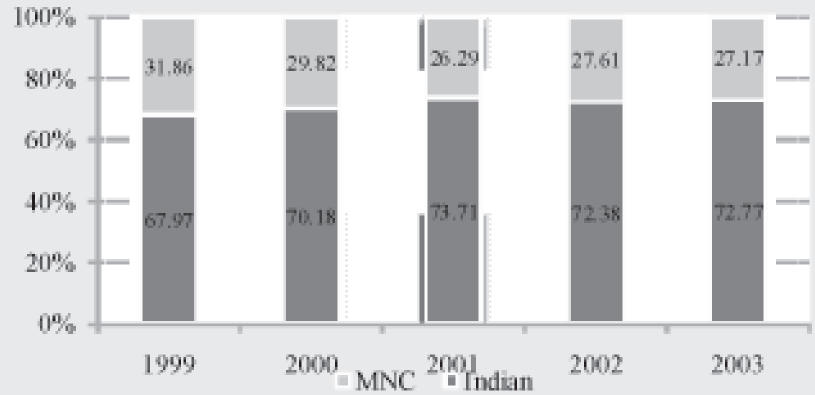


Fig 4-18.03: Market Share comparison between Indian and Foreign Companies
Source: *FICCI, 2005*

We find that there has also been an increase in both Annual Sales and Annual R&D Expenditure. R&D Intensity (RDI) is defined as the ratio of expenditures by a firm on research and development to the firm's sales and the exhibit presents the poor average states of affairs for 64 companies.

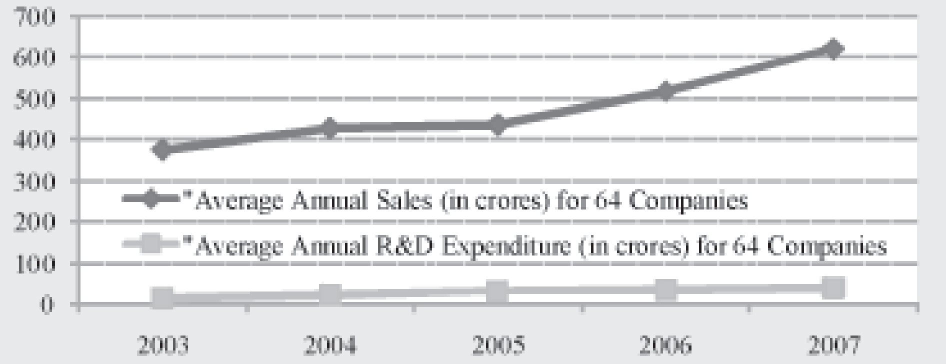


Fig 4-18.04: Average Annual Sales and Average RDE comparison (2003-2007)

Out of these 64 companies, 10 are foreign companies, 53 are private Indian companies while one is a joint state and private venture. A comparison shows that the average turnover of the 10 foreign companies is slightly more than that of the 53 Indian companies (Fig 4-18.06). However, when we compare Annual R&D Expenditure (Fig 4-18.07) and RDI (Fig 4-18.08), we find that there is a significant gap between the R&D inclination of Indian and foreign companies. The average RDE and RDI values for the Indian companies are higher than those of the foreign companies.

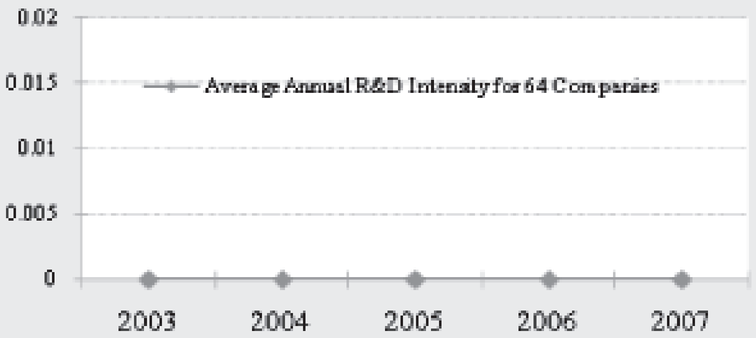


Fig 4-18.05: Average Annual R&D Intensity for 64 Companies (2003-2007)

Table 4-18.01 gives figures for the royalty paid by pharmaceutical companies from 2003-2007. Although the number of companies paying royalty has decreased slightly in 2007 when compared to 2003, there are still many companies who are acquiring and absorbing new technologies to compete in the global marketplace. This decrease could possibly be due to the increasing amount of money spent on in-house research facilities.

The patent data has been collected for these 591 companies from Ekaswa C, a database of the Patent Facilitating Centre (http://www.indianpatents.org.in/db/db.htm). The foreign MNC's whose patents have only come from their parent company, and none from Indian subsidiaries, have been placed in the zero patents category (Table 4-18.02).

Fig 4-18.06: Comparison of Annual Sales from 2003-2007 between Foreign MNC's and Indian Companies

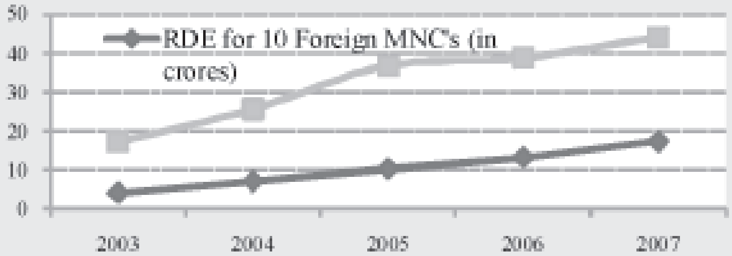


Fig 4-18.07: Comparison of R&D Expenditure from 2003-2007 between Foreign MNC's and Indian Companies

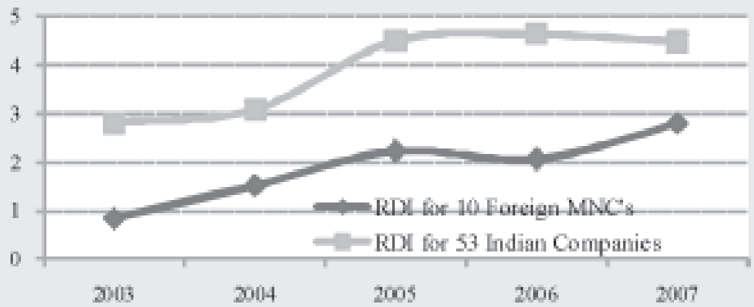


Fig 4-18.08: Comparison of RDI from 2003-2007 between Foreign MNC's and Indian Companies

Table 4-18.01: Royalty Paid by the Companies (2003-2007)

Year	No. of companies paying royalty	Royalty amount paid (Rs. Crores)
2003	52	40.08
2004	53	42.81
2005	53	38.99
2006	46	51.80
2007	46	53.19

Source: *Prowess database, CMIE, 2008*

Table 4-18.02: Average Number of Patents Published by the Companies (2005-2007)

Average No. of Annual Patents	Number of Companies
0	517
<1	16
1-2	14
2-5	14
5-10	10
10-20	7
20-40	9
40-75	3
>75	1

Source: *Ekaswa C, Patent Facilitating Centre http://www.indianpatents.org.in/db/db.htm*

Structure and Performance of Small and Medium Scale Pharmaceutical Firms

The pharmaceutical SME sector is a fragmented and heterogeneous sector, with firms having very varied levels of technological capability and expertise. The upper cut-off value of plant and machinery for pharmaceutical SSIs has been gradually increased from Rs 1million in 1975-76 to Rs. 2 million in 1980-81, then to Rs 10 million in 1999-00 and finally to Rs 50 million in 2003.

Brief Profile

Total strength: Around 6470 units, comprising both registered and unregistered units. Accurate and recent post-patent regime estimates not available.

Type of Units: Mostly bulk drug units, formulation units and units producing intermediates.

Therapeutic Expertise: Majority of the small firms produce anti-infectives, anti-bacterials, nutritional supplements and anti-inflammatory drugs. A few medium scale firms manufacture some specialized drugs.

Contribution to total pharmaceutical production: 42% of total .**Geographical concentration**: Maharashtra, Gujarat, Andhra Pradesh & U.P.

Technological activities: Manufacture of generic fixed dose combinations and conventional dosage forms (formulation units). Process related activities related to generic drugs by small processes and new processes by some medium scale firms (bulk drug units).

Quality certification: Local GMP until Schedule M was introduced in 2001. Deadline later extended to June 2005. Significant percentage of the units has been unable to comply with new Schedule M requirements and up-gradation as yet. Najma Heptullah Subordinate Committee report on issues related to Schedule M compliance tabled in Parliament recently.

Post-patent regime strategies: Contract manufacturing of generics for the organized sector, mostly in the form of sub-contracting and loan-licensing activities.

Problems faced by sector: Gradual reduction of list of drugs under DPCO, inability to generate investments for Schedule M requirements and automation, paucity of skilled labour, lack of consistency and standardization in drug quality requirements, imitation not feasible under new patent regime, under-utilization of plant capacity, lack of adequate information about the new patent regime and its consequences .

Strengths: Provides life saving drugs at affordable prices, particularly in rural India.

Initiatives by the government: Development of clusters through involvement of industry associations, interest subsidy and provision of soft loans for technological up-gradation through PTUF scheme, providing technical and marketing related skills, proposal to build common quality control and testing facilities for small firms.

Source: *Planning Commission report 2006; ASI database; MSME database, Third Census*

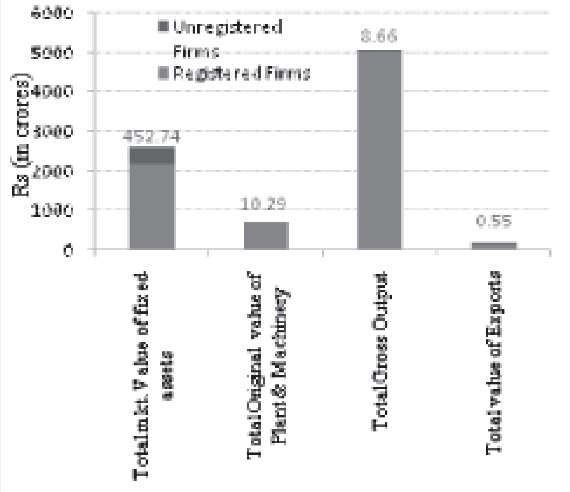


Fig 4-19.01: Total value of Assets, Exports & Output of Pharmaceutical SMEs (in current prices)

Source: *MSME database, Third Census*

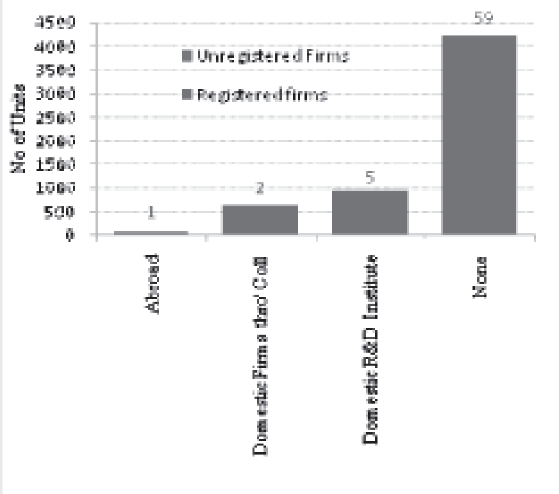


Fig 4-19.02: Sources of Technical Know-How for Pharma SMEs.

Source: *MSME database, Third Census*

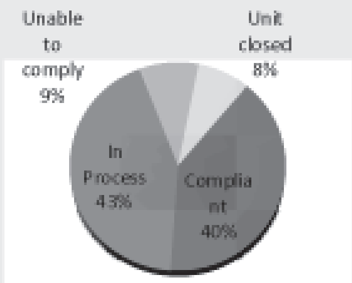


Fig 4-19.03: GMP compliance status of SSI units in pre-patent regime

Note: The data refers to GMP compliance status in the period before the revised Schedule M protocols were made mandatory. Schedule M compliance was made mandatory for firms June 2005 after several extensions. Also, the data broadly refers to the compliance status in the pre-patent regime.

Source: *Planning Commission report 2006*

Table 4-19.01: Total strength of SSIs and SSSBEs in Indian Pharmaceutical Sector along with strength of work force.

Type of Unit	SSI	SSSBE	Total no. o employee
Registered	5676	727	70297
Unregistered	52	15	321
Total	**5728**	**742**	**7061**

Source *MSME database, Third Census.*

New Initiatives for SMEs

- Development of Pharmaceutical SEZs which facilitates the availability of infrastructure, market access, boosts capacity utilization, encourages exports and facilitates excise relief

- The National Pharmaceutical Policy 2006, has included some initiatives like reduction in excise duty from 16% to 8%, enhancing the exemption limit for excise duty from Rs.10 million to 50 million and setting up of a dedicated research fund, Pharma Technology Up-gradation Fund (PTUF), for providing interest subsidy on borrowings to SMEs towards building necessary infrastructure for standardization of their products.

- The Najma Heptullah Subordinate Committee on Schedule M has recommended the adoption of clear guidelines on Schedule M related up-gradation of firms. The Committee has recommended some flexibility with respect to space stipulations and air handling units and has noted that 80% of the Schedule M norms required change in mindset of technical persons and good practices and only 20% of the norms required change in infrastructure facilities, which entailed some financial investment. The Committee also referred to the proposal initiated by the Department of Chemicals and Fertilizers, pending approval by the Planning Commission, which would provide a 5% interest subsidy on an amount up to Rs 1 Crore. The Committee also recommended the promotion of Credit Linked Capital Subsidy Scheme (CLCSS) and Credit Guarantee Fund Scheme, rationalization of fiscal incentives and stated that it was in the process of gathering statistics pertaining to Schedule M up-gradation and related closure of small pharmaceutical firms.

- Establishing formal linkages between Pharma SMEs and pharmaceutical research and educational institutions for technical up-gradation and know-how related to R&D, and auditing and monitoring of quality control. The government has initiated a step in this direction through the efforts of National Institute of Pharmaceutical Education and Research (NIPER) and through the building of a specimen Schedule M unit and utilizing the efforts of the institute to act as an intermediary organization in providing technical support and training under the new regulatory regime.

Regulatory Issues in the Indian Pharmaceutical Industry

This section undertakes a review and assessment of regulatory issues in the Indian pharmaceutical industry. Understanding the current regulatory scenario in this sector is extremely crucial in the context of the rapid and ongoing changes at the global level, largely with reference to good manufacturing practices (GMP), good clinical practices (GCP) and good laboratory practices (GLP) and also due to the onus on the Indian regulatory bodies to ensure the production and marketing of safe and efficacious drugs at affordable prices in the domestic sphere and to sustain current growth prospects in the global markets.

Temporal Progression of Drug Policies and Acts

The Patents Act of 1970, Drug Price Control Order 1970, Foreign Exchange Regulation Act 1973 & New Drug Policy, 1978 helped in the building of indigenous capability and availability of quality drugs at low prices. DPCO 1987 heralded increasing liberalization and reduction of the number of drugs under price control to 143. DPCO 1995 focused on regulation of monopoly, decreased the number of drugs under price control to 74 and led to the inclusion of products manufactured by small scale producers under price control list.

In 1997, the National Pharmaceutical Pricing Authority was constituted in order to administer DPCO and deal with issues related to price revision. The Pharmaceutical Policy 2002 carried forward earlier governmental initiatives in terms of ensuring quality drugs at reasonable prices, strengthening of indigenous capability for cost-effective production, reducing trade barriers and providing active encouragement to in-house R&D efforts of domestic firms. In 2003, the Mashelkar Committee undertook a comprehensive examination of the problem of spurious and sub-standard drugs in the country and recommended a series of stringent measures at central and state levels. The regulatory body came in for censure with the committee noting that there were only 17 quality-testing laboratories, of which only seven laboratories were fully functional. The National Pharmaceuticals Policy 2006, among other initiatives, has proposed a slew of measures such as increasing the number of bulk drugs under regulation from 74 to 354, regulating trade margins and instituting a new framework for drug price negotiations in a move to make drugs more affordable for the Indian masses.

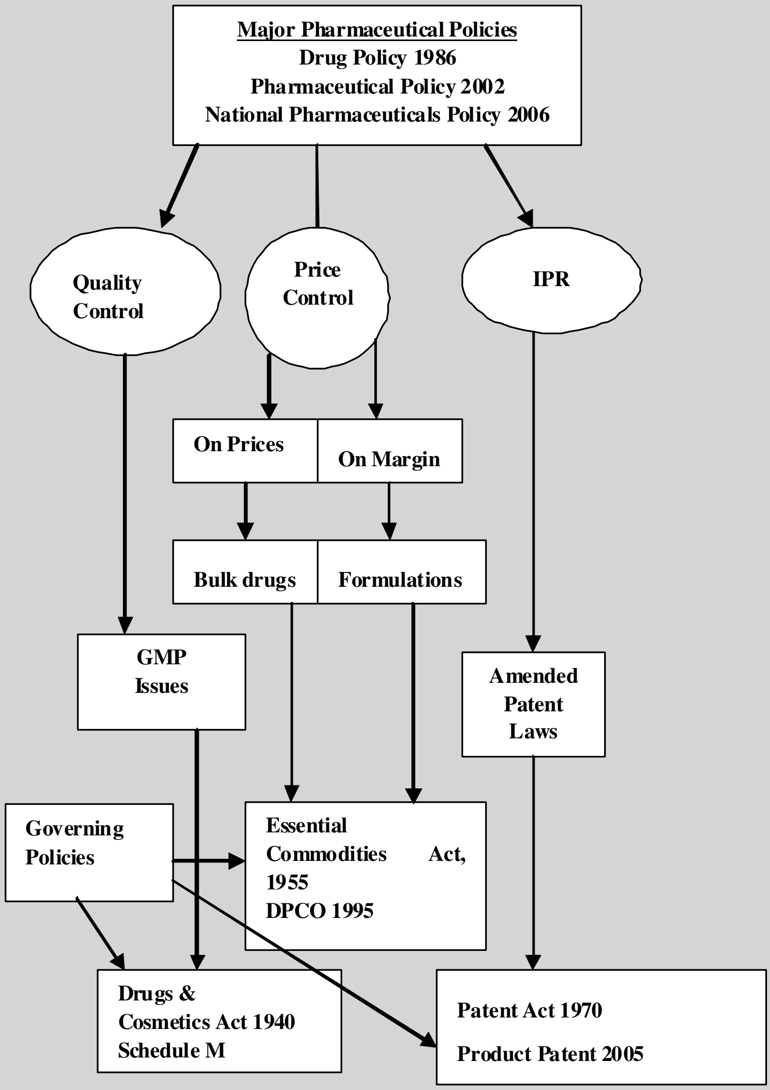


Fig 4-20.01: Regulation in Indian Pharmaceutical sector

Patents and Data Protection related Issues

The Indian Patent Act, 1970 was amended through the Patents Amendment Act (2005). A technical expert group was constituted under the chairmanship of Dr. R. A. Mashelkar, the then Director General of the CSIR. The Mashelkar Committee decision was that it would be TRIPS incompatible to limit the grant of the patent for pharmaceutical substance to new chemical entity or new medical entity involving one or more inventive steps and also that it would not be TRIPS compatible to exclude microorganisms from patenting. The committee opposed the granting of frivolous patents and ever-greening and recommended the formulation of detailed guidelines to ensure that only those patents proving ‘substantial human intervention’ and ‘utility’ were granted. As per the provisions of Article 39(3) of the TRIPS Agreement, member countries are obliged to provide protection to regulatory data submitted for receiving market approval of pharmaceutical products under specific circumstances. The Government of India constituted an expert committee under the chairmanship of Mr Satwant Reddy to formulate adequate steps to deal with the issue of data protection. The Reddy Committee report, brought out in 2007, stated that in the context of pharmaceuticals, the present legal regime was not adequate to address the issues relating to data protection with respect to Article 39 (3) provisions. It also called for more clear and stringent mechanisms within the Drugs and Cosmetics Act to ensure that undisclosed test data was not put to unfair commercial use in India.

Major Regulatory Bodies

- Ministry of Health & Family welfare focuses on pharmaceutical issues in the context of public health policies. The **Central Drugs Standards Control Organization** (CDSCO) and state regulatory authorities, located under the aegis of MOHFW, have authority to issue licenses and monitor standards of drugs, cosmetics, medical devices and diagnostics
- The **Department of Chemicals and Petrochemicals** oversees policy, planning, development and regulatory activities pertaining to chemicals, petrochemicals and pharmaceutical sector. It looks at regulation in the context of industrial policy. The **National Pharmaceutical Pricing Authority** (NPPA), instituted in 1997, fixes or revises the prices of decontrolled bulk drugs and formulations at judicious intervals; periodically updates the list under price control through inclusion and exclusion of drugs in accordance with established guidelines; maintains data on production, exports and imports and market share of pharmaceutical firms; and enforces and monitors the availability of medicines in addition to imparting inputs to Parliament on issues pertaining to drug pricing. Both these bodies are located under the aegis of Ministry of Chemicals and Fertilizers.
- The **Department of Industrial Policy and Promotion** and the **Directorate General of Foreign Trade**, located under the aegis of Ministry of Commerce and Industry monitor issues related to drug exports, patent regulations and government support to the industry.
- With respect to licensing and quality control issues, market authorization is also regulated by **Department of Biotechnology**, Ministry of Science and Technology and **Department of Environment**, Ministry of Environment and Forests.

Drug Pricing

Price control on medicines was first introduced in India in 1962 and has subsequently persisted through the Drug Price Control Order (DPCO). As per the directive of NPPA, the criterion for price regulation is based on the nature of the drug in terms of whether it has mass consumption and in terms of absence of sufficient competition for the drug. The year 1978 witnessed selective price controls based on disease burden and prevalence. The list of prices under DPCO subsequently witnessed a gradual decrease over a period of time. Around 80% of the market, with 342 drugs, was under price control in 1979. The number of drugs under DPCO decreased from 142 drugs in 1987 to 74 in 1995. Drugs with high sales and a market share of more than 50% are targeted for price regulation. These drugs are referred to as scheduled drugs. The NPPA also regulates the prices of bulk drugs. The MRP excise on medicines was levied by the Finance Ministry in 2005. The objective was to increase revenue and lower prices of medicines by using fiscal deterrent on MRP. This change may have had some impact in terms of magnifying the advantage to industries located in the excise free zones. This also succeeded in attracting some small pharmaceutical firms to these zones. As the report by NIPER, submitted to the Ministry of Chemicals and Fertilizers in 2007 points out, this may have led to tax disparities among firms located in tax exempt zones and tax non exempt areas. This has also led to small firms in non-exempt areas requesting for tax subsidies from the government. For drugs not under price control, firms can set the Minimum Retail Price (MRP). The NPPA only intervenes in cases where drugs have significant sales and where the annual price increases by 10%. This is a recent development, which came into effect in 2007, as in the past the NPPA would intervene only if the annual price increases were more than 20%. This development indicates the heightened sensitivity of the government towards consumer access to medicines at reasonable prices and keeping a check on profit mongering by the industry.

Good Manufacturing Practices (GMP)

- Constitute an international set of guidelines for the manufacture of drugs and medical devices. GMP protocols are being followed in over 100 countries either in the form of regulations (Japan, Korea & U.S.), or Directives (EU) or Guides (UK).
- Objective is to minimize risks with regard to manufacturing, packaging, testing, labelling, distributing and importing of drugs, cosmetics, medical devices, blood and blood products.
- Protocols concerned with parameters such as drug quality, safety, efficacy and potency.
- WHO GMP protocols instituted in 1975. India is one of the signatories to the certification scheme. The certificate, which has a two-year validity may be granted both by central and state drug authorities in India after inspection of premises.

International Regulatory Certification

- A large number of domestic players are seeking international regulatory approval from agencies like US-FDA, MHRA-UK, TGA-Australia & MCC-South Africa in order to export their products, mostly generics, in these markets.
- India has the distinction of having the largest number of US-FDA approved manufacturing units, totaling 100, outside of the United States.
- Around 814 manufacturing units in India have WHO-GMP certification. Most of these units are concentrated in the states of Gujarat (307), Maharashtra (136), Andhra Pradesh (138) and Karnataka (52). WHO GMP certification is essential in order to compete for exports to CIS countries and other Asian markets.

Recent Trends

Clinical Trials to establish the safety and efficacy of drugs constitute nearly 70% of research and development costs. The clinical market in India is expected to grow at a consistent rate of 20-25 %. The recent regulatory revisions in the pharmaceutical industry and stricter patent laws have made it easier to conduct trials, making it the fourth largest market in terms of volume. India's clinical development sector has witnessed a tremendous growth in recent times. In 2005, the revenues from contract R&D for international sponsors totalled $100 million and the sector enjoys an annual growth rate of about 40 per cent. Several global Contract Research Organizations (CROs) have entered the Indian market in the last few years. Some of these have also entered into alliances with local CROs. In 2005, Drugs Technical Advisory Board (DTAB) made GLP practices mandatory for all laboratories and in-house units of pharmaceutical firms and CROs. In 2007, norms pertaining to the Phase lag have also been revised and Schedule Y now permits Phase I trials to be carried out concurrently in India along with the rest of the world. For an efficient and ethical growth of the clinical trials industry, the appropriate mechanisms to be adopted include the presence of a strong centralized regulatory regime to effectively monitor GCP guidelines and ensure transparency in the functioning of Institutional Ethics Committees (IECs).

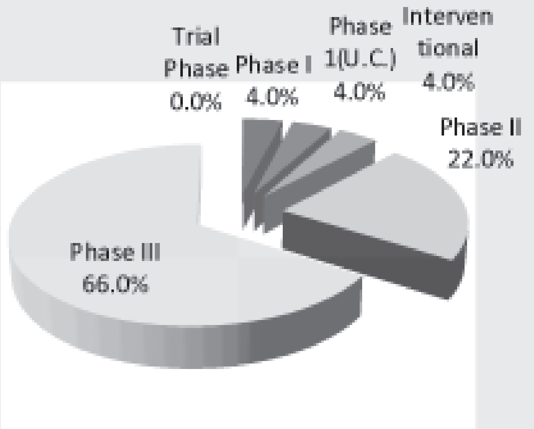


Fig 4-20.02: Phase-wise break-up of clinical trials carried out in India
Source: *FICCI-2005*

Table 4-20.01: Clinical trial cost differences in India and United States

	United States	**India**
Phase 1	$ 20 mn.	< $10mn.
Phase 2	$ 50 mn.	< $30mn.
Phase 3	$ 100mn.	< $60mn.

Limitations of the Present Regulatory Regime

- Proliferation of spurious and substandard drugs in the Indian market.
- Dual licensing mechanism acts as a deterrent to uniform implementation of regulatory procedures.
- Lack of transparency in licensing procedures.
- Inadequate regulatory expertise and testing facilities to implement uniform standards.
- Need for greater thrust on institutional support to small scale firms to enable speedy implementation of Schedule M up-gradation and standardization of drug quality.
- Need for greater clarity on patentability of pharmaceutical substances and conditions under which firms can apply for compulsory licenses to prevent legal battles between local firms, MNCs and civil rights groups.
- Need for greater coordination and transparency among different ministries concerned with drug regulation.

New Initiatives

- Integrated regulatory system through the constitution of a National Drug Authority so that quality regulation is performed by a centralized body.

- Establishment of pharmaco vigilance centres at national, zonal and regional levels to monitor adverse drug reactions.
- Move to bring nearly 374 bulk drugs under price control and regulate trade margins.
- Capability strengthening to monitor clinical trials, including the setting up of the Clinical Trials Registry of India (CTRI).

Indian Herbal sector

India perhaps has the world's oldest as well as largest tradition of traditional systems of medicine. The term Indian Systems of Medicine covers both the systems which originated in India as well as outside but got adopted in India in course of time. These systems are Ayurveda, Siddha, Unani, Homoeopathy, Yoga and Naturopathy. They have become a part of the culture and traditions of India. India with its strong base in traditional knowledge on herbal medicine and vast plant biodiversity has a great potential in this sector.

AYUSH Health Network

Hospitals	61561
Dispensaries	21437
Registered Medical Practitioners	725338
Institutionally qualified RMP	506229
Non institutionally qualified RMP	219109

Infrastructure

The health services provided by this network largely focus on primary health care. The sector has a marginal presence in secondary and tertiary health care.

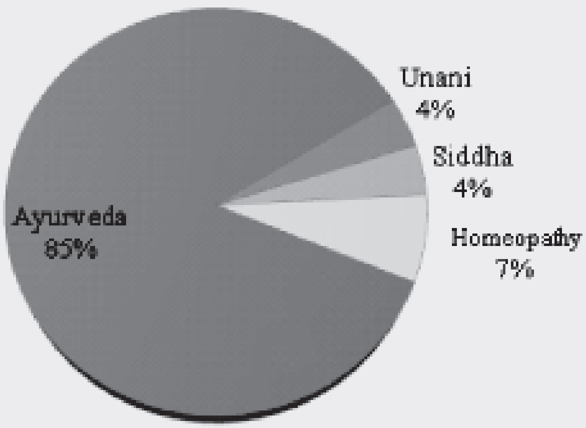


Fig 4-21.01: Proportion of manufacturing units of different systems

***Source**: Dept of Ayush (data as on 01/04/07)*

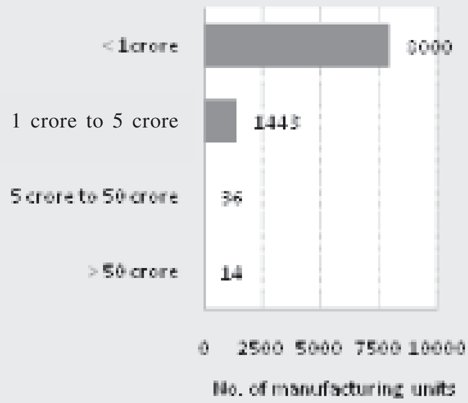


Fig 4-21.02: Herbal manufacturing units

***Source**: Demand & supply, MMPB 2008*

Industry

The recent upsurge in use of herbal medicines has led to a sudden increase in herbal manufacturing units. In India, there are about 14 well-recognized and 86 medium scale manufacturers of herbal drugs. Other than this about 8,000 licensed small manufacturers are on record. In addition, thousands of Vaidyas also have their own miniature manufacturing facilities. The estimated current annual production of herbal drug is around Rs. 3,500 crores.

Whereas, the largest number of such manufacturing units are registered as 'pharmaceuticals', there are others that are engaged in making plant based cosmetics and food supplements. Even within the pharmaceutical units, there are manufacturers of Ayurveda, Siddha, Unani and Homeopathic formulations (Fig.4-21.01) with a few even making western medicines. Another group of manufacturing unit are engaged in making extracts and distilling oils for use by other industries and for exports.

Government Stand

Ayurveda, Unani, Siddha, Naturopathy, Homeopathy and Yoga are all recognized by the Government of India. The first step in granting this recognition was the creation of the Central Council of Indian Medicine Act of 1970 while the Central Council of Homeopathy was constituted in 1973.

A separate Department was constituted in November 2003, named as Department of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy (AYUSH).

To ensure and enhance the quality of ASU medicines, the Government of India has notified Good Manufacturing Practices (GMP) under Schedule 'T' of the Drugs and Cosmetics Act 1940.

IPR Issues

The Legal protection accorded to traditional knowledge in India is through its:

- Patent laws with the Amendment Act of 2005, which contain provisions for mandatory disclosure of source and geographical origin of the biological material used in the invention while applying for patents and also allow the composition of a drug to be patented.
- The Indian Biodiversity Act 2002, which follows the Convention of Biological Diversity guidelines regarding benefit sharing.
- India has established a central authority "National Biodiversity Authority" to monitor and control foreign access to Indian biological resources including traditional medicine.
- Development of a database called "Traditional Knowledge Digital Library" (TKDL) that will document as well as establish the prior art to hinder patenting Indian knowledge. This task has been entrusted to NISCAIR, a CSIR laboratory.

Loss to the country

The rich heritage of traditional systems of medicine and vast repository of natural resources put India at a prominent position in global scenario of herbal sector. But to revitalize these traditions, the route employed is being considered as erratic. Medicines produced in large scales are generally being compromised on their quality resulting in poduction of substandard or spurious drugs. There is no due to absence of strict regulation way to keep a rein on it. This has projected indigenous medicines in a bad repute. The concept of Vaidyas prescribing and formulating medicines according to the need of an individual has been replaced by University educated doctors prescribing OTC medicines. The holistic and individualistic approach, one of the keystones of the systems is now critics aver, antiquated. The traditional lineage of Vaidyas/Hakeems is being lost. So, at present there is a need to revive the systems along the lines of prevalent traditions and promote the usage of herbal medicnes otherwise our heritage will be lost, resulting in a great loss to the country.

Human Vaccine Science and Technology Status in India

India was one among leaders, when vaccine research began to gain importance in the rest of the World and India continues to retain so even today despite some lag periods during I & II world wars and the subsequent period till 1970s. Several dedicated vaccine R&D institutions were set up during 1950-80s with the help of Rockefeller Foundation, United Nations Children Fund (UNICEF) etc. The real emphasis on vaccine research was initiated and promoted by the Department of Biotechnology (DBT) that was set up in 1986. In fact, DBT's initiative provided tremendous boost to vaccine research and development (R&D) in this country.

Vaccine R&D Status in India

There are around 26 vaccine R&D institutions in India that are actively engaged in research and development of vaccines, 2 institutes under DBT (came up in the late 1980), 11 under Indian Council of Medical Research (came up between 1950 - 1990), 6 under Council of Scientific and Industrial Research, and others include university departments and other autonomous institutions like All India Institute of Medical Sciences (New Delhi), Indian Institute of Science (Bangalore) etc. (Fig 4-22.01). Some of the vaccine R&D organizations such as Central Research Institute (Kasauli), Haffkine Institute (Mumbai), King Institute of Preventive Medicine (Chennai) and Pasteur Institute of India (Coonoor) are century old institutes that came up during British India, whose institutional structures are based on the innovation model where R&D and production exist under the same roof. This was basically to facilitate and conduct research that would lead to vaccine development against particular disease and transfer of technology to the production division. This model facilitated better and faster coordination between R&D and production division; for scaling up technology and other improvements and technological up-gradation. The research institutions that were set up after independence are only dedicated to research and development of vaccines.

Vaccine R&D Efforts

The genetically engineered vaccines against HIV/AIDS, cholera, leprosy, malaria and TB (mycobacterium habana) were developed from indigenous strains and reached various stages of clinical trials. Basic research and development efforts are for developing candidate molecules against HPV, rotavirus, edible cholera vaccine (edible, subunit), anti-rabies (tissue culture based), improved BCG vaccine, filarial, dengue, JE (tissue culture based, chimeric peptide), typhoid, HIV, filarial (recombinant), Pneumococcal (thermostable) and Hepatitis E (vaccine like particles). Out of these few, the rotavirus vaccine, HIV/AIDs type C and malaria candidate vaccines have been developed under Indo-US bilateral programme called Indo-US Vaccine action Programme (Indo-US VAP), which was initiated in 1987 between India and US. Around 35 collaborative research projects have been funded so far to develop vaccines and diagnostics.

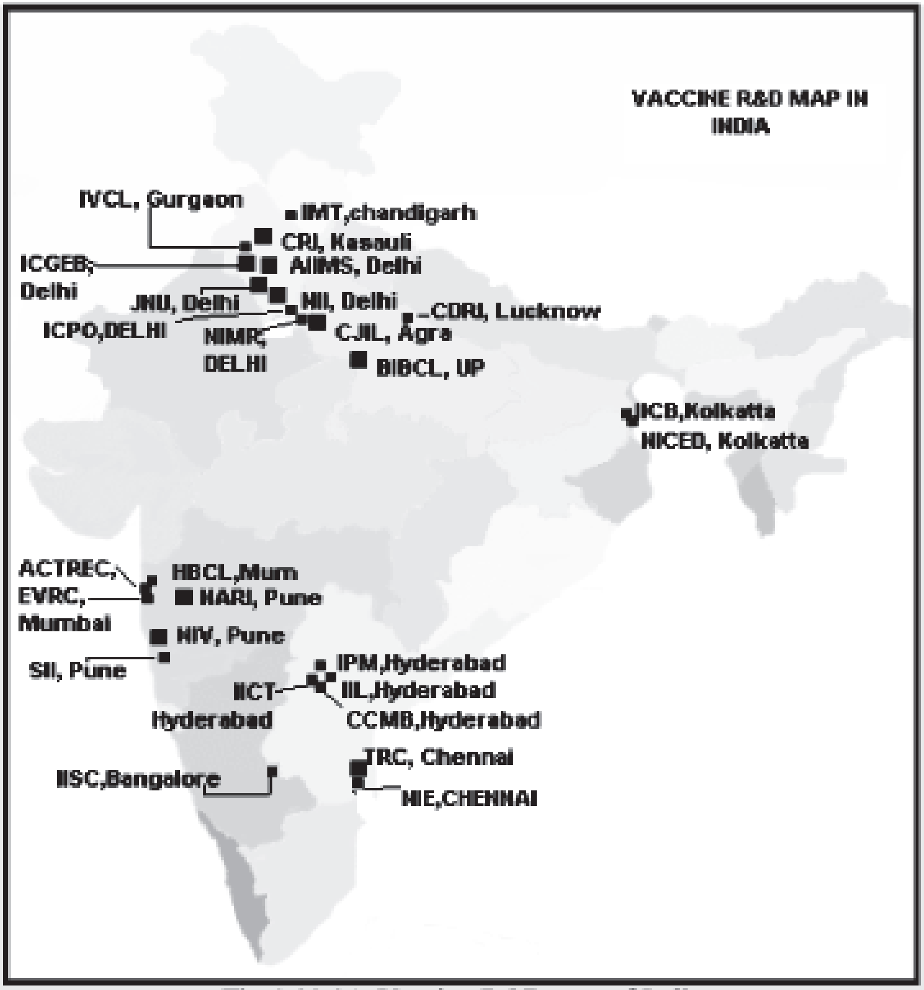


Fig 4-22.01: Vaccine R&D map of India

Highlights of Indian Vaccine R&D Achievements

Institutions like National Institute of Virology (Pune), National Institute of Immunology (Delhi), All India Institute of Medical Sciences (Delhi) are actively engaged in identifying and developing several vaccine candidate molecules which are at different stages of development.

- So far 10 institutions have developed around 12 vaccine candidate molecules and transferred the technology to industry.
- Anti-leprosy vaccine (immuvac) developed by National Institute of Immunology (NII) has been transferred to Cadila Ltd., Ahmadabad and the technology has been commercialised.

- The collaborative effort of three institutions namely Institute of Microbial Technology (IMTECH), Chandigarh, National Institute of Cholera and Enteric Diseases (NICED), Kolkata and Indian Institute of Chemical Biology (IICB), Kolkata led to the development of a indigenous recombinant cholera vaccine which is currently undergoing phase II clinical trials. The technology has been transferred to Shantha Biotech Ltd., Hyderabad.

- Indian Immunologicals Ltd. (IIL) Hyderabad, a public sector company developed human anti-rabies vaccine indigenously and launched in the market in 2002.

- National Institute of Immunology (Delhi), developed a tissue culture based JE vaccine and National Institute of Virology (Pune), developed a synthetic peptide vaccine against Japanese encephalitis.

- International Centre for Genetic Engineering and Biology, Delhi is actively engaged in malaria vaccine research and the candidate vaccine molecules against *P.vivax and P. falciparum* are undergoing trials now. The technology has been transferred to Bharat Biotech International Ltd., Hyderabad.

- Several indigenous technologies like hepatitis B, typhoid, anti-rabies, DTP-HB, DTP-HB-Hib, mOPV type1, leprosy, hepatitis A have been commercialized during the last decade. Prominent Indian companies that have commercialized indigenous vaccine technologies are Shantha Biotech Ltd, Bharat Biotech International Ltd (BBIL), Panacea Biotech, Cadila Pharaceutical Ltd., USV Biopharmaceuticals and Indian Immunologicals Ltd., a public sector company.

Knowledge Capability and Capacity in Biomedical field

Generation of knowledge, capability and the capacity of a country in the biomedical area are largely determined by the complex structures and institutions of the biomedical market involving the interplay of drugs, the medical devices and the physicians. Contests among these three institutions define the current endowment of resources, flow as well as the allocation of future resources, formation of coveted assets, capabilities and capacities.

Resources are distributed over several markets, governed by distinct and different sets of rules, where multiple institutions compete between them for getting access to as also in engendering greater resources. Contests between institutions result in movement of resources across boundaries of institutions implying that the circuit of governance reaches beyond the inside of the organisation to the domain where a firm/organization competes for negotiating power.

Contests between drugs, devices and the physicians take place through sets of institutionalised practices/ rules. These are broadly: the clinical observational and interactive practices undertaken by the physician (often in hospital); next is the theory-driven and theory-building open and not-for-profit knowledge practices of the university; and the third is the closed-door, for-profit organized science-research often controlled by the pharmaceutical firms. The devices research while in practice shares the same institution with the drug firms, in market these are fiercely competing for the grab and they compete to define different sets of practices for the patient. Institution of devices maps a body differently from the mapping enforced by the drug firm. Institutional contests for domination refer to the power to: define agenda; influence and shape practices; therefore decide definition of what constitutes an asset and, ultimately induce flow of most of funds and other resources to a particular institution.

The fact that an average physician in India examines very large number of patients afflicted with multiple diseases provides the doctors with extremely rich repertoire of clinical knowledge. Further, genetic diversity in India is perhaps the highest in the world. Doctors thus possess the richest source of knowledge for advancing innovations in biomedical areas. However, research systems of development of drugs and clinical healing practices, the two institutions, share very little complementary knowledge and experiences, and the sharing between devices and clinical practices is perhaps nil.

Most business firms and public R&D as well as University R&D in drugs and pharmaceuticals have therefore developed upon the relatively cheaper and surer chemical routes as the country has more advanced biochemistry knowledge compared to biology knowledge. The business of drugs received a fillip with the opening up of the market for generics in the USA as well as from the parallel growth of the domestic market. Firms could take up manufacturing generics and later even discovering new molecules of drugs with the assistance from the public R&D. Production, mostly of old and off-patent formulations, has increased rapidly – within two decades since 1980 it increased by more than 100 times in value terms. Because of cheaper costs exports grew and since the end of 1980s the country has remained net exporter. By 2003, there was 400 bulk drugs manufacturer with output valued at Rs. 78 billion. In generics or formulations there are 60,000 items spread over 60 therapeutic categories and total export has crossed Rs. 141 billion by 2003. However, following WTO and TRIPS and changes in business strategy of very large global drug firms of taking generics into fold over the last few years together have forced domestic drug firms and domestic R&D systems rethinking on the sustainability of the previous research as well as business strategy.

A large number of pharmaceutical firms are small or medium, most often unlisted and the total of firms is about 10,000 out of which only about 300 are in the listed organized category. A large number of these listed firms have US FDA approved GMP certificates; a few have the WHO certified GMP. By 2003, number of Drug Master Files (DMF) filed with US FDA was 126. With industry-total of R&D expenditure at Rs. 6.6 billion by 2002-03 with industry turnover of Rs 226 billion, only a handful of firms could claim around 2003 spending about 6% of sales turnover on R&D with the rest spending below 2%. Few domestic firms have been developing new molecules for new discovery drugs. Currently, more than 10 molecules are under various stages of development.

A typical discovery process passes through several stages spreading beyond 10 years in general and the cost particularly in different phases of clinical trials is very large therefore, unaffordable to the domestic drug firms. As a result, in all cases of new molecules, local firms have entered into alliances with large global firms. Several other firms have entered the new fields of contract research and contract manufacturing. Large part of the former is devoted to the undertaking of clinical trials, a field that has recently opened up and is currently experiencing high growth. However, in most cases these two types have left out the very large and distributed knowledge base with the doctors, the real repositories of ground data.

Journals rarely reach a doctor. Evidence based practices are most often unknown. There is no regulation or regulatory body on evidence based medicine. A doctor retains, close network linkages with her local peers and her potential and current transactions partners. Reputation asset remains therefore highly localized. Network-routed information sends signals to a practitioner on practices including surgical methods, on local epidemiological trends, on the local portfolio of drugs and devices and similar others. The important asset with this doctor is her knowledge of the local bodies and her knowledge of how to investigate a local body. The worlds of organized research and that of the University are very far from the world of clinical practice in India.

However, networks between major Indian research centres/Universities and the Indian organized public and private research on the one hand and the global majors on the other hand, are very active. The Indian counterparts often become a partner in the global program somewhat as a laggard and as a supplier of human resources. The same are however, not true for both the institutions of distributed innovations and the clinical practice.

Clinical practice institution in India thus has two faces - its practices are most genuine to the patient in which the doctor and patient together heals body and at the same time the clinician informs us that little contemporary advances reaches her. Biomedical innovation in India hence must stand on these three pillars namely, drugs, devices and practices.

Research from Hospitals: Evidence

The extent of research conducted and research capability in medical and non-medical streams have been estimated by using a public database, PubMed MEDLINE *(http://www.ncbi.nlm.nih.gov/PubMedOld/medline.html)*. A comparison of research output has been made between eight countries, namely, USA, UK, Israel, India, Singapore, Malaysia, China and Chile (for the period 1995-2007). The overwhelming dominance of USA can be appreciated from the fact that six years output of USA when compared to the total output of seven countries for eleven years, the former alone retains a share of 69.8%, followed by UK with 17.7%, Israel with 4%, China 3.8%, India 3.1%, Singapore 0.7%, Chile 0.6% and Malaysia 0.2% (Fig. 4-23.01).

MEDLINE data covers about 10 million articles that are classified into several publication types (PT). PT relevant for the present exercise include (i)Clinical Trial (CT): pre-planned clinical study of diagnostic, therapeutic or prophylactic drugs, devices or techniques on humans; (ii) Randomised Controlled Trial (RCT): clinical trial involving at least one test treatment and one control treatment and also involves randomized

Table 4-23.01: Global growth across types of publications in MEDLINE

Year	CT	RCT	CCT	MS	PG	CC	RRC	CR
1999 (March)	248238	113363	48254	27826	3664	2568	35098	917175
2005(February)	395409	195709	67268	61393	8583	4301	51165	1154745
2006	36021	17150	2654	10489	1139	297		54902
2007	37568	18398	2031	12049	1012	271		56573

Source for 1999 data is Ojasoo, Maisonneuve & Dore, 2001, except for CR

selection of administered treatment; (iii) Controlled Clinical Trial (CCT): clinical trial involving one or more test treatments, at least one control treatment and pre-specified measure for evaluation; (iv) Multicenter Study (MS): controlled study conducted in several cooperating organizations relating to administration of drugs or a new procedure or devices, it thus involves PH (physician as healer)/RP (researcher as physician) in research directed or influenced by non-medical such as pharmaceutical firm or equipment firm; (v) Practice Guideline (PG); (vi) Clinical Conference (CC) of physicians on their observations of patient at bedside; (vii) Review of Reported Cases (RRC) in literature on all known cases of a disease; (viii) Case Reports (CR) on patient cases, this group of research refers to dominant role of physician as researcher, and the RP relates directly to the patient as a healer and much less as a provider of certain drug or technique or device.

It may be seen in Table 4-23.01 that the first group of research consisting of CT, RCT, CCT and MS where physician acts more as provider of clinical services, globally has grown faster than the second group consisting of PG, CC, RRC and CR where physician acts more as healer-researcher. It is apparent from the table that PH is increasingly becoming a RP; and RP is increasing the Mode-2 type of research with physician as the

Table 4-23.02: Distribution of publication types across countries in 2008 (February) in MEDLINE

Country	CT	RCT	CCT	MS	PG	CC	RRC	CR
India	3574	1969	417	280	16	36	619	12821
China	6011	3619	553	735	7	21	257	5819
Israel	5038	2284	645	878	25	59	851	11655
UK	25158	13523	2570	6565	509	92	1200	29544
USA	100957	50463	8117	27288	1907	2032	7426	125829

key to research while possibly, and may be equally significantly, systemic pressures are increasing on physician to cooperate often as the second fiddle on research agenda set by non-medical business interest.

Cross country comparison of publications (Table 4-23.02) reveals that while the relative distribution of publications from a country over four types in the first group remain similar, in both USA and China the MS, organized by either the country bureaucracy (as in China) or by the large and powerful business interests from pharmaceuticals or devices firms (as in the USA), occupies importance. In India MS occupies a weak position. If we compare the relative contribution of a country in the global total of type-publication (such as in CT) both India and China contribute less than on average 0.5%, Israel contributes about 1%, USA about 15% (however, in MS the contribution by USA is above 25%) and UK about 4%.

In the case of second group, the contribution from India and China are better compared to the contribution from USA. Further, in both CC and RRC India's relative contribution is higher and in fact much ahead of China. The CR too suggests a similar strength. Moreover, in terms of share in the global total of publication, USA contributes less than 10% in CR and about 10% in RRC, India is close to 1% in both. CC in particular represents a domain of the physicians and USA shares about 30% of global reporting. Given the high shares of CC and RRC, Indian physicians appear to enjoy higher autonomy, larger public sphere and less occupied to serve organized health delivery. Conversely physicians here are less subjected to the institutional compulsions to undertake clinical trials or follow guidelines suggested by non-medical systems of knowledge. Israel has certain strangeness; it shows coexistence of both organized and directed clinical practice together with less-organized and relatively autonomous actions by physicians. USA and UK exhibit dominance of organized and directed physician practice, however, USA simultaneously represent the existence of spheres of autonomy.

Global Biomedical Research

Another important aspect is the emergence of voluminous data which to a large extent determine the course of innovation and research in biomedical. USA enjoys strong dominance in this data based research; however, some other OECD countries too are strong contenders. Research in biomedical is conducted by physicians on patients often as part of ongoing clinical investigation or healing. A typical stand-alone investigation or experiment can be budgeted for under R&D and can be conducted under a separate entity. However, in order to appreciate the extent of research in biomedical it would be preferable to consider statistics not of R&D expenditure instead it should be output that are published or patented. Since the researches are context specific, the knowledge or publication can hardly be appropriated. In Mode-1, research inferences based on past data are made by a physician on another new specific context without framing a general rule. Each Mode-1 inference therefore, generates another context-specific data, and the field of applicability of data increases. In Mode-2, however, rule formation is the principal objective. Past data are now made amenable to all future contexts.

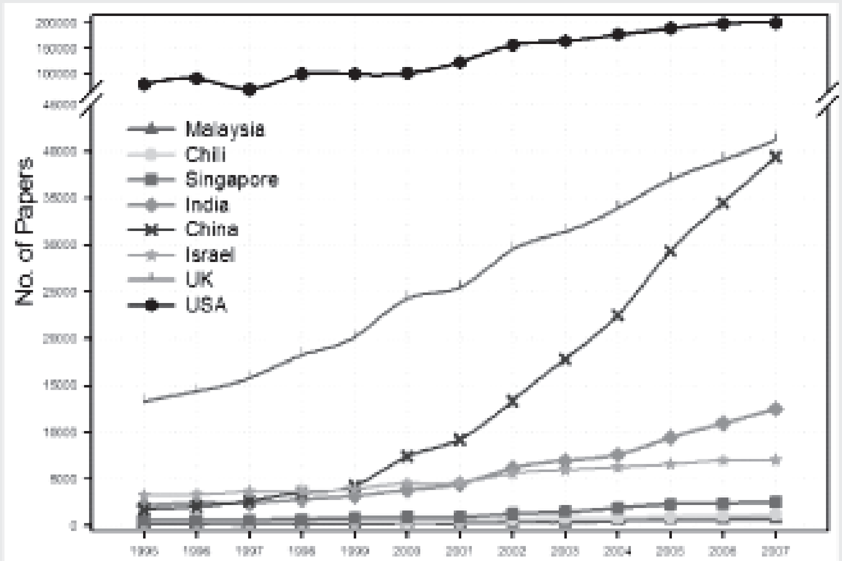


Fig 4-23.01: Cross-country comparison of biomedical publications, 1995-2007
Source: MEDLINE

Table 4-23.03: Distribution of total (1991-2001) publication over types of institutions

Country	Medical/Hospital	University	Others/Research
India	50.2	35.1*	14.7
China	48.8	43.4	7.9

*This includes research institution's contribution at 10.3%, and university's at 24.8%

Typically, business firms from pharmaceuticals follow this latter route. This generalization generates a property right that can be appropriated at any future space and time. Traditionally, a multinational pharmaceutical firm alone used to look for global data. Local physicians could care little for global data because the data was out of reach. However, with increasing digitization the reach of both group are increasing and as a result it is necessary for us to care for global comparisons of research and data-generation.

Institutional Distribution of Biomedical Knowledge

Geographic distribution of knowledge assets compounded by the institutional distribution followed by organizational compounding characterizes the distribution of knowledge asset in a country. Distribution of biomedical research from the University institution of India exhibits characteristics similar to China. In several cases of Indian Universities, such as with the Banaras Hindu University (BHU), the output is indeed

Table 4-23.04: Medical and non-medical authors in country publications of India, China and Israel

Country/Authors	Total authors	No. of authors from medical	Number of authors from non-medical
India	3808	1742	2066
China	8029	1761	6240
Israel	458	36	422

Source: *Scidirect 1994-2004*

from the hospital system and is not from the University departments. BHU tops the list of Indian University institution whose contribution to the country total at lowers than 24.8% is much smaller than its Chinese counterpart. Second highest contribution is from the IISc. at Bangalore, followed by Delhi and Punjab University, followed by in close succession the two universities from Kolkata, and similar others. Regionally as well as spatially somewhat evenly balanced research assets in biomedical is also characterized by non-dominance of any particular university organization.

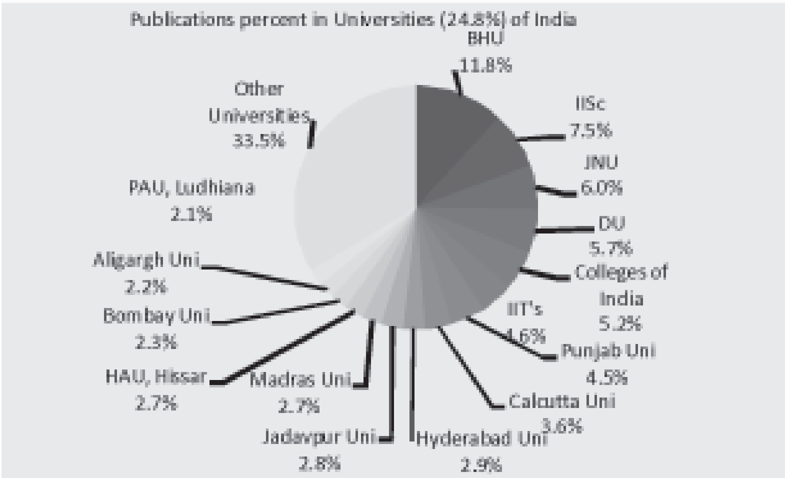


Fig 4-23.02: University system in biomedical publications of India

Research assets in biomedical contributed by public organized research is, however, geographically skewed. Hospital institution contributes most to biomedical research in India; at above 51% of country total, the distribution of research assets across hospital organizations and regions is, however, skewed. The specialty research-based hospitals contribute a very large proportion of research at above 32% of country total. AIIMS in Delhi tops the list, followed by the PGI at Chandigarh, followed closely as fourth the SGPGI from Lucknow. From South a large contribution appears from Vellore based CMC, from the western part Mumbai based TMH too contributes a bit. However, from amongst these major research-intensive hospitals there are only a few from east, such as from Kolkata the contribution is less than 2% and from Kerala in south less than 1%. The 'others' segment is little above half of the country total, and to this segment belong the large number of hospitals spatially well distributed.

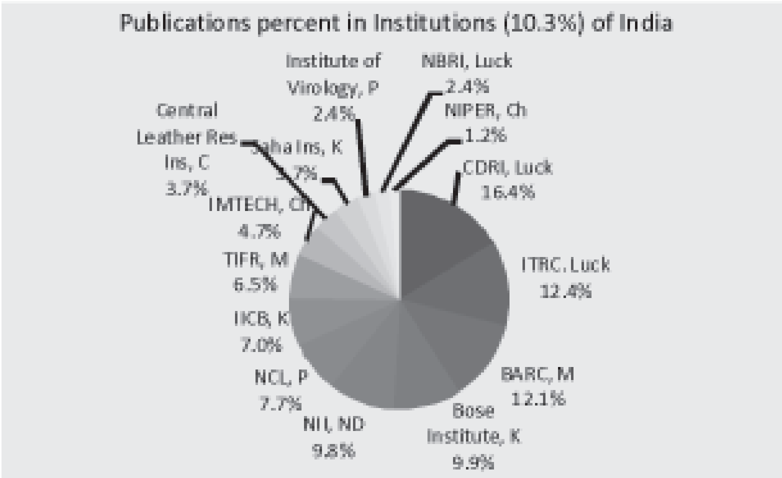


Fig 4-23.03: Organized research in biomedical publications of India

China has sharp coastal-geography based assets. The UK too evidenced three major asset-geographies. Israel and Malaysia too exhibited geographic patches. India alone possibly remained most distributed. In USA, as in China, there are two strong geographies in the Northeast (NE) and in the Southwest (SE), although Texas evidences strong research assets. The NE is dominant.

Concentrated geography while reducing transaction costs and hastening spillovers, does make it easier for institutions and respective affiliating organizations to compete with each other. Competing research agenda might in lieu of becoming cumulative be non-cumulative and dissimulative. Possibly more important is that close and intensified geography makes it easier to compete, and especially for an institution and its powerful member organization to be in a position to effectively influence the research agenda, the research processes and the flow of finance as well as the generation and flow of human capital to the competing institution and its member organization. In short, geographic corporate governance appears feasible.

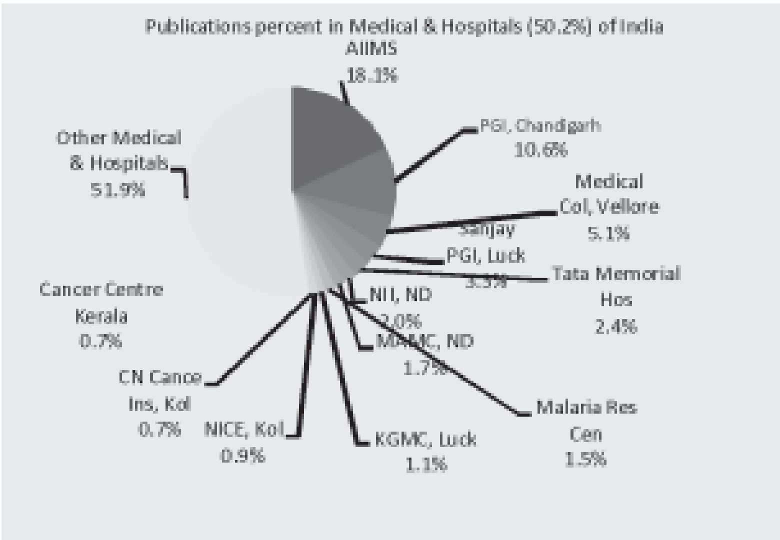


Fig 4-23.04: Hospitals in biomedical publications of India

For a country governor from India for example, it would be easier to monitor funding and increase output per funding if organizations were more concentrated. Possibly more importantly, the large and diffused research base such as in Indian hospital institution could prove a threat as well as act as deterrence to the dominant global paradigm of organized research. With increasing manipulation of research agenda in another institution such as in hospital or the university, the organized research would cherish enhanced organizational dominance, such as through opening more research University or research hospitals that could suck off most of the finances and human resources available.

Role of hospitals in research

Research from hospitals or the clinical system is distinctly different from the research undertaken at University system or at research laboratories. For instance, (1) a physician even while performing a research must remain primarily a healer and this concern for the well being of the patient sets the core ethical guidelines whereas a University professor or a researcher may not be guided by such a code. This difference sets in a specific methodology of inquiry, specific goals of research and important constraints on research. (2) physician is driven by practice while a professor would be driven more by theory or experiment; (3) research goals of a physician cannot often be set beforehand and the goals are in general emergent, while goals are pre-determined for a professor; (4) medical theories can be built when feasible from data, and often in lieu of theories there would be a plethora of guidelines, rules or standards and observation while non-medical research is least driven by data and facts and are directed to refuting or revisioning of existing theory-pieces; (5) much of data generation and of observation is dependent upon the skill of a physician and this is so even after healing practices been made dependent upon medical devices, and thus medical research presents a classical locus of serendipity, however, non-medical research has increasingly removed any element of serendipity.

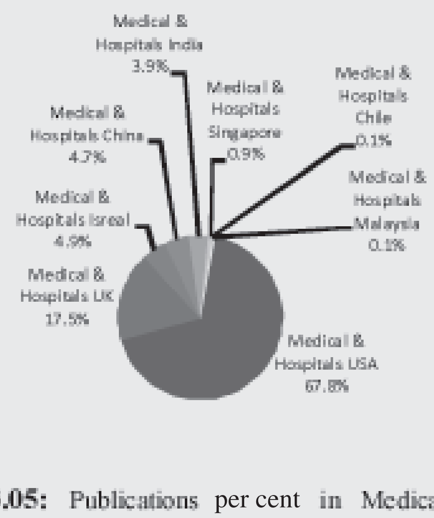


Fig 4-23.05: Publications per cent in Medical & Hospitals of different countries; ***Source:*** *Medline Database*

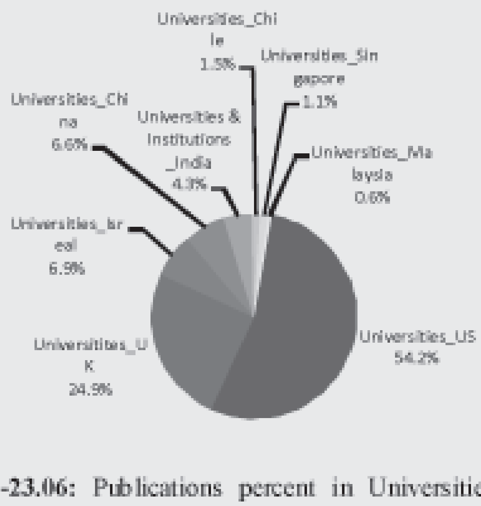


Fig 4-23.06: Publications percent in Universities of different countries; ***Source:*** *Medline Database*

Finally, hospital represents a system which unlike a business corporation generates and perpetuates a distinct mode of autonomous inquiry dependent much up on serendipitous formulation of the 'problem' in the patient. This research refers least to problem solving approach. Reputation plays great role in medical profession and in its research, and much of reputation builds upon this faculty to formulate a problem that can be solved. A physician is at the center of multiple relationships. The physician relates to the patient, to the medical profession and to the hospital or clinic, to the pharmaceutical company and to the payment system in practice in the country. Several parties to the relations can be ingratiated and the physician has often been accused of opportunistic behaviour. A professor does not have many relations to be ingratiated, and scope for opportunistic behaviour is extremely limited. Much of property rights in medical research are generated through pharmaceutical firm initiated clinical research. These differences in economic incentives set up different patterns and different rights to access in these two systems of research, i.e., from hospital and that from University and research centres.

Out of the total publications from the medical and hospital systems of the eight countries, India, China, Malaysia, Singapore, Israel, Chile, USA and UK, the USA alone accounted for 67.8%, UK accounted for 17.6%, Israel for 4.9%, China for 4.7% and India for 3.9% of the total. Other countries accounted for negligible share of the total. Similarly, out of the total publications from the University systems including from other research bodies, USA contributed 54.2%, UK 24.9%, Israel 6.9%, China 6.6% and India 4.3%. Other countries such as Malaysia or Chile contributed insignificant share. Remarkably for USA, the relative contribution in biomedical research by Universities is significantly lower than the contribution from the hospital system. Contrarily, in UK the University system contributes significantly higher proportion of output. For both Israel and China University system's contribution is growing and for India contribution from the University system (several medical colleges come under University though) is marginally above that from hospitals.

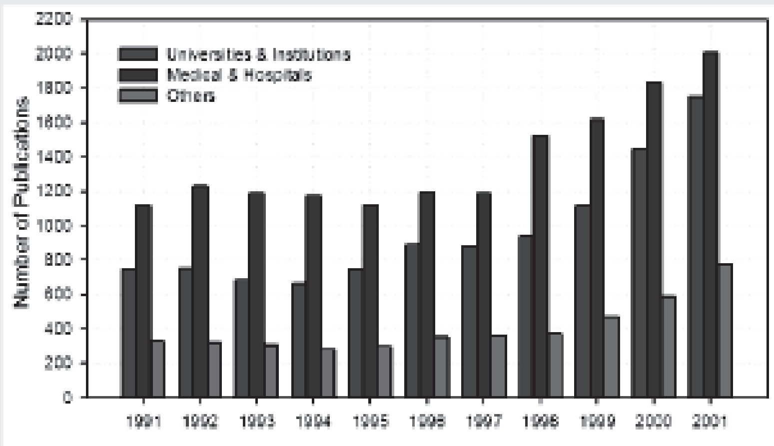


Fig 4-23.07: Distribution of Publication over various Universities/Medical of India (1991-2001)

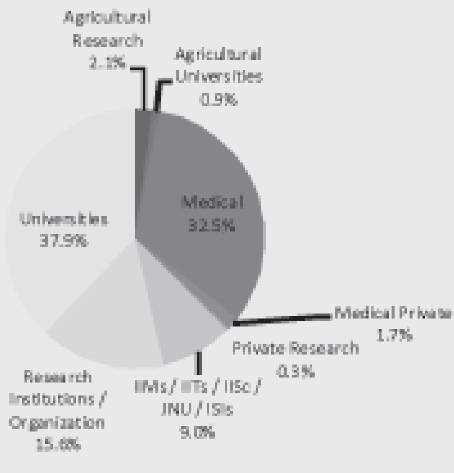


Fig 4-23.08: Publications percent of different sectors in India

In UK, hospitals contributed nearly twice the output from university and other research bodies. During 1991-2001, output from hospitals grew by 100%, from university by about 500% and from other research bodies by 300%. In China, growth has been spectacular. Output from Universities grew by more than 1500% and from hospitals by about 500% whereas it declined for research bodies. India, however, experienced a modest growth - from hospitals by about 160%, from Universities by about 200% and from other research bodies by about 200%. However, because of the early lead the hospitals still retained their higher position. In the US all the three segments grew about the same rate, the other research bodies had the early lead with their output above the hospitals both during 1995 and 2001.

Role of Hospitals in India and China

Hospital, provide for the scope to undertake integrated research, and research on a very large number of patients with all possible types of diseases. Both India and China have very large population and this alone provides for a very large research pool. However, the genetic pool in India is much diverse and India offers a virtual microcosm of global genetic abundance. More importantly, in both the countries hospitals, are the most important providers of health care.

Organized research under publicly funded system has contributed significantly to Indian Medical System (Fig 4-23.08) - Universities contributed 37.9%, organized public research contributed 15.6% and higher research-teaching establishments such as the Indian Institutes of Technology (IIT) and the Indian Institute of Science (IISc) contributed 9%. Private research and private medical research contributed 0.3% and 1.7% respectively while pure hospital-based research contributed 32.5%. However, the output of organized research and of the hospitals including from the universities are often joint. Apart from making the data regarding origination of research a suspect, the major role of such joint research is in influencing the research. In India, University system (when medical universities are taken out) contributes far less and even the non-medical organized research pursuing such problems as genomics, proteomics, drug design, and other chemical-biological problems in biomedical research contributes far less compared to both USA and UK.

Biomedical knowledge assets in Indian cities

Medical practice and medical case-based knowledge assets exhibit excellently the characteristic of severalty. In case accumulation of quantity of knowledge asset is possible, severalty of assets would be undervalued while large quantity amassed under one category or the efficiency of operation would be valued. Possibly a good amount of non-serendipitous research knowledge in areas such as chemistry or biotechnology belong to these classes.

In the type of assets where severalty is valued, the spatial distribution and spatially unique characteristic of for example medical knowledge receives high value. This space could refer to physical geographical space, the genetic space, or the temporally observed series of facts on a group of subjects belonging to a single locality. It follows then distribution characteristics of assets within institutions of knowledge are important.

Spatial distribution of medical knowledge generation should be considered highly desirable. Spatial concentration of chemical or biotechnological knowledge could in contrast be desired, especially because both spillovers would be higher and the transactions costs lower in concentrated space. A market in such a case would be constituted by transactions between organizations. In the other type of medical knowledge, assets would better remain dispersed, often even through physicians' networks and the market would be constituted the least through inter-organizational transactions.

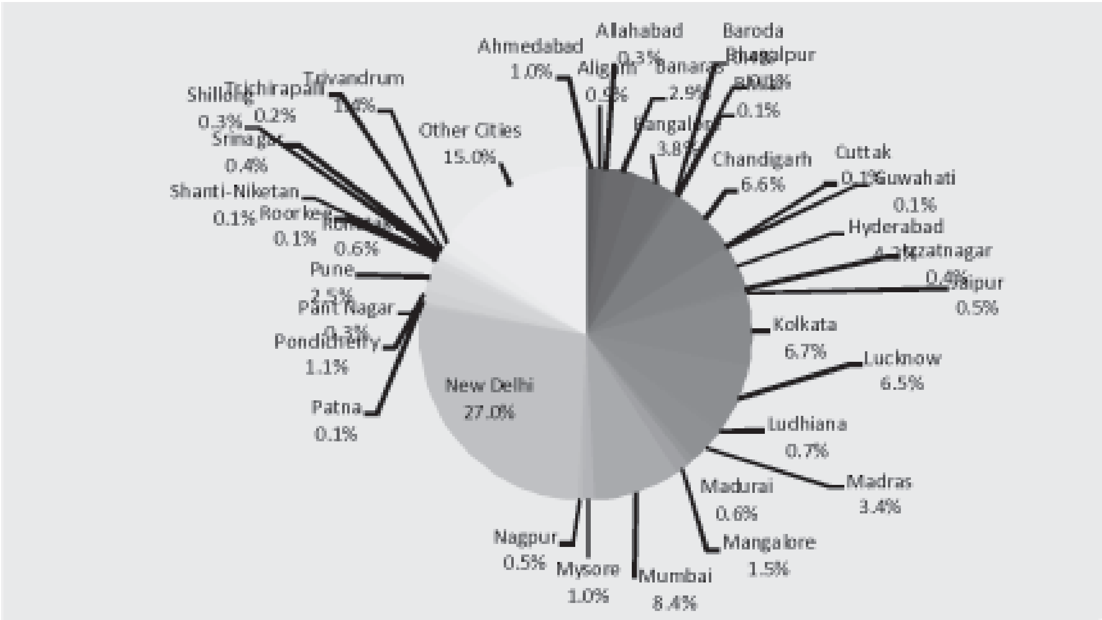


Fig 4-23.09: Publications per cent in Cities of India; *Source:Medline Database - 1991-2001*

Fig 4-23.09 presents the distribution of cumulative biomedical publications over eleven years across several cities, and a detailed annual break up of publications over thirty-five smaller cities from India exhibiting interesting pattern. Publication is an asset in so far as the institution can appropriate it. Publishing personnel are otherwise the assets, and publication as a dummy can represent distribution of active asset-holding personnel. The institution of hospital contributes the larger part of the output from the large cities such as Delhi, Bangalore, Kolkata, Mumbai, Lucknow or Hyderabad and Madras. Further, the contribution from non-major cities for example Patna, Mangalore, Coimbatore, Guahati and similar others are largely due to hospital.

Mumbai offers sharply contrasting features: (1) large number of hospitals participating in research process, (2) total contribution by hospitals are dominant, and (3) non-dominance of organized research. More than thirty-two hospitals out of forty non-major contributors from Mumbai (such as the Tata Memorial hospital, the Edward, the Nair, and similar others with contributions above 2% of the city total) have participated in research during the last decade. University has low participation, and organized research from the BARC, the TIFR and others put together contribute little above 25%. No single organization in Mumbai has contributed more than 15% of total city publication, while IISc in Bangalore alone has contributed about 49%. Hyderabad and Kolkata exhibit features intermediate between Mumbai and Bangalore. No single organization from Hyderabad and Kolkata contributes above 29% and 14% respectively of total city publications. There are eight and seven non-major hospitals in both the cities out of a total of fifteen non-major participants in biomedical research. Distributions in both these cities are not sufficiently long-tailed.

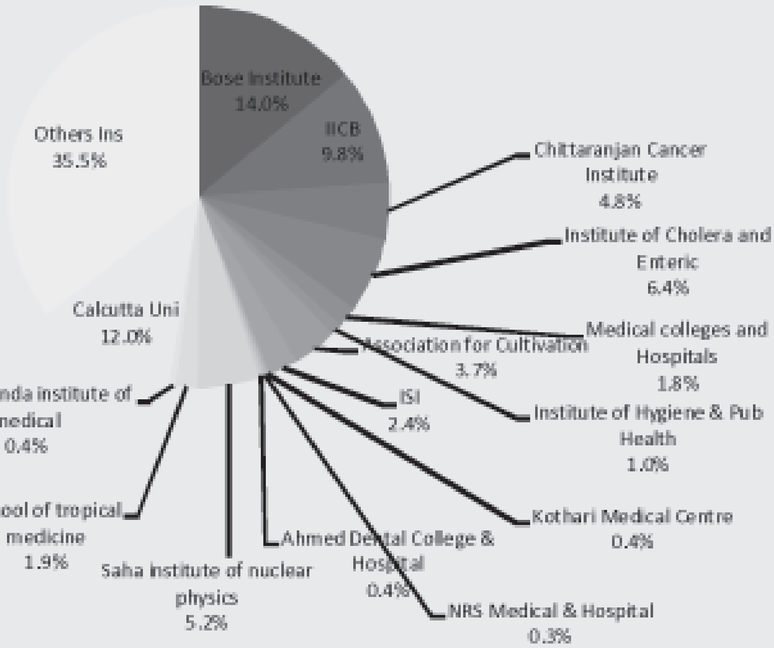


Fig 4-23.10: Publications per cent in Institutes of Kolkata (1991-2001)

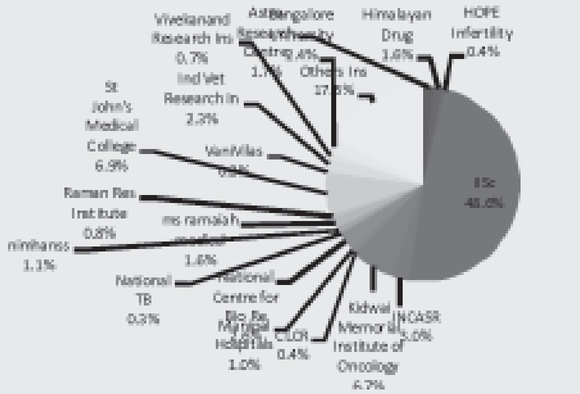


Fig 4-23.11: Publications per cent in Institutes of Bangalore (1991-2001)

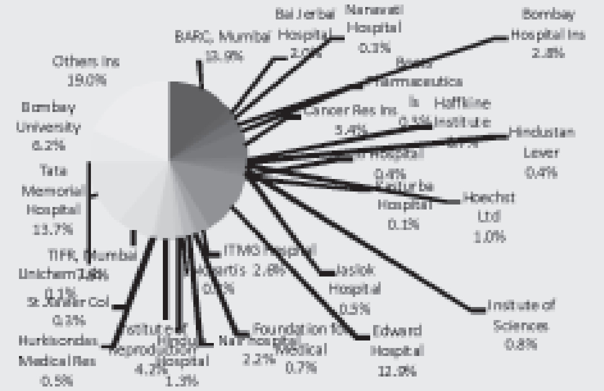


Fig 4-23.12: Publications per cent in Institutes of Mumbai (1991-2001)

Chennai has, however, a long tail, quite close to what we observe for Mumbai, and this distribution is very different from what we see at Lucknow. Organized research is relatively weak with about 13% contribution to the city total. Hospitals are many, and none dominating the research, a feature, which even Mumbai cannot display. Most research-intensive hospital contributes about 5% of city total, and there are four of them. Large hospitals contribute about 30% of city total of publications. Research in Lucknow has been parcelled between a handful of organizations most of whom are from public organized research, which contributes about 52% of total city publication. Delhi has some other kind of uniqueness. Its tail end is as long as Mumbai, however, its distribution is more skewed than Mumbai. The AIIMS, a specialty research hospital, alone contributes the dominant share of 33.6%, followed by the next most-contributing hospital the Maulana Azad with only 3.1%. University system in Delhi contributes a little above 12%, with nearly the total output shared by the two major universities of the city, the Delhi University and the Jawaharlal Nehru University. Organized research contributes only about 7% of city total.

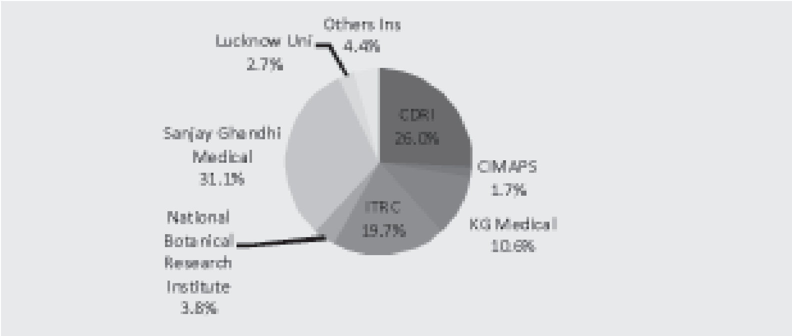


Fig 4-23.13: Publications percent in Institutes of Lucknow (1991-2001)

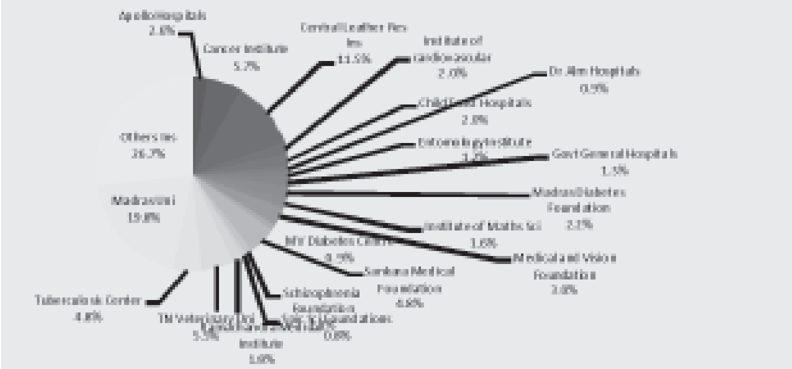


Fig 4-23.14: Publications percent in Institutes of Chennai (1991-2001)

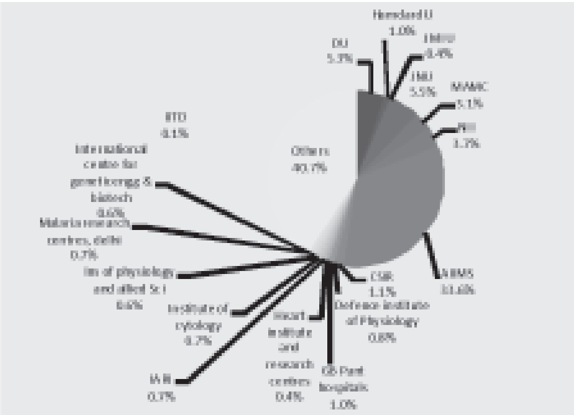


Fig 4-23.15: Publications percent in Institutes of New Delhi (1991-2001)

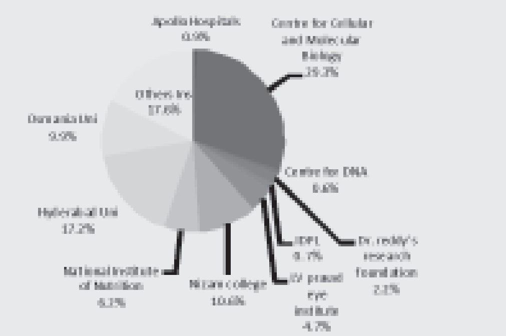


Fig 4-23.16: Publications percent in Institutes of Hyderabad (1991-2001)

The 'others' category of each city provides an insight. Delhi has the highest figure, at 40.7% of city total, followed by Kolkata at 35.5% of city total, followed by Chennai at 26.7%, then Mumbai, Bangalore and Hyderabad at par, and Lucknow with the lowest figure of 4.4% of city total being contributed by the 'others'. The number of non-major organizations is also indicative: Delhi and Mumbai both at 44, Chennai at 24, Bangalore at 21, Kolkata and Hyderabad at 15, and finally Lucknow at 5.

Another way of characterizing these cities would be along the dominance of institution. Bangalore is dominated by organized research, undertaken mostly at the research-university of the IISc. Hospital institution dominates Mumbai. However, no single organization dominates the medical research there. Hospital institution dominates Delhi too, however, there exists organisational dominance. Chennai is equally shared between institutions, although when one takes into account medical research under university as belonging to hospital institution, the latter as institution dominates. The institution of organized research dominates Kolkata. In fact, most part of the university contribution comes from the hospital system. Hyderabad too shares similarity with Kolkata but with one difference that university institution is strong at Hyderabad. Two institutions, and two organizations, one each from each institution dominate Lucknow, the CDRI from public organized research and the Sanjay Gandhi from hospital institution. These cities are distributed along the entire geography of India. Mumbai is from West, Chennai and Bangalore from South, Hyderabad from Central, Delhi and Lucknow from North and Kolkata from the East keep the geographical balance. Each geography offers distinct knowledge or asset pool. This, however, is not the status of some other countries. China shows a distinct geographical concentration. Research assets in China appear to be highly concentrated in the coastal ring, which contributes above 81% of China total. While London-Cambridge output is cornering about 50% of the output of UK, two poles of biomedical research in US- North-Eastern pole and South-Western pole, together produce the majority of US research.

India's Capability and Competence in Energy sector R&D

Energy requirement of Indian economy is enormous and growing fast. Growth of industry implies growing requirements for energy. Coal, oil, and natural gas are the three primary commercial energy sources. Huge parts of this demand for energy are met through imports of energy resources. The recent energy policy and before that the Prime Minister's statement has laid out a broad policy framework on energy. Given such a framework and global vicissitudes, this section explores the country's capability to identify, cultivate, develop and harness novel energy resources based on novel applications of S&T.

Demand and supply scenario

Coal: Coal is the major source of energy in India; it contributes 55% of total energy demands. The consumption of raw coal has increased in the period of 1970-2007. Till the mid 70's railways were the major consumer of coal followed by steel, electricity generation, and cement industries. Gradually railways upgraded

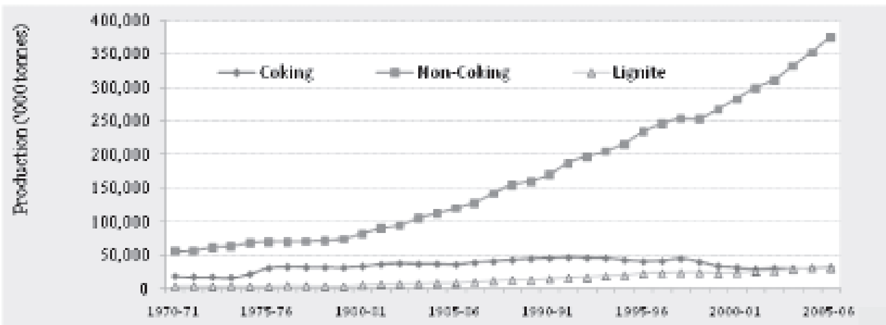


Fig 4-24.01: Production of Coal and Lignite in India
Source: CSO Energy Statistics 2007

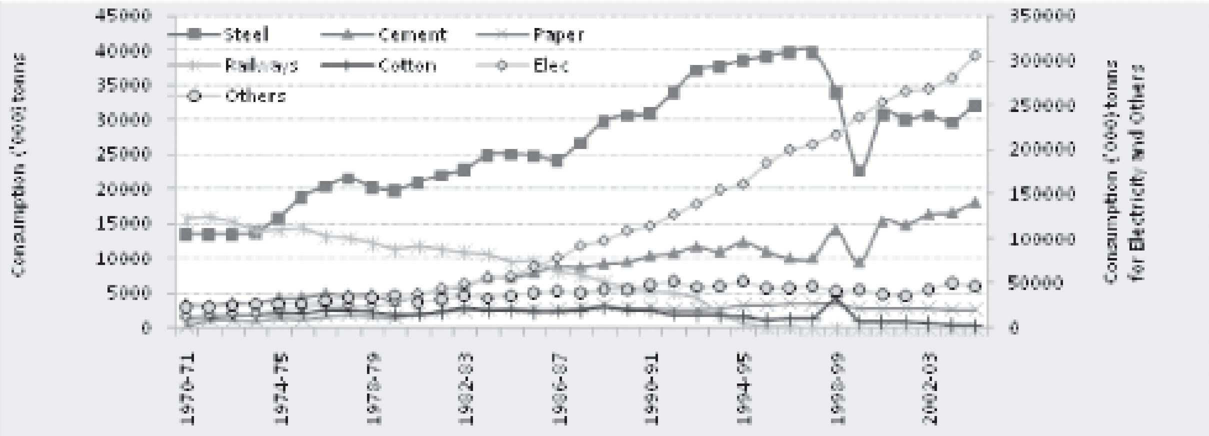


Fig 4-24.02: Consumption of Raw Coal by different industries in India
Source: CSO Energy Statistics 2007

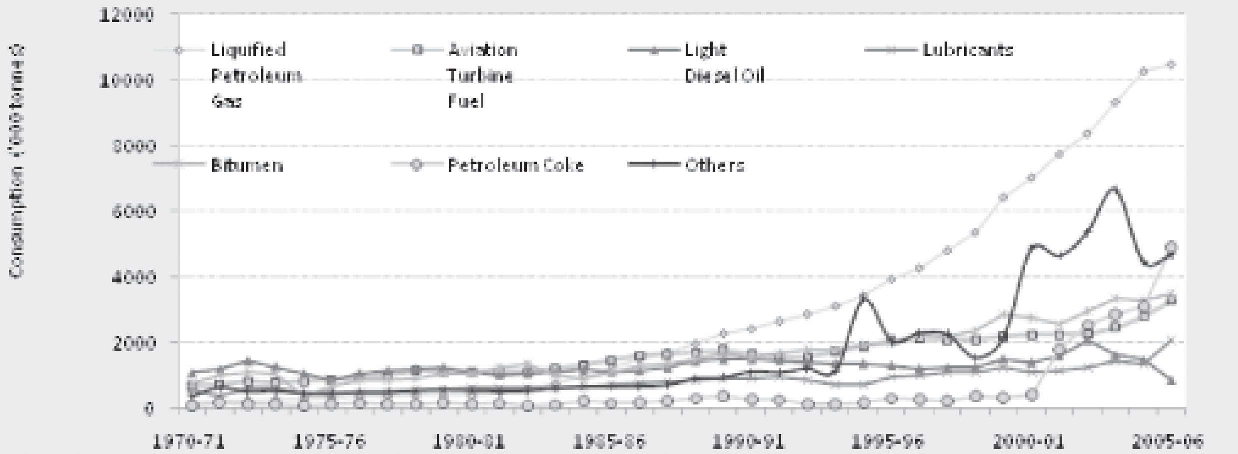


Fig 4-24.03: Consumption of Domestic-petroleum products in India
***Source:** CSO Energy Statistics 2007*

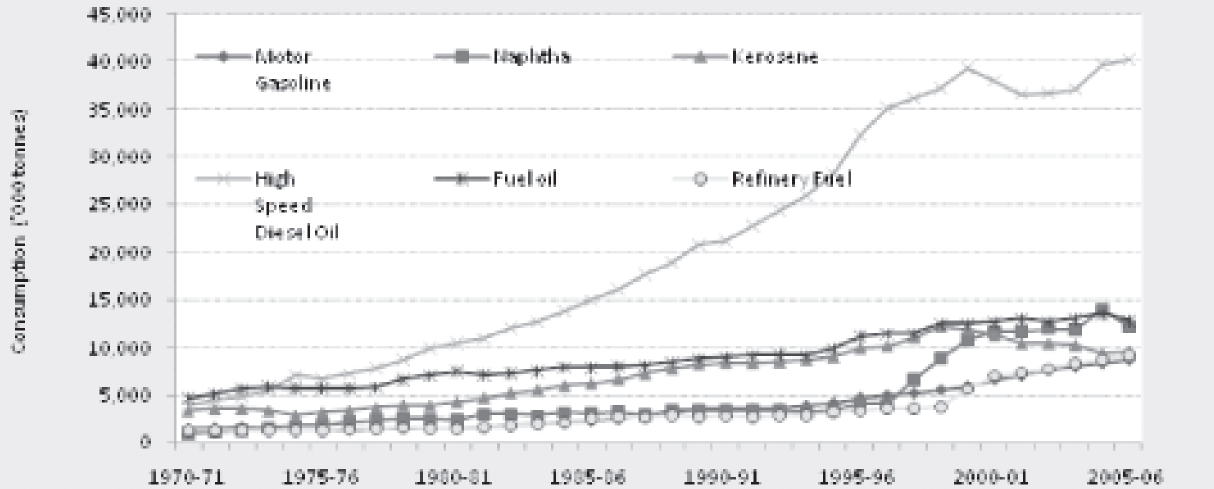


Fig 4-24.04: Consumption of Domestic-petroleum products in India
***Source:** CSO Energy Statistics 2007*

their technology and reduced their share of direct consumption. Today electricity generation is the biggest consumer followed by steel. As per ministry of commerce and industry the wholesale prices of coal, coke and lignite are on an increasing trend.

Crude oil: Of the total world production of 3,914 million tonnes of crude oil in 2006, India's share was about 1.0% whereas in consumption, its share was 3.1% of the total world consumption of 3,889.8 million tonnes. Out of the total domestic production of 135.3 million tonnes of all types of petroleum products in 2006-07, high speed diesel oil accounted for the maximum share (39.5%) followed by naphtha (12.3%), fuel oil (11.6%), motor gasoline (9.3%) and kerosene (6.3%).

Natural gas: In case of production and consumption of natural gas, India's share is to the tune of 1.1% and 1.4% respectively. Production of natural gas increased from 1,445 million cubic metres in 1970-71 to 31,747 million cubic metres in 2006-07. Of the total quantity of natural gas off-take in India in 2006-07, the largest consumption was in power generation (38.1%), followed by the fertilizer industry (27.1%).

Renewable energy: Renewable energy growth in India has been significant. The various non conventional energy resources are solar, biomass, wind and water. The total installed capacity of grid connected renewable power was more than 10 thousand Megawatts, as on March 2007. Contribution of Wind power was the maximum at 70% of the total installed capacity followed by small Hydropower (19%) and Biomass power (11%). There have been vigorous efforts in exploiting these sources for energy generation, as these resources not only provide sustainable alternatives to fossil fuels but also help in mitigating global warming.

Electricity: Total installed capacity (utilities only) for electricity generation, has increased

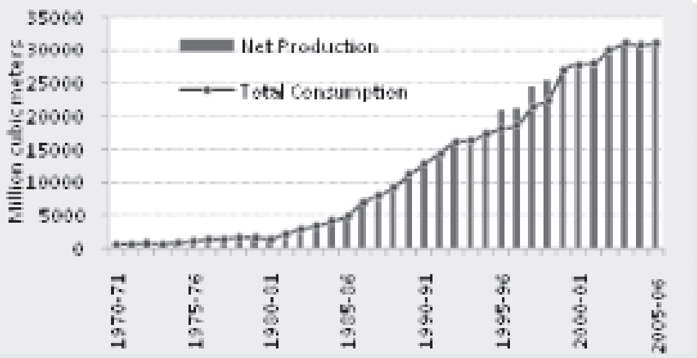


Fig 4-24.05: Production and consumption of natural gas in India
Source: *CSO Energy Statistics 2007*

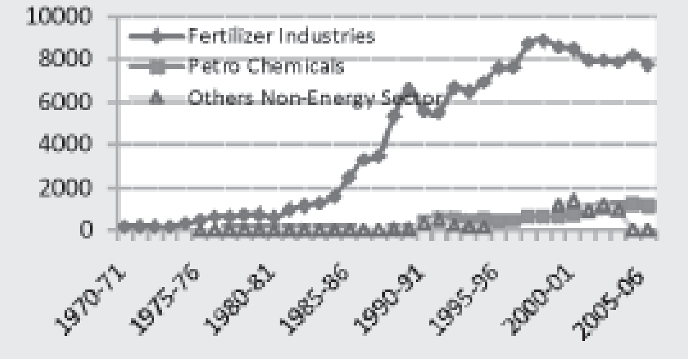


Fig 4-24.06: Industry-wise Off-take of Natural Gas for non-energy purposes in India
Source: *CSO Energy Statistics 2007*

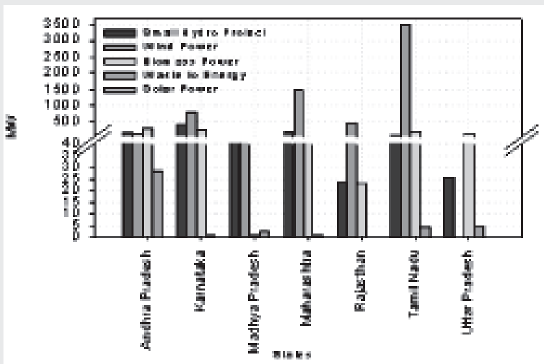


Fig 4-24.07: Grid-connected Renewable Power (State wise details of schemes/programmes being implemented and cumulative achievements)
Source: *CSO Energy Statistics 2007*

from 14,709 MW in 1970-71 to 132,329 MW in 2006-07. Average generation of electricity per Kilowatt of the installed capacity in India is found to be the highest for Thermal (5,711 KWH) followed by Nuclear (4,771 KWH) and Hydro (3,271KWH). Of the total electricity consumed in 2006-07, industry sector accounted for the largest share followed by domestic, agriculture and commercial sectors. However, electricity consumption in domestic sector and agriculture sectors has increased at a much faster pace compared to other sectors during 1970-71 to 2006-07. It is a cause of concern that transmission losses have increased from about 17% in 1970-71 to about 30% in 2006-07.

Government policy: On 26 Dec 2008, Government of India approved the "Integrated Energy Policy" which envisions a road map for sustainable growth with energy security to be achieved over a reasonable period of time. This was conceived to ensure better coordination among different energy sectors set up by different ministries. The policy prepared by Planning Commission of India seeks to make energy markets more competitive, have market-determined energy pricing and resource allocation, transparent and targeted subsidy disbursal and improved efficiency, optimal

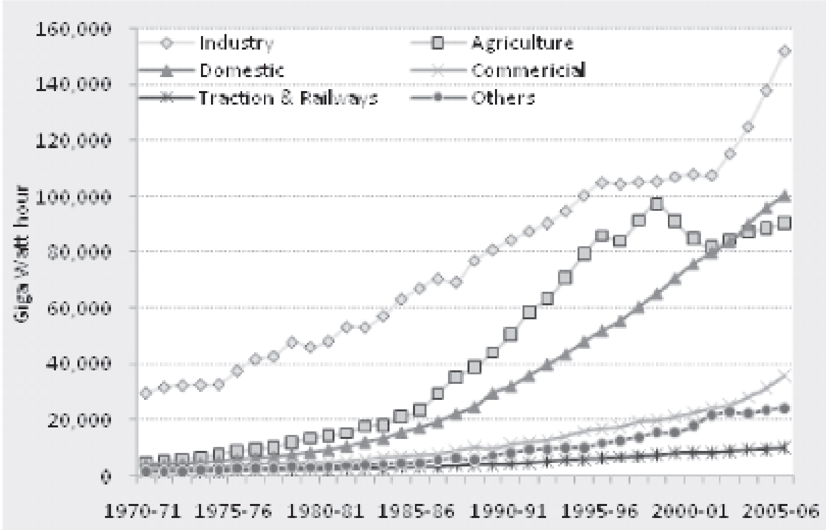


Fig 4-24.08: Consumption of electricity(from utilities) by sectors in India
Source: *CSO Energy Statistics 2007*

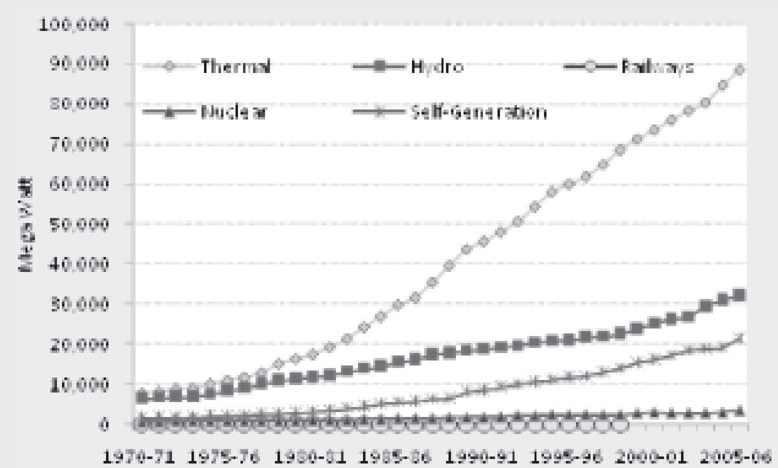


Fig 4-24.09: Installed Generating Capacity of Electricity in Utilities and Non-utilities in India
Source: *CSO Energy Statistics 2007*

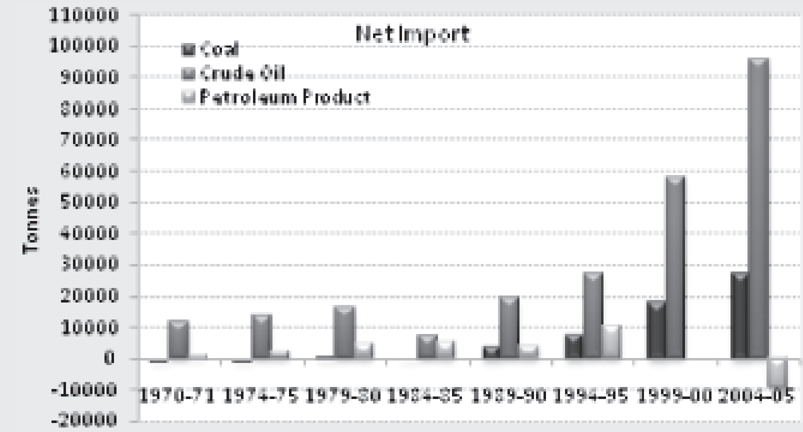


Fig 4-24.10: Foreign Trade in Coal, Crude Oil and Petroleum Products in India
Source: *CSO Energy Statistics 2007*

exploitation of domestic energy resources, and exploring and acquiring energy assets abroad to attain energy security for the country.

Role of Private Sector in Energy Sector R&D

The major energy consuming industries are manufacturing, agriculture, mining, transportation and construction. Industries use energy for a wide range of activities such as process and assembly uses, space conditioning, and lighting. The rising cost of energy and the growing concern over climate change and global warming has led industries to undertake R&D on new technologies aimed among other things, at reducing the environmental impact of energy production and consumption. In year 2005, there were around 188 listed Indian industries dealing in energy sector in areas of coal & lignite, electricity generation, crude oil, dry cell, storage battery, refinery & solar energy. Out of these 33 companies were directly involved in R&D, while 38 were paying royalty for technical know-how. Within the last ten years the private and public company expenditure on R&D has remained nearly constant. If we look at the power consumption of the industries with respect to their sales, it shows that it has decreased considerably.

This proves that there has been considerable amount of technological innovation regarding enhancing energy efficiency in the industries which is reflected from the data showing lowered power consumption. It also seems that at present this innovation is largely dependent on technical know-how from outside rather than from in-house R&D. But with the increase in rate of forex earnings compared to expenditure, a time is not far when the earnings will surpass expenditure and India will be the hub of R&D.

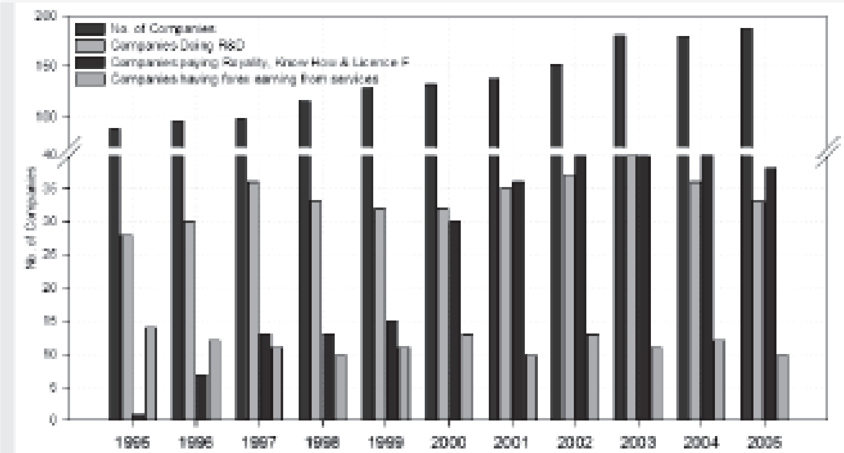


Fig 4-24.11: No. of companies involved in R&D in Energy Sector in India, based on listed companies

Source: Prowess Database

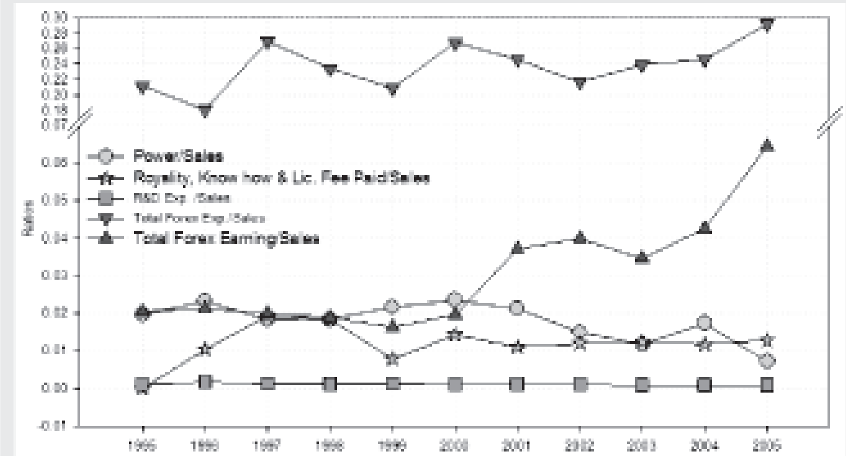


Fig 4-24.12: Innovation indicators of the companies doing R&D in Energy

Source: Prowess Database

Role of Public sector in Energy Sector R&D

Coal: An overview of scientific articles published in coal sector between 1995 and 2007 reveals that Indian share of published papers is increasing gradually, with an exception for the year 2006 which showed a reverse trend. However, the number of citations of these research papers shows a dismissal picture. The rate of citations presently is abysmally low as compared to earlier years. In India, scientific research on coal related areas is being conducted by both universities as well as institutes. Among institutes CSIR holds the maximum number of research papers in coal area followed by the Indian Institutes of Technology while in academic sector BHU holds the maximum number of research papers. Moreover CSIR and IITs are far ahead in paper publishing as compared to other institutes and universities.

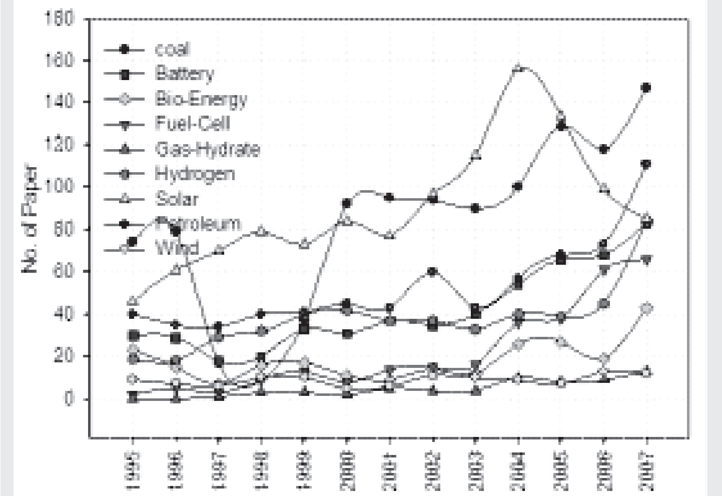


Fig 4-24.13: Indian publication in different fields of energy research
Source: Web of Science

Petroleum: The trend in number of research papers published in petroleum sector has remained stable by and large though an increase was seen during 2007. However a large increase was seen in the involvement of authors (numbers) publishing those papers. This shows that the scope of research is high in this area.

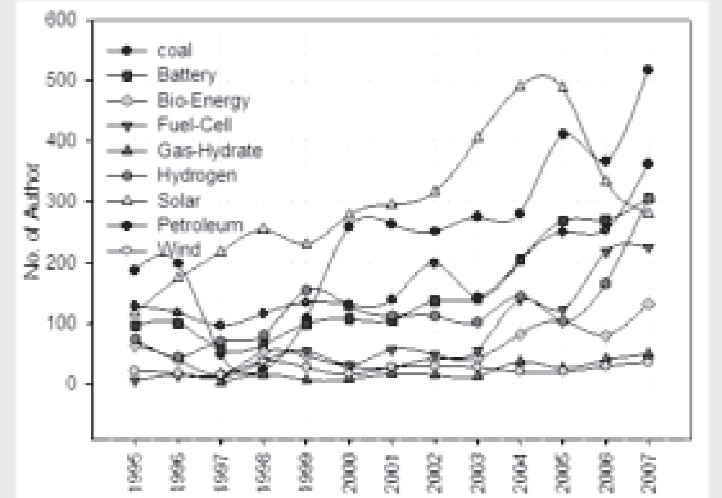


Fig 4-24.14: Indian authors involved in different fields of energy research
Source: Web of Science

Solar energy: An increasing trend was seen till 2004 but after that a negative growth in number of research papers output in solar energy as well as in number of authors involved was seen. Even the citations are abysmally low. IITs hold maximum number of papers in solar energy research and are way ahead followed by DRDO and CSIR. Among the universities, Shivaji University tops the list with 50 publications.

Bio-energy: Bioenergy includes energy from biofuels as well as from biomass. The trend on number of research papers published during the last 10 years pertaining to Bio-Energy research has more or less remained stable, with an exception in 2007 when it showed significant increase.

In the beginning of the millennium, both, number of papers and authors, decreased but after that there has been a significant increase in number of researchers and papers till date. Citations of papers published in bio-energy sector show a decline.

Gas hydrates: In India scientific work on gas hydrates was initiated during 1997 and is still in its nascent

Table 4-24.01: Foreign collaborators in Indian energy research publication output(1995-2007)

Foreign Collaborator	Coal	Petroleum	Battery	Bio-Energy	Fuel Cell	Gas Hydrate	Hydrogen	Solar	Wind
USA	99	51	56	23	29	8	71	245	33
Japan	18	4	21	5	18		14	264	5
China	13		2	7	6			183	
Germany	27	30	9	5	26		27	72	8
France	27	11	11		6		10	105	
South Korea	8	14	39		28	2	11	56	
England	13	7	5	2	14	6	8	67	1
Italy		4	6	1	13		25	65	
Canada	37	2	18	1	3		17	19	4
Australia	6	6	19		10		4	27	
Mexico		8		1	3		3	53	
Turkey		2						64	
Netherlands	4	1		2			8	26	2
Spain	6						7	23	1
Thailand	3			17				16	
Brazil	1			2			2	29	2
Sweden	5	2		6	1		4	14	
Switzerland	1	1			9		2	19	
Taiwan		19		1	4		1	6	

Source: Web of Science

Table 4-24.02: Top Indian Universities undertaking Energy R&D on the basis of publication output(1995-2007)

	Coal	Petroleum	Battery	Bio-Energy	Fuel Cell	Hydrogen	Solar	Wind
BHU	47	12	17	6		46	19	4
Anna Univ.	10	10	16	5	5	8	23	8
Jadavpur Univ.	23	13	2	10	9	13	9	1
Shivaji Univ.		5	2	2	2		50	
Alagappa Univ.	0	2	41		3	1	10	
Sri Venkateswara Univ.	5	0	12			3	20	
Delhi Univ.	1	6	6	4	1	2	14	
Jnv Univ.							34	
Madras Univ.	5	4	5			8	10	
Jai Narain Vyas Univ	1					1	30	
Calcutta Univ.	6	9		4	1	7	4	

Source: Web of Science

Table 4-24.03: Collaboration pattern in India in energy research (1995-2007)

No. of papers co-authored	Coal	Battery	Bio-Energy	Fuel-Cell	Gas-Hydrate	Hydrogen	Solar	Petrol
1-coauthored	150	28	15	5	4	46	99	50
2-coauthored	357	118	78	63	10	142	368	201
3-coauthored	277	165	70	98	15	142	307	182
4-coauthored	145	101	39	56	14	93	189	134
5-coauthored	76	69	19	31	15	39	104	54
6+coauthored	75	63	18	33	4	24	106	91

Source: Web of Science

stage. Since 2004 there has been a slight increase in Gas Hydrate research in India. Similarly the authors involved in publishing their research are on an increase, that too significantly from 2005 onwards.

Hydrogen: Though in recent years publication output and researchers involved in hydrogen field has increased but a sharp fall is seen in the paper citations especially after 2001. IITs holds maximum number of research papers in Hydrogen energy and are quite ahead of other institutes. They are followed by CSIR. In academic sector BHU heads the list.

Battery: The number of publications has increased two fold in battery research during the last 10 years while the number of authors involved has tripled thereby showing an increase in interest in this area. Paper citations show a reverse trend with a sharp drop in year 2007 indicating that more and more researchers are entering this field. In battery research India holds 11 patents.

Endnote

According to various projections, in near future, India's demand of energy would rise so sharply, that it would be quite difficult for India to sustain itself in this competitive world. So, how can India become self reliant or achieve security in energy? Increasing the supply of energy is one way of dealing with energy shortage in our country. A second way is to improve energy efficiency or reduce energy requirements. The challenge therefore before the nation is to focus R&D on technologies that seek to achieve progressively higher levels of efficiency covering all the different stages and forms of energy conversion, as well as those that seek to improve the efficiency at the end use stage. The other broad concern of energy R&D would be to identify new and novel resources/methods of energy generation (especially renewable), improve technology to tap known but uneconomic and novel energy resources, develop energy conversion systems with higher efficiency, develop standards for new energy sources, etc. As a result, R&D in the energy sector is quite critical for India's energy prospects.

Put together the country needs to develop critical capacities and capabilities in new energy research and this has to be achieved by a set of policies already enshrined in the framework enunciated by the Prime Minister and by the Energy Policy.

The main challenge facing India's energy sector would be to increase its efficiency in an environmentally and socially acceptable manner. It needs to augment its domestic energy resources. It is a long term imperative that renewable resources are exploited optimally as India's sustained economic development is vitally dependent on its energy security and on the promotion of sustainable and environment friendly energy technologies. The underlying assumption therefore is that novel S&T capability and capacity would endow the country with required energy resources.

Materials R&D and Innovation

Due to their influence on the extent of sophistication and standard of living, materials have defined the ages of mankind. The development of the field is determined to a great extent by societal needs ranging from national security and communications to health and housing. Aspiration of India to become a developed nation by 2020 necessitates development of novel materials. At the same time increasing the availability and affordability of traditional materials is also essential to sustain and improve the quality of her people. Fulfilling these ambitions or promises requires a strong R&D foundation; public, private and/or joint initiatives.

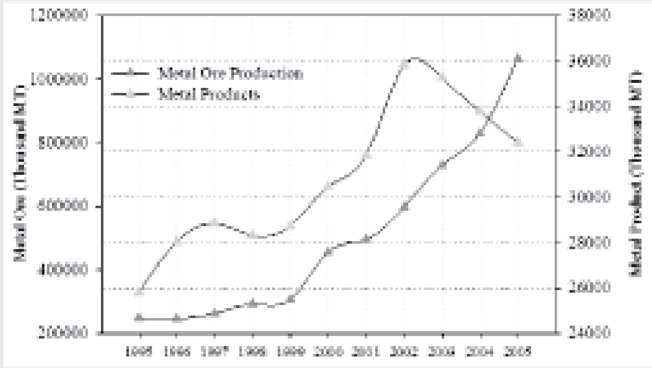


Fig 4-25.01: Materials production in India;
Source: *United Nations Statistics Division - UNSD*

Materials Production in India

One segment of materials production comprises of production of raw metal ores and production of metal products. National production of metal ores has increased with an AAGR of around 16% except for a bit of negative growth (-1.3%) during 1996.

Zinc ore and its concentrates contribute on an average 77% to the total metal ore production followed by iron ore and its concentrates (21%) and gold ore and its concentrates have the lowest contribution. This production dynamic may be indicative of the country's reserves of the ore and hence has significant implications in shaping national materials R&D.

Production of metal products implies value addition and the AAGR of production of metal products is only about 2% and the lowest (negative) growth (-4.14%) was observed in the year 2004. Production of iron products accounts for maximum share (90%) of production of metal products.

India's Materials Trade

India trades materials in different forms; raw metals, metal products as well as fabricated metal products including machinery and equipments in finished form. The share of material trade in total trade is about 23%. During the 90s and the first decade of this century, on an average, the percentage share of material exports (24.57%) is higher than the percentage share of material import (21.81%) in total Indian material

Table 4-25.01: Relative share of materials trade (%) to total trade of India;

Year	Export	Import	Total Trade	Trade balance
1991	20.47	19.16	19.79	4.54
1992	23.28	21.14	22.12	9.25
1993	25.25	20.51	22.82	-78.21
1994	23.70	17.88	20.67	-48.00
1995	23.24	17.40	20.11	-20.38
1996	21.14	19.18	20.08	7.56
1997	22.15	24.04	23.18	33.95
1998	24.29	27.48	26.08	39.00
1999	27.85	25.82	26.68	20.08
2000	24.59	23.82	24.18	18.12
2001	24.36	23.40	23.84	17.82
2002	26.33	21.70	23.84	-6.37
2003	26.71	23.46	24.92	8.96
2004	28.96	24.79	26.56	13.07
2005	25.56	20.83	22.76	10.28
2006	25.12	19.57	21.82	7.75
2007	24.76	20.66	22.30	12.43
Average	**24.57**	**21.81**	**23.04**	**2.93**

Source: *United Nations Statistics Division - UNSD* trade.

Monetarily, materials trade has increased at an average annual growth rate of 16.73% during the period which is higher than the average annual growth rate of the volume of trade of all commodities. The volume of export and import of materials has grown by 15.93% and 17.85% respectively. The trade of materials in terms of quantity has increased steadily especially after 2001. There is positive trade balance especially 2003 onwards, which was of course due to the higher export of raw materials indicating the lack of value addition and hence technological inefficiency.

Materials R&D Strategy of India

From the preceding paragraphs it is apparent that the dynamic of foreign trade in materials is better than foreign trade of all commodities put together. However, increasing the availability as well as affordability of traditional materials and development of novel materials depends to a large extent on the country's materials R&D status. The world emphasis on materials is shifting from the present silicon based approach to diverse and novel materials like nano materials, cryogenic materials, biomaterials, and mesoscopic materials, energy materials, biomaterials, etc. Accordingly, the national S&T policies on materials science could focus on three basic facets:

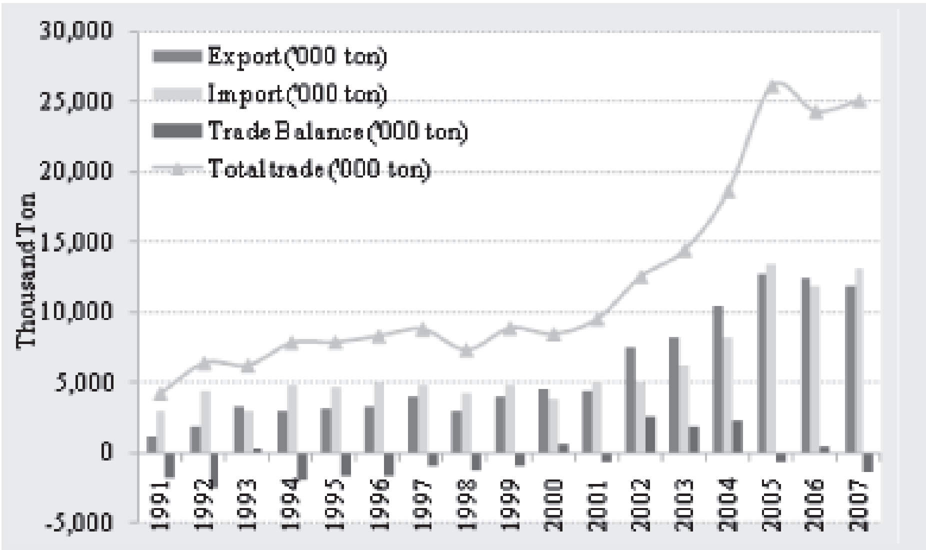


Fig 4-25.02: Foreign Trade of materials by India in quantitative terms; ***Source:*** *United Nations Statistics Division - UNSD*

1. *Domestic value addition:* India exports more of raw materials than metal products and metal fabricated products. Policies could be formulated in such a manner as to encourage more value addition in domestic produce. This will enhance forex earnings.

2. *Technology for processing advanced materials:* Another feature of India's material industry is that we are short on, rather virtually nil in strategic materials like Vanadium, Uranium, and Lithium etc. Non-availability of a resource is a natural phenomenon and the country needs to enhance technological capacity to process those strategic materials or their substitutes in order to have substantial bargaining power in the market.

3. *Capability and capacity to produce novel materials:* To meet the growing national demands of health, hygiene, sanitation, housing, energy and to improve the standard of living should be the third objective of national materials science strategy. There is an urgent need to enhance the capability and

capacity to develop advanced and novel materials.

In the following paragraphs the present state of affairs of materials science research in India has been captured as a pre-requisite to formulating a strategic plan.

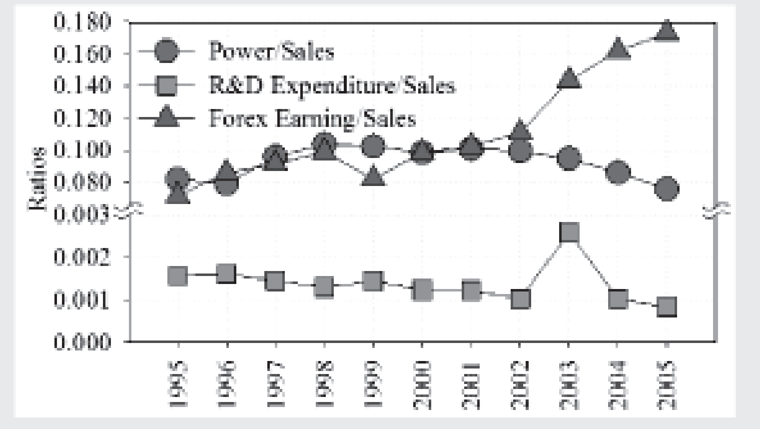


Fig 4-25.03: Trend of innovation in the materials related companies; *Source:* CMIE

Materials R&D in the Private Sector

Among the listed companies, the number of companies doing materials related R&D decreased over the period 1995-2005. Likewise, there is also a decline in the number of companies paying Royalty and License fee etc. However, there has been a rise in the number of companies' earnings from forex. The quantity of power consumed per unit of sales has been on the decline which indicates efficiency of the technology or product used. The amount of royalty paid, license fee paid per unit of sales is also decreasing over the considered period. Both forex expenses as well as forex earning per unit of sales is increasing. What is more serious is the decreasing R&D expenditure per unit of sales, which needs immediate attention.

Materials R&D in the Universities/Research Organizations: Knowledge Generation

Research Institute and Universities play a major role in advanced knowledge generation through both fundamental non-commercial and development research. The knowledge generated is communicated or disseminated in the form of publications and protected mainly through patents. This knowledge becomes the feedstock to bridge organizations for development of engineering solutions for industries who convert the knowledge to commercial products or processes.

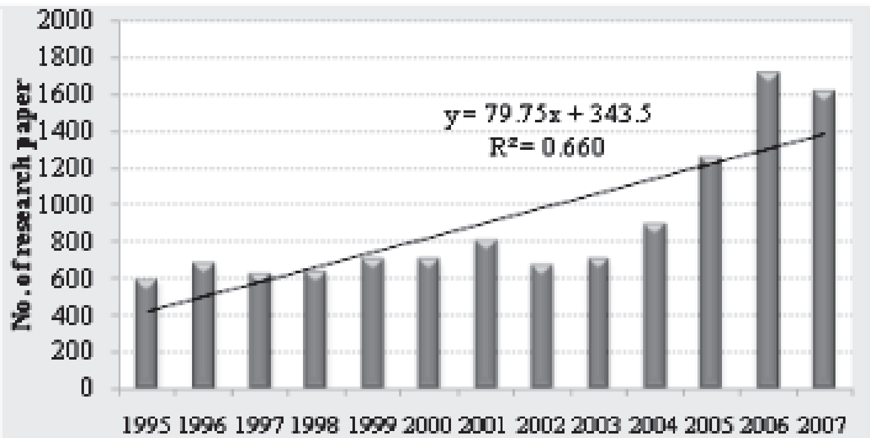


Fig 4-25.04: Trend of India's publication in Materials science; *Source:* Web of Science

Overall output in Material Science: The average annual growth in material science research in India is about 10%, over the period 1995-2007. There has been approximately 3 fold increase in the number of publications in a span of 13 years. Indian publications in material sciences is concentrated more in the conventional disciplines of material research. Highest number of papers have been published in the polymer (7,079 nos.) followed by those in alloy (4,007). Though India has publications in as high as 24 of the 25 areas of materials science outlined by NSF, only the top 12 areas are worth mentioning.

Table 4-25.02: Top Institutions/Universities in material science publication; (based on number of papers of the top 12 fields of material science)

Institute/University	No. of papers	No. of areas
IITs	3376	11
CSIR	2516	12
IISc	1212	12
DRDO	692	9
BARC	658	12
Banaras Hindu Univ	507	10
IACS	455	8
Anna Univ	393	9
TIFR	349	8
Univ Delhi	257	7

Source: Web of Science (19952007)

Based on the total publications in these 12 areas, the IITs together occupy the top position with 3,376 papers followed by CSIR (2,516 papers) and IISc (1,212 papers). However, in terms of number of areas, only three institutes namely IITs, CSIR, and IISc have published in all the 12 top areas of material science followed by BARC (11 areas), BHU (10 areas). Indian Association for Cultivation of Science and Annamalai University are the two institutes having publications in 9 areas. Both TIFR and Delhi University have published in 8 areas. But rest of the institutes have publications in only 1 or 2 areas of material science. About 27.75% of publications are 3-authored papers and around 27.3% are 2-authored papers. In terms of collaborative publication, there appears to be a good understanding between Indian and German researchers (627 joint publications), followed by USA and Japan (Table 4-25.03). There are joint publications with authors from the countries other than the listed one, but those are not significant. This is actually the position of the top 10 foreign countries with which India has joint publications.

Table 4-25.03: Foreign Collaborator in materials science in India; *Source:* Web of Science (1995-2007); (based on number of papers of the top 12 fields of material science)

Area	GER	USA	JP	FR	S. KR	UK	ITALY	TAI	SING	AUS
Polymer	182		92	107	90	65	53	69		39
Alloy	186	223	89	33	41	44	38		44	
Semi conductor	93	112	62	22	47	28	18	18		
Ferro electric	32	75	41	9	20	10		8		
Super conductivity	46	85	80	44		21	22	17		
Liquid Crystal	30	46	34	9	8		5			
Composites	3	19	7	2	7	3			7	
Energy Materials	14	15	9	3	3	2				
Material Growth	5	11	6		2	2		3		
Metallic Glass	23	13	17	4	5			3	3	
Magnetic material	9	8	9	7	2	3	2			
Ceramics	4	4	1	1				1		

Area-wise scenario of Material Science Research in India: Further, knowing whether the publication in a particular sub-area e.g. Polymer is increasing or decreasing, or what is the standard of their publications (read citations), or who are national leaders (institutes) etc. is critical for formulating suitable strategies.

The output in Polymer research has increased gradually in last 13 years. The involvement of authors in this area has shown a sharp increase after 2005. In Alloy research, number of research papers shows an increasing trend over the period, but that increment is very low, whereas the number of researchers increased rapidly. The output in Semiconductor research has grown, in India, over the last 13 years. Increase in number of authors creates more scope for further research in this area. In Ferro-Electric research in India, the number of papers has constantly increased over the last 13 years.

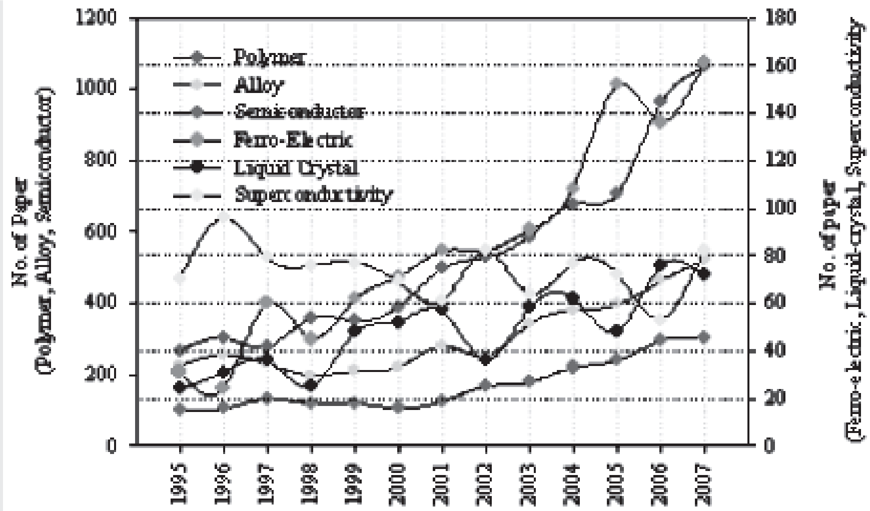


Fig 4-25.05: Trend of publication in selected areas of materials science; *Source*: Web of Science

The number of authors involved in these fields also increased significantly; this shows greater scope for further research opportunities in this area. The output in Super-conductivity is almost constant over the time period of last 13 years. But there is certain increment in number of authors involved in this area.

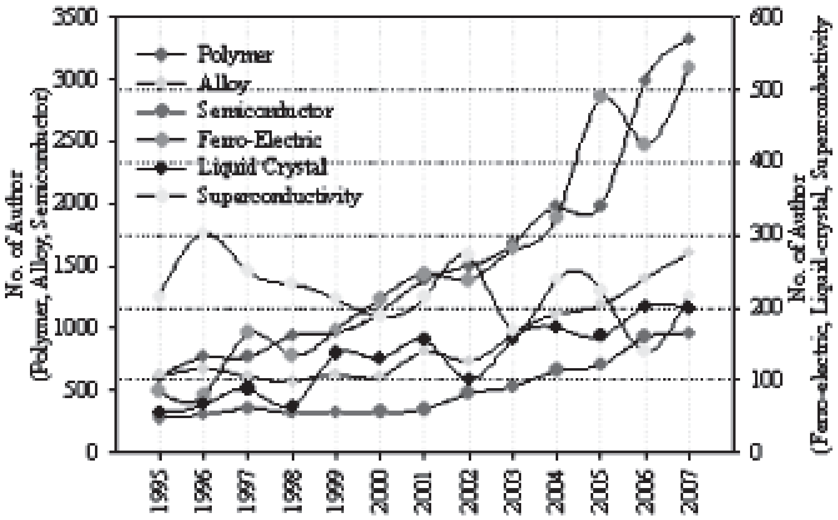


Fig 4-25.06: Involvement of authors in selected areas of materials science; *Source*: Web of Science

In terms of institutes, IITs top the list by having highest publications in 7 out of the 12 fields of material science, followed by CSIR having maximum number of research papers in 2 fields and TIFR, CLCRI and IISc each having maximum publications in 1 field only (Table 4-25.04). The IITs have published highest number of papers in alloy (1,021) while CSIR's highest publication is in the field of polymer (1,257). Among the universities, Annamalai University has publications in 3 fields followed by Jadavpur University in 2 fields. Though BHU has published in only one field (Alloy), but it has the highest publication among all the universities, irrespective of number of fields. Neither single authored papers nor papers authored by more than 3 authors could lead in any of the 12 fields. This is a clear indication that 2 or 3-authored paper is the ideal form of collaboration.

United States of America appears to be the most preferred foreign collaborator for Indian material science

Table 4-25.04: Different aspects of the publications in the 12 dominant areas of material science India;

Area	Top Inst	Top Univ	Top co-authorship	Top Collaborating Country
Polymer	CSIR (1257)	MG Univ (215)	2-authored (2197)	Germany (182)
Alloy	IITs (1021)	BHU (221)	3-authored (1197)	USA (223)
Semi conductor	IITS (407)	Anna Univ (68)	3-authored (609)	USA (112)
Ferro-electric	IITS (251)	Anna Univ (43)	3-authored (336)	USA (75)
Super conductivity	TIFR (196)	Saurashtra Univ (36)	2-authored (196)	USA (85)
Liquid Crystal	CLCRI (88)	Nagarjuna Univ (33)	3-authored (165)	USA (46)
Composites	IITs (109)	Aligarh Muslim Univ (11)	3-authored (108)	USA (19)
Energy Materials	IITs (75)	NIT (REC) (12)	2-authored (93)	USA (15)
Material Growth	IITs (32)	Anna Univ (22)	2-authored (54)	USA (11)
Metallic Glass	IISc (36)	Rajasthan Univ (13)	3-authored (47)	Germany (23)
Magnetic material	IITs (29)	Jadavpur Univ (9)	3-authored (40)	Japan (9)
Ceramics	CSIR (27)	Jadavpur Univ (2)	3-authored (28)	USA (4)

Note: Figures in parenthesis indicate number of publications
Source: *Web of Science (1995-2007)*

researchers. As many as 9 out of the 12 fields have USA as the leading collaborator, followed by Germany (2 fields) and then Japan (one field).

The Way Ahead

The present investigation shows that materials trade has a comparatively better trade balance than the trade balance of all commodities. This picture of material trade balance owes partially to the increased investment on R&D and innovation by the industries. Perhaps, more emphasis on novel materials like nano materials, cryogenic materials, biomaterials and mesoscopic materials, energy materials etc by the research organizations and institutions to generate adequate feeding material for the industries may improve the status of materials trade, or at least keep up the present trend. More importantly, enhanced research activity in novel materials is essential for security and for meeting the national requirements.

S&T Output and Patents

Overview

The ability to generate, access and exploit new scientific and technological knowledge is becoming increasingly strategic and decisive for the economic performance of countries and regions in the present competitive globalized economy. Contributions under this *theme* reflect upon the performance of Indian science and technology as indicated by its publications and patents output and may help therefore to understand its strategic abilities to generate and exploit the new scientific and technological knowledge. The Scientific Policy Resolution, 1958; the Technology Policy Statement of 1983; and the Science and Technology Policy, 2003 of the Government of India indicate continued political commitment to the support of science and technology and embody a vision for its development in the country. This political commitment led to the creation of a vast S&T infrastructure within government R&D institutions, universities, non-governmental organizations and firms in the industry; which have been playing a major role in the development of new scientific and technological knowledge in various fields of science and technology and utilizing such knowledge to meet the challenges and opportunities before the country.

Over the years, science and technology have become closely intertwined, and to be effective need to reinforce each other. The publications brought out by scientists and patents obtained by them, broadly indicate the output of science and technology, that can be used to understand growing Indian capacities and potential in different fields of science and technology. A review of these indicators may provide significant insights into the national R&D capacities, emerging priorities, performance and future directions of scientific and technological institutions in the country. Several contributions under this theme focus on some such salient dimensions. The analysis based on the publications data from SCOPUS database examines India's performance on several measures including country's publication share in the world research output and country's publication share in various subjects in the national context and in the global context. In addition, it profiles high productivity institutions, scientists and cited papers and the share of international collaborative papers at the national level as well as across subjects. The Indian Science Abstract presents an alternative dataset of the Indian S&T literature published in Indian S&T journals, the analysis of which has been made to reflect the performance of government and academic institutions. The publications output in specific cases of mathematics and global malaria vaccine research has also been examined. The health of scientific journals is important for effective communication and dissemination of the results of research and the performance of the S&T enterprise. The salient features of which are examined under: Profile of Indian Science Journals, Membership of editorial boards of US and UK journals in Clinical Medicine field, Access to international journals using citations: a case study of medical science research in India. The contribution – Appropriation and value of assets signifies the role of citations in the publications process.

The analysis of patent output indicates the characteristic features of the spurt in growth of patenting in India and the Indian industry's growing inventiveness and competitiveness. Indian industry has expanded its commercial base across countries as indicated by the patent protection sought by them for their inventions in countries synonymous with their commercial interests. The Indian publications and patents output has been examined in specific cases of Information and Communication Technology, and nanotechnology. A review of the Indian patents in biotechnology signifies the emerging national potential in this field. The contribution on strategic worth of patenting delves on the citations made in Indian patent documents.

The full text of these extended summaries is available at *http://www.nistads.res.in*

Status of India in Science and Technology as reflected in its Publication Output in Scopus International Database, 1997-2007

Indian publications for the period 1997-2007 can be examined for (i) analyzing India's current publications rate and its share in global publications in comparison with select leading countries, (ii) comparing and understanding similarities between India's national research profile and of select leading productive countries, (iii) determining the most productive and weak subject areas of research in Indian science and technology, (iv) determining India's share of international collaborative papers in its total output, leading co-author countries collaborating with India as well as its publications share across main subject areas, (v) determining the most productive and weak geographical regions, and (vi) understanding the characteristics of highly productive institutions, scientists and of cited papers.

The output data is as indexed by Scopus database, indexing over 15000 international peer reviewed journals in science and technology, besides more than 500 international conference/seminar proceedings. The study uses 11 years publications data from 1997 to 2007 on India. In addition, it used citations data for measuring quality and visibility of Indian research output. Three years, two year and one year citations window has been used for computing average citations per paper for all S&T papers published by India during 1997-2004, 2005 and 2006. The study has used a number of absolute publications, citation and collaborative measures for developing S&T indicators, as needed for depicting India's status in science and technology from 1997 to 2007.

India's Publication Share and Rank in World

As reflected in the Scopus database, India published 3,22,956 research papers during 1997-2007, with an average output of 29,360 papers per year. The cumulative output of India increased from 65,601 papers during 1997-99 to 121518 papers during 2005-07, showing a growth rate of 85.24%. The country achieved an annual average growth rate of 7.76% per annum during 1997-2007. It also improved its annual average growth rate from 4.31% during 1997-2002 to 11.21% during 2003-07. India holds 12th rank among the top 20 productive countries in science and technology with its global publications share of 2.11% as computed from cumulative world publications data for 1997-2007. The country has shown a rise in its global publications share, rising from 1.86% to 1.97%, and to 2.55% from the year 1997 to 2002, and to the 2007, respectively. Correspondingly India improved its world ranking from 13th position in 1997 to 12th in 2002 and to 10th in 2007. Table 5-01.01 lists 20 most productive countries based on the cumulative output of these countries for the period 1997-2007.

Subject Profile of India in Science and Technology

As per cumulative publications output data for 1997-2007, India's research profile by broad disciplines indicates that the physical science subjects together contributed the highest publication share (41.07%), followed by life sciences (29.68%), engineering sciences (29.59%) and health sciences (22.06%).

Table 5-01.01: World Publication Share of Top 20 Countries in Science & Technology, 1997-2007

Country	Cumulative Publication Output	Publication Share	Publication Rank
	1997- 2007	1997- 2007	1997- 2007
USA	3,584,564	23.44	1
UK	1,130,827	7.40	2
Japan	1,057,233	6.91	3
Germany	958,647	6.27	5
China	993,717	6.50	4
France	691,720	4.52	6
Canada	525,931	3.44	7
Italy	510,298	3.34	8
Spain	372,277	2.43	9
Russia	355,564	2.33	10
Australia	337,376	2.21	11
India	322,956	2.11	12
Netherlands	291134	1.90	13
South Korea	257,034	1.68	14
Sweden	212529	1.39	15
Switzerland	207,737	1.36	16
Taiwan	192,106	1.26	18
Brazil	194,024	1.27	17
Poland	177,288	1.16	19
Belgium	157,930	1.03	20

***Source** : Scopus*

Among top 20 most productive countries of the world, India has close subject similarity with four other international countries, namely, Russia, China, South Korea and Taiwan. This is because all of them have strong to moderately strong emphasis in physical sciences and engineering sciences, but are weak in health sciences.

Medicine, chemistry, physics, agricultural & biological sciences, engineering, biochemistry, genetics & molecular biology and materials science are considered as the seven high priority areas of India in S&T, each contributing publication share between 12.0% and 19.15% in the cumulative national publication output during 1997-2007.

Earth & planetary sciences, environmental sciences, pharmacology, toxicology & pharmaceutics, chemical engineering, mathematics, immunology & microbiology, veterinary sciences and computer science are the eight medium productive subjective areas of Indian research, each contributing between 2.65% to 6.36% share in the cumulative publication output by India during 1997-2007.

Energy and neurology are the two low productive subject areas contributing publications share between 1.33% and 1.84% in cumulative publication output by India during 1997-07. In addition, public health nursing and dentistry are the three least productive Indian subject areas contributing each less than 1% publication share in cumulative publication output for the same period.

The largest increase of 3.68% (from 16.57% to 20.25%) in national publication share from 1997-99 to 2005-07 has been observed in medicine, followed by 2.63% (from 11.68% to 14.31%) in biochemistry, genetics & molecular biology, 1.34% (from 3.09% to 4.43%) in computer science, 1.03% (from 12.75% to 13.78%) in engineering, 0.93% (from 11.51% to 12.44%) in materials science, 0.77% (from 3.42% to 4.14%) in immunology & microbiology, 0.53% (from 6.11% to 6.64%) in pharmacology, toxicology & pharmaceutics, 0.50% (from 5.93% to 6.43%) in environmental science, 0.23% (from 5.87% to 6.10%) in chemical engineering, 0.23% (from 0.40% to 0.63%) in public health, 0.20% (from 0.09% to 0.29%) in nursing and 0.15% (from 1.20% to 1.35%) in neurology. In contrast, the largest decrease of 2.37% (from 14.55% to 12.18%) in national publication share from 1975-99 to 2005-07 was observed in agricultural & biological sciences, followed by 1.33% (from 5.71% to 4.38%) in earth & planetary sciences, 1.00% (from 3.15% to 2.15%) in veterinary science, 0.87% (from 15.10% to 14.23%) in physics, 0.22% (from 2.09% to 1.87%) in energy and 0.15% (from 4.37% to 4.22%) in mathematics**.**

In terms of global publication share in 20 broad subject areas during 1997-2007, the largest share (5.36%) is accounted by veterinary science, followed by chemistry (4.57%), agricultural & biological sciences (4.05%), materials science (3.41%), pharmacology, toxicology & pharmaceutics (3.39%), chemical engineering (2.77%), environmental science (3.32%), physics (2.73%), mathematics (2.31%), earth & planetary sciences (2.27%), immunology & microbiology (2.22%), biochemistry, genetics & molecular biology (2.11%), energy (2.02%), engineering (1.69%), computer science (1.49%), medicine (1.48%), dentistry (1.36%), neurology (0.91%), public health (0.73%) and nursing (0.30%).

India has substantially improved its global publication share in 16 broad subjects out of 20 subjects over the years, but the largest increase (1.89%) is achieved by chemistry (from 3.73% to 5.62%) from the year 1997 to the year 2007, followed by 1.84% (from 0.82% to 2.66%) in dentistry, 1.74% (from 1.55% to 3.29%) in immunology & microbiology, 1.25% (from 2.67% to 3.92%) in environmental science, 1.24% (from 1.62% to 2.86%) in biochemistry, genetics & molecular biology, 1.17% (from 3.10% to 4.27%) in materials science, 0.92% (from 0.61% to 1.53%) in neurology, 0.78% (from 3.60% to 4.38%) in agricultural & biological sciences, 0.76% (from 3.23% to 3.98%) in chemical engineering, 0.75% (from 1.01% to 1.76%) in medicine, 0.71% (from 2.61% to 3.32%) in physics, 0.62% (from 0.45% to 1.07%) in public health, 0.42% (from 1.71% to 2.03%) in engineering, 0.37% (from 0.11% to 0.48%) in nursing, 0.24% (from 1.66% to 1.90%) in computer science and 0.05% (from 2.42% to 2.47%) in earth & planetary sciences. In contrast, the largest decrease in India's global publication share (1.70%) from the year 1997 to the year 2007 was observed by pharmacology, toxicology & immunology (from 5.09% to 3.39%), followed by 0.49% (from 2.67% to 2.18%) in mathematics, 0.34% (from 2.92% to 2.58%) in energy and 0.13% (from 5.41% to 5.28%) in veterinary science.

Status of India's International Collaboration in Science & Technology

Based on publications output data for India in science and technology for 1997-2007, it is found that India's average annual share of international collaborative papers to its total cumulative publication output during 1997-2007 has been 15.21% (Table 5-01.02). India witnessed marginal rise in their share of internationally collaborative papers from 14.30% during 1995-97 to 17.08% during 2005-07. Compared to India, developed countries' share of collaborative output in their total national output during 1997-07 was significantly higher.

India's collaboration with Europe and North America contributed the largest share of international collaborative papers (43.54% and 42.47%), followed by Asia (25.63%), Oceania (4.43%), South America (2.97%) and Africa (2.83%) in the cumulative collaborative publications output by India during 1997-2007.

Among the 25 leading collaborating countries with India, the major ones from the developed world are: United States with 37.30% share, followed by Germany (13.94% share), United Kingdom (12.88% share), Japan (10.11% share), France (7.50% share), Canada (5.64% share), Italy (4.33% share), Australia (3.83% share), Netherlands (2.98% share) followed by three countries Switzerland, Russia and Spain (2.81%, 2.41% and 2.47% share), and four countries Sweden, Belgium, Poland and Hungary (1.93%, 1.43%, 1.38% and

1.07% share). Similarly, leading countries from the developing world collaborating with India are: South Korea with 4.08% publication share in the total collaborative publications during 1997-07, followed by China (3.09% share), Taiwan (2.64% share), Brazil (2.10% share), Malaysia (1.80% share), Singapore (1.80% share), Columbia (1.66% share), Mexico (1.61% share) and Israel (1.31% share).

Table 5-01.02: India's Share of International Collaborative Papers 1997-2007

Period	Total Publications	Total International Publications	Share of International Collaborative Publications (%)
1997	21058	3011	14.30
1998	21698	3298	15.20
1999	22846	3264	14.29
2000	23284	3216	13.81
2001	24280	2822	11.62
2002	25990	3132	12.05
2003	29972	5199	17.35
2004	32311	5585	17.29
2005	36403	6271	17.23
2006	40979	7027	17.15
2007	44126	7536	17.08
Average Share of Int. Collaborative Papers		15.21	

India witnessed shift in its share of collaborative papers with different countries from 1997-99 to 2005-07. With developed countries, like United States, Canada, Italy, Netherlands, Russia, Columbia and Hungary, India witnessed decline in its share of collaborative papers and with other countries, such as UK, Japan, Sweden, Switzerland, Australia, Spain, Russia, Germany, France, Netherlands and Belgium, it witnessed rise in its share of collaborative papers from 0.16% to 0.93% for the same period. With developing countries, like South Korea, Taiwan, Malaysia, China, Brazil, Israel, Singapore and Mexico, India witnessed rise in its share of collaborative papers ranging from 0.26% to 4.52% and with Columbia, it witnessed decrease by 0.14% from 1997-99 to 2005-07. This analysis is based on India's cumulative publication output during 1997-07.

Among the various subjects, the largest share (27.84%) of international collaborative papers is recorded by India in physics during 1997-2007, followed by mathematics (27.66%), nursing (25.04%), computer science (23.70%), earth & planetary sciences (22.24%), biochemistry, genetics & molecular biology (19.51%), immunology & microbiology (19.36%), materials science (17.29%), public health (16.67%), neurology (16.34%), energy (16.27%), engineering (14.38%), chemistry (13.75%), chemical engineering (13.73%), agricultural & biological sciences (11.87%), medicine (11.14%), environmental science (10.80%), pharmacology, toxicology & pharmaceutics (9.10%), dentistry (6.54%) and veterinary science (4.0%)%). India's share of international collaborative papers has increased in 16 out of 20 broad subjects from 1997-99 to 2005-07. The largest increase (6.29%) in international collaborative papers share has been recorded by neurology from 1997-99 to 2005-07, followed by earth & planetary sciences (6.05%), public heath (5.53%), materials science (5.30%), medicine (4.31%), agricultural & biological sciences (3.44%), environmental sciences (3.29%), nursing (2.98%), chemical engineering (2.98%), pharmacology, toxicology & pharmaceutics (2.68%), veterinary science (2.51%), mathematics (2.31%), biochemistry, genetics & molecular biology (2.28%), chemistry (2.14%), physics (1.40%) and engineering (1.12%). In contrast, there is a decrease (10.10%) in international collaborative papers share of India from 1997-99 to 2005-07 by computer science, followed by dentistry (6.96%), energy (1.08%) and immunology & microbiology (0.26%).

Output & Impact of National Funding

In terms of publications output, the largest number of publications (36,501) during 1997-2007 was contributed by 7 Indian Institutes of Technologies (IITs), followed by the Council of Scientific & Industrial Research (CSIR) (26,976), Department of Atomic Energy (DAE) (17,524), Ministry of Health & Family Welfare supported institutes (13,271), Department of Science & Technology (DST) supported institutes (11,376), etc.

The CSIR scored highest in terms of total citations secured, and the followers were the seven IITs, the DAE institutes, the DST institutes, and similarly. Ranking in terms of publications impact as measured through citations per paper, the Department of Biotechnology (DBT) supported institutes lead with 4.09 citations per paper, followed by Department of Atomic Energy (DAE) institutes (3.64) and others as shown in Table 5-01.03.

Table 5-01.03: Impact of National Agencies in India on R&D Research, 1997-07

Funding Agencies	1997-2007		
	Papers	Citations	ACPP
Council of Scientific and Industrial Research (CSIR)	26976	87272	3.24
7 Indian Institutes of Technology (IITs)	36501	80105	2.19
Department of Atomic Energy (DAE) Institutes	17524	63829	3.64
Department of Science and Technology (DST) Institutes	11376	36070	3.17
Ministry of Health & Family Welfare (MHFW) Institutes	13271	29639	2.23
Indian Council of Medical Research (ICMR) Institutes	4375	16202	2.8
Defence Research & Development Organization (DRDO)	4763	11102	2.33
Indian Council of Agricultural Research (ICAR)	8430	9432	1.12
Department of Space (DOS) Institutes	2976	7212	2.42
Department of Biotechnology (DBT) Institutes	1726	7062	4.09

ACPP: Average citation per paper

High Productivity S&T Institutions in India

A total of 36 organizations were identified as high productive ones publishing more than 800 papers during 1997-2007 (Table 5-01.04). These 36 organizations include: (i) Nine institutes of national importance (ii) Ten research institutes and (iii) Seventeen universities. These top 36 organizations together contributed 45.98% papers to the total cumulative research output by India during 1997-2007. These organizations individually published between 881 and 12,856 papers in 11 years, with an average output of 4,243 papers per organization, of varying size of manpower. Some of these organizations are many times larger than the smaller organizations. Some fields of research have very large population of researchers and hence both high rate of publications and citations. Only 13 organizations have contributed publications output above the 36-organizations average (4,243 papers per institution) during 1997-2007. The publication share of these 36 organizations to the total output by India showed decline over time from 46.19% in 1997-2002 to 45.85% in 2002-07.

These 36 organizations witnessed average growth in their publications output over time (1997-2001 to 2002-07) by 48.52%. Of these, 17 units showed growth rate higher than the 36-organizations-average. The average h-index of these 36 organizations during 1997-2007 was 43.69. Of these, 20 organizations showed h-index higher than the 36-organizations averages. The average citation per paper recorded by these institutions during 1997-2007 was 2.64. Of these, 12 organizations showed citations performance above 36-organizations' citations average. The average share of the international collaborative papers of these 36 institutions during 1997-2007 was 18.28%. Only 15 out of 36 organizations have shown higher share of international collaboration papers than the average share of 36 units. To recall, these organizations are of different sizes and are contributing in different fields.

Table 5-01.04: Top 36 Productive Organizations in S&T in India, 1997-2007

Affiliation	1997-2007				Total Papers		
	TP	TC	ACPP	h-index	1997-2001	2002-2007	Growth rate from 1997-2001 to 2002-07
IISc, Bangalore	12856	44081	3.43	82	4542	6676	46.98
BHU, Varanasi	4993	9985	2	44	2141	2192	2.38
University of Delhi (DU), Delhi	9664	24237	2.51	57	3208	5054	57.54
AIIMS, Delhi	7893	19014	2.41	50	2701	4129	52.87
IIT, New Delhi	7604	15898	2.09	52	2344	4145	76.83
IIT, Mumbai	6799	17154	2.52	51	2003	3741	43.35
IIT, Chennai	6678	12986	1.94	51	2322	3338	53.88
IIT, Kharagpur	6565	15157	2.31	50	2190	3370	86.77
BARC, Mumbai	6059	17385	2.87	50	2217	3178	43.76
IIT, Kanpur	5996	18246	3.04	59	1989	3155	58.62
TIFR, Mumbai	4954	31870	6.43	76	2011	2407	19.69
University of Hyderabad, Hyderabad	4716	14160	3	55	1702	2356	38.43
Jadavpur University, Kolkata	4492	10541	2.35	45	1507	2335	46.72
ISI, Kolkata	4158	11923	2.87	56	1464	2148	65.02
Indian Institute of Chemical Technology (CSIR), Hyderabad	4013	17775	4.43	50	1166	2220	12.88
National Chemical Laboratory (CSIR), Pune	3987	19023	4.77	59	1489	2023	90.39
University of Madras, Chennai	3715	8125	2.19	38	1537	1735	35.86
Anna University, Chennai	3429	6626	1.93	34	1024	1859	81.54
IACS, Kolkata	3095	11590	3.74	46	1186	1493	25.89
IIT, Roorkee	3091	6386	2.07	18	912	1620	57.32
University of Pune	2870	10103	3.52	47	949	1493	88.62
Punjab University	2760	11004	3.99	51	889	1467	77.63
Aligarh Muslim University, Aligarh	2387	4090	1.71	32	703	1326	52.28
University of Bombay, Mumbai	2331	5389	2.31	36	803	1248	55.42
Saha Institute of Nuclear Physics (SINP),Kolkata	2030	6080	3	37	818	959	98.92
JNU, Delhi	2013	5363	2.66	36	779	1022	65.68
Rajasthan University, Jaipur	1938	4753	2.45	29	584	1081	31.19
IARI, New Delhi	1928	3193	1.66	29	679	1034	31.95
Central Drug Research Institute (CSIR), Lucknow	1712	4255	2.49	30	542	898	120
National Physical Laboratory (CSIR), Delhi	1661	3603	2.17	29	649	774	85.1
IVRI, Izatnagar	1645	1574	0.96	17	717	711	-0.84
PGIMER, Chandigarh	865	1495	1.73	20	207	527	54.94
Andhra University, Hyderabad	1462	2084	1.43	23	554	731	17.24
Karnataka University, Dharwad	1297	2968	2.29	31	372	740	19.26
IGCAR, Kalpakkam	919	1126	1.23	18	197	503	154.59
JNCASR, Bangalore	824	3607	4.38	34	185	407	155.33

Institutes of National Importance: These 13 institutions together contributed 20% share to the total publications output in science and technology in India during 1997-2007. Individually, these institutions published 407 to 12,856 papers in 11 years (1997-2007), with an average of 4,968 papers per institution. The publication share of these 13 institutions in the total output by India showed increase from 18.53% in 1997-2001 to 20.60% in 2002-07. These 13 institutions showed an average growth rate of 145.41% over time (from 1997-2001 to 2002-07). The average citation per paper of these 13 institutions was 2.49. These institutions together witnessed rise in their average citations rate per paper from 2.87% in 1997-2001 to 3.89% in 2002-07. The average h-index of these 13 institutions was 42.69. Of these, 8 institutions showed h-index higher than the 13-institutions average. The average share of international collaborative papers contributed by 13 institutions to the total output by India was 16.61%. The international collaborative publication share of these institutes have both increased and decreased from 1997-2001 to 2002-06.

Research Institutions: The top 23 most productive research institutions together contributed 13.53% share to the total cumulative publications output by India in science and technology during 1997-2007. Their individual publications output in 11 years ranged between 722 and 6,059 papers with an average output of 1,900 papers per institution. Only 7 institutions achieved publications output above the 23-insitutions average (1900 papers per institution). The publication share of these 23 institutions in the total output by India showed decline over time from 13.92% in 1997-2001 to 13.35% in 2002-2007. The average growth in publications output by these 23 institutions in eight years (1997-2001 to 2002-07) was 52.97%. The average h-index of these 23 institutions during 1997-2007 was 35.09. The average citation per paper of these 23 institutions during 1997-2007 was 3.14. These 23 institutions together witnessed marginal rise in their average citations rate with time from 3.38 citations per paper in 1997-2001 to 3.39 in 2002-07. The average share of international collaborative papers contributed by these 23 institutions to the total publications output by India during 1997-2007 was 18.74%. These institutions together witnessed rise in their share of international collaborative papers over time from 16.73% in 1997-2001 to 20.18% in 2002-07.

Universities: The top 43 Indian universities together contributed 26.80% share to the total cumulative research output by the country for 1997-2007. These universities individually published between 659 and 9,664 papers in 11 years, with an average of 2,013 papers per university. Of these, only 12 universities contributed publications output individually above the 43-universities average (2,013 papers). The publication share of these 43 universities to the total output by India showed decline over time from 26.98% in 1997-2001 to 26.52% in 2002-07. The average growth in publications output by these 43 universities (during 1997-2001 to 2002-07) was 63%. The average h-index of these 43 universities during 1997-2007 was 29.33. The average citation per paper of these 43 institutions during 1997-2007 was 2.04. These universities together showed rise in their average citation rate over time from 2.0% in 1997-2001 to 2.68% in 2002-07. The average share of international collaborative papers contributed by 43 universities to the total output by India during 1997-2007 was 15.76%. These universities together witnessed rise in their share of international collaborative papers over time from 12.56% in 1997-2001 to 16.81% in 2002-06.

Inter-comparison of different type of institutions reveals that publications productivity of Indian ‘research institutions’ had been the lowest, 1,900 papers per institution in 11 years. In contrast national institutes of importance have been the most productive institutions with an average of 4,968 papers per institute in 11 years, followed by universities (2,013). An average university has, however, many times more faculty than an average research organization, whose average size is also often lower than average size of national institution of importance. Moreover, if comparison is done on citations per paper, ‘research institutions’ are the leader with an average of 3.14 citations per paper, followed by national institutes of importance (2.49), and universities (2.04).

India's Research Output by Geographical Regions

High Productivity States: Tamil Nadu, Maharashtra, Delhi, Karnataka, West Bengal, Uttar Pradesh and Andhra Pradesh and Kerala are the top 8 high productivity states in terms of publications output and share. Together these eight states accounted for approximately 89% of the India's total cumulated publications output during 1997-2007. Individually, their national publication's share ranged from 3.6% to 16.3% in India's total cumulative publication output. Among these states, the national publication share of Karnataka has increased by 2.08% from 1997-99 to 2005-07, followed by Tamil Nadu (1.45%), Andhra Pradesh (0.41%), Delhi (0.40%) and Kerala (0.31%). In contrast, the national publication share of Uttar Pradesh has declined by 0.14%, followed by West Bengal (0.13%) and Maharashtra (0.10%) during the same period. Karnataka witnessed the highest publication growth rate of 119.65% from 1997-99 to 2004-06, followed by Tamil Nadu (102.09%), Kerala (101.70%), Andhra Pradesh (95.96%), Delhi (90.83%), West Bengal (82.97%), Uttar Pradesh (82.90%) and Maharashtra (73.05%).

Medium Productivity States*:* Gujarat, Chandigarh, Madhya Pradesh, Rajasthan, Haryana, Uttarakhand, and Punjab are the seven medium productivity states. Together these states accounted for approximately 22.78% of the India's total cumulated publications output during 1997-2007. Their individual publication's share ranged from 2.32% to 3.47% in India's total publications output.

Among these states, the national publication share of Chandigarh has increased by 0.60% from 1997-99 to 2005-07, followed by Uttarakhand (0.46%), Kerala (0.22%) and Rajasthan (0.20%), while shares declined for Haryana (0.20%), Madhya Pradesh (0.18%), and Gujarat (0.09%). In terms of publication growth rate from 1997-99 to 2005-07, the highest (113.11%) was achieved by Chandigarh, followed by Punjab (112.67%), Haryana (109.02%), Rajasthan (85.96%), Kerala (82.44%), Gujarat (67.15%), Madhya Pradesh (59.22%), and Haryana (58.57%).

Low Productivity States*:* Orissa, Assam, Jharkhand, Jammu & Kashmir, and Himachal Pradesh are the five low productivity states and together they accounted for approximately 5.66% of the India's total cumulated publications output during 1997-2007. Their publication's share ranged from 0.96% to 1.37% in India's total research output. Assam's contribution by way of national publications share increased by 0.30% from 1997-99 to 2005-07, followed by Jharkhand (0.24%) and J&K (0.15%). Himachal Pradesh witnessed decline of 0.11% in national publication share during same period, followed by Orissa (0.31%). In terms of publication growth rate from 1997-99 to 2005-07, the highest (129.90%) was achieved by Jharkhand , followed by Assam (129.01%), followed by J&K (114.07%), Himachal Pradesh (66.30%), and Orissa (42.43%).

Most Productive Journals in Science & Technology

The top 25 productive journals of Indian origin together contributed 14.18% share to the total cumulative publications output by India for 1997-2007. The top 25 journals of foreign origin together contributed as much as 7.08% share to the total cumulative publications output by India for 1997-2007. India's output in high impact journals (with IF range from 10 to 47.4 citations per journal) was also analysed. It was found that only 0.32% of the total Indian output was published in these high impact journals.

High Cited Papers from India

India published a total of 100 high-cited papers in science and technology as seen from the publications output data for 1997 to 2007. Since their publication between 1997 and 2007, these select papers received between 221 and 2,995 citations per paper. These were much higher than the citations their counterparts received during the same period. Of these 100 papers, 82 were articles, 16 review papers, 1 each note and short survey. All these 100 high-cited papers were collaborative papers. Indian institutions and authors were the lead authors in 42 papers and foreign institutions and authors were the lead authors in 58 papers. In overall, Indian participation in these 100 papers was confined to 55 institutions, which included 9 institutes of national importance, 21 research institutes, 19 from universities & colleges, 2 international institutes, 3 hospitals, and 1 was from industry. Among the various institutes, the largest numbers of high cited papers (8) were from IISC-Bangalore, followed by University of Hyderabad (7), AIIMS-Delhi (5), IIT-Chennai (4), IIT-Kharagpur (4), IIT-Mumbai (4), Punjab University- Chandigarh (4), University of Jammu (4), etc.

These 100 high cited papers were published in 60 journals including 8 papers in *Nature*, 8 papers in *Physical Review Letters*, 7 papers in *Chemical Reviews*, 6 papers in *Science*, 4 papers in *Physics Report*, 3 papers *in Journal of American Chemical Society*, 2 papers each in *Circulation*, *Chemical Communications, Chemistry of Materials, IEEE Communications Magazine, IEEE Personal Communications, International Journal of Modern Physics D*, *Lancet, Microbiology and Molecular Biology Reviews, Nuclear Instruments and Methods in Physics Research Section A, Nuclear Physics A and Physics Review D*, and one each in 44 other journals. Many of these high-cited papers were published in high impact factor journals.

Endnote

Based on analysis of publications output data for India for 1997-07 it is seen that India's scientific activity is on the rise; it is growing at an average rate of 7.76% per annum. However, despite the significant rise in its average growth rate, India's global share for 1997-07 is still very small (2.11%) compared to leading world economies especially China.

India still lacks equable distribution of resources as many geographical states in India still contribute very little publications share (less than 1% each) in science and technology. Some of such least productivity states are: Chhattisgarh, Pondicherry, Bihar, Goa, Meghalaya, Manipur, Arunachal Pradesh, Tripura, Sikkim, Nagaland, Mizoram, Andaman & Nicobar, Lakshadweep, Dadra & Nagar Haveli, and Daman and Diu.

The country needs to improve publications productivity especially in the university sector, as its average productivity compared to national institutes of importance and research institutions is still the lowest. This is an issue that policy makers in India need to address seriously so that universities, the knowledge centers of the country are able to improve their quality and productivity in science.

India's share of international collaborative papers in the cumulative publications output by the country during 1997-07 was 15.21%. Its collaboration with countries from America continent contributed the largest share of international collaborative papers (44.33%), followed by Europe (43.24%), Asia (26.92%), Oceania (4.09%), and Africa (2.85%).

Indian Scientific Output as seen through Indian Science Abstracts

Numerous studies have been reported in literature on the assessment of Indian scientific output using Science Citation Index (SCI) or Science Citation Index Expanded (SCI-E). Both these databases have a poor coverage of Indian science journals as compared to journals indexed by Indian Science Abstracts (ISA). To envision a complete picture of Indian scientific output it becomes imperative to use a more comprehensive database like ISA, which is more suitable to assess the Indian scientific output.

Data, from the web-edition of ISA for the years 2006, 2007 and 2008, covering all journals including those that are published behind schedule were analyzed for distribution of output according to different agencies, institutions and disciplines.

During 2006 ISA abstracted 18,224 articles from 445 journals published from India. These articles originated from 3,439 institutions located in different parts of the country. Of these, most prolific 50 institutions contributed 4,508 (~ 25%) of the total output and the remaining 2,894 institutions contributed 13,716 (~75%) publications (including individuals and anonymous authors).

Academic institutions (universities and colleges) are the major contributors (~35%) of the total output, followed by output from State Agriculture Universities (18%) and medical colleges (17.5%). The remaining output came from engineering colleges including IITs (4.9%), ICAR (6.7%), CSIR (2.8), State Government institutions (1.7%), Ministry of Environment and Forests (1.2%), DST (1.2%) and DAE (1.0%), private sector industrial R&D units (3.7%) and institutions under different economic ministries (1.7%). Contributions from DRDO, ICMR, and DOS were less than 1%.

Medical science and veterinary medicine as well as agricultural sciences including forestry, animal husbandry and fisheries each contributed about one-fourth of the total output. Thus, these two disciplines together constitute about half of the total Indian output. Remaining half of the output is scattered among other 15 disciplines, among which chemistry, botany and engineering contributed more than 5% of the output.

Most prolific 41 journals published 34% of the total output. However, 119 journals account for 65% of the total Indian output in ISA. These observations must be taken into account while formulating initiatives to enhance the publication output of the Indian S&T system.

Mathematics Output

Capability in mathematics is considered most generic, extremely important and one amongst the most productive even for innovation in the long run. In this section an analysis of the output from mathematics research in India has been undertaken. For this purpose, MathSci database, a compilation of data from mathematical review of 1998 and data from the database Scopus has been used. Fig 5-03.01 below exhibits details of papers in mathematics and related areas from India for 2000-2007. Sheer volume of publication has progressed steadily over the last eight years since 2000. Numbers of journals accessed for publishing research too has nearly similarly progressed and overall citations had increased since 2003 (except last few years when by

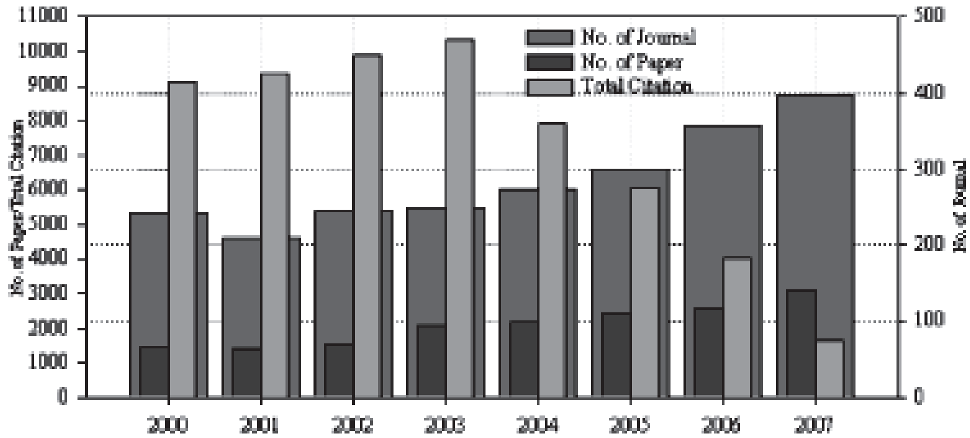


Fig 5-03.01: Output in Mathematics from India
Source: *Scopus Database*

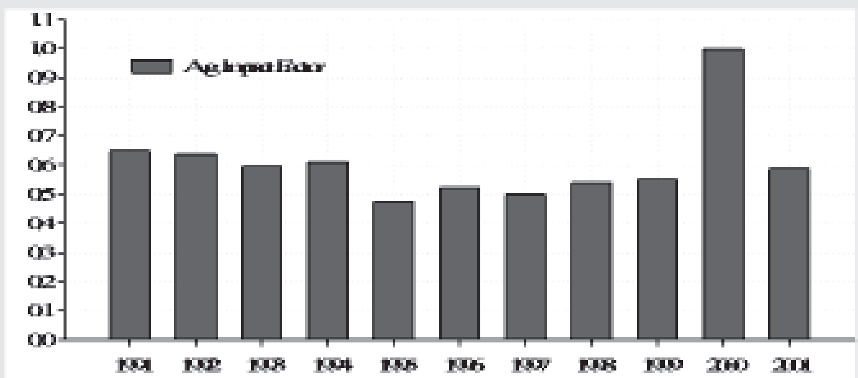


Fig 5-03.02: Average Impact Factor of journals publishing Indian output
Source: *MathSci Database*

definition citation data remained incomplete), the gross average of citation per paper failed to exhibit that trend.

Fig 5-03.02 represents the average values of the IF's of all journals in which Indian publications appeared in that year as per the MathSci database.

Fig 5-03.03 takes a look at the possible relation between IF value of a journal and the number of papers that it publishes from India. It shows clearly how both the journal-sets publishing only one, and publishing between 5 and 10 share rather similar values of IF over the decade of 1990. Possible irrelevance of IF could be the answer. Fig 5-03.04 shows the distribution of papers over journals in which Indian contributions appeared in 1991, 1994, 1997 & 2001 along three categories – IF, non-IF and Indian, non-IF and international.

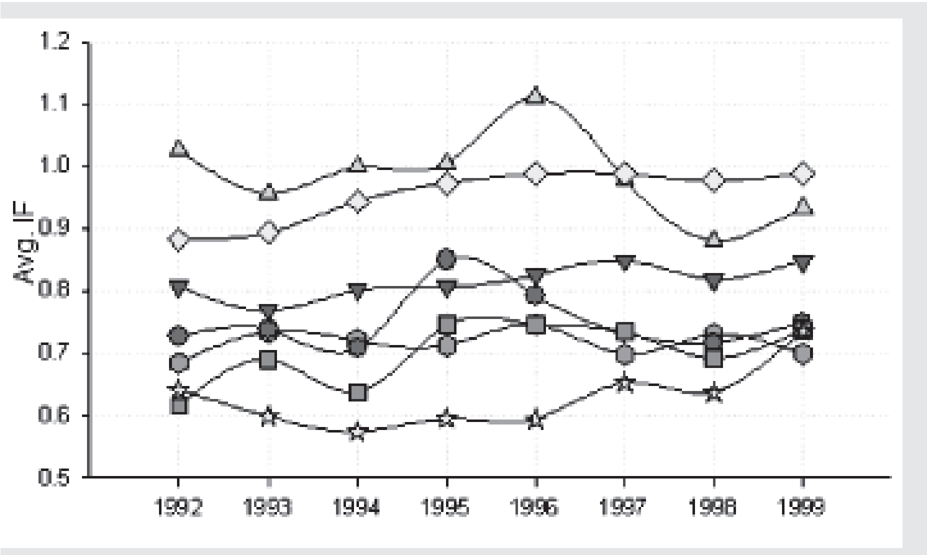


Fig 5-03.03: Journal Publication category and the Impact Factor values in 1990's

Output data of four years from MathSci shows a particular distribution of authorship across organizations. Figure 5-03.05 captures this, showing that contributions from the IIT system constitutes more than half of total. This distribution also captures the fact that a fairly large number of publications in mathematics originate in organizations and research projects belonging to areas of engineering and biology. Mathematics papers having received reviews in the four-year period subsequent to publications in journals also could be considered to have higher qualities. Figure 5-03.06 shows organization-wise distribution of numbers of such reviewed and therefore of higher quality papers. ISI occupies the most coveted position followed by the TIFR.

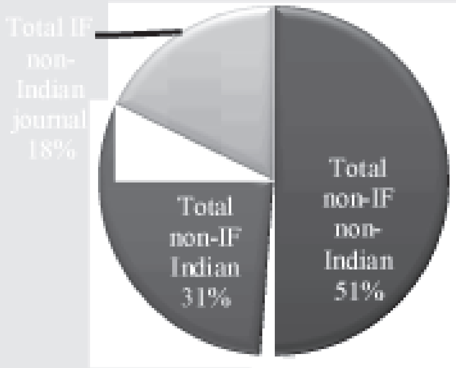


Fig 5-03.04: Distribution of Indian mathematics papers over IF & non-IF category journals for 1991, 1994, 1997 & 2001

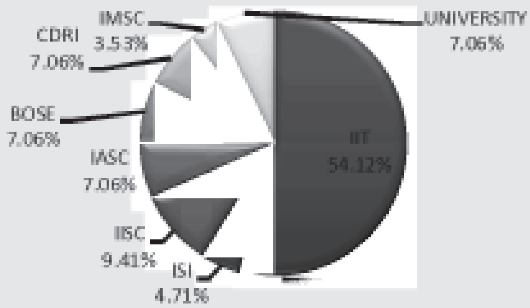


Fig 5-03.05: Organization-wise distribution of authorship of mathematics papers

Source: *MathSci (for 1990s)*

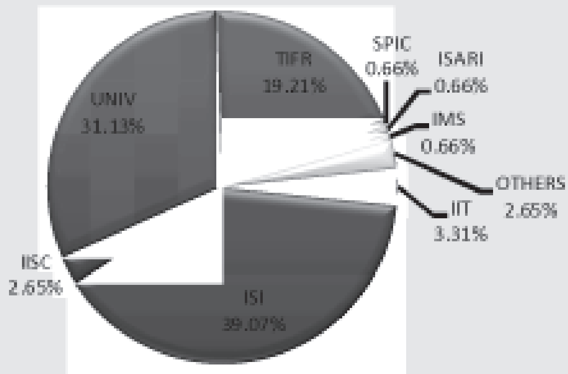


Fig 5-03.06: Reviewed-paper distribution across organizations

Source: *World Directory of Mathematicians, 1998*

Global Malaria Vaccine Research: Reflections from Publication

The study evaluates malaria vaccine research carried out in different parts of the world during 1972-2004 using Pub Med (web edition) as a source of data. The study examines pattern of growth of the output, its geographical distribution, profile of different countries in different sub-fields of malaria vaccine research and pattern of citations using GOOGLE Scholar.

Malaria vaccine research constitutes about 9% of total malaria research output. The study indicates that a total of 2,007 publications scattered in 352 journal titles originating from 40 different countries including India were published on malaria vaccine. As expected, the number of publications was less in the first five blocks i.e. 1972-1986, which started increasing during the later blocks and reached the peak in the year 1990-1992. After a slight decline during 1993-1995 and 1996-1998, it started increasing again. The highest number of publications was in the last block i.e. 2002-2004.

USA, UK and Australia together contributed more than half (~57%) of the total publication output. India contributed only 4% of the total output. Publication activity has decreased in Switzerland and Sweden, but has increased in Brazil, China, Japan and India. Total publication output 1972-2004 came from 420 institutions scattered among 59 countries. However, most of these institutions were concentrated in the USA, the UK, France and Australia. International Centre for Genetic Engineering and Biotechnology (ICGEB) of India was one amongst the most prolific contributor.

Different countries concentrate their research efforts in different sub-disciplines of malaria vaccine research. Development of asexual blood stage malaria vaccine has received more attention as compared to pre-erythrocytic and transmission blocking malaria vaccine.

The pattern of citations of the research output indicates that 2,007 papers received 35,299 citations during 1972-2004. The average rate of citation is ~ 18. Of the 2,007 published papers, 264 (~13%) papers did not get any citation and the rest 87 % got one or more citation. Of the cited papers, ~ 26% papers were cited 1 to 5 times and the rest 74% were cited more than 5 times. About 2% (36) papers received more than 100 citations.

The pattern of citation varies among different countries and most of the highly cited papers originated from USA. Citation per paper is also highest for USA. However, most of the developed countries have less than average value of citation per paper, which implies that their work is not quoted quite often. The value of RQI is highest for Papua New Guinea followed by USA. Most of the prolific institutions are situated in the USA.

Among the prolific institutions John Radcliffe Hospital (UK) had the highest value of citation per paper, while University of Edinburgh (UK) had the highest value for RQI. Citation per paper and incidence of high quality papers for the USA, the UK, Papua New Guiana and Denmark are more than the average.

The results of the study may be taken into account while formulating policy for future malaria vaccine research and for the control of malaria.

Profile of Indian Science Journals

This section presents the status of Indian science journals as reflected by their coverage in different data sources such as Ulrich International periodical directory, SAARC directory of periodicals, journals subscribed at National Science Library and journals indexed by Indian Science Abstracts. The list is not exhaustive as many more titles still remain to be included in the database.

Scientific publication activity in India dates back to early 19th century. Fig 5-05.01 presents the data on the growth pattern of the journals published from India prior to the year 1900 in blocks of ten years. In the initial blocks, the number of periodicals published grew slowly; however, there was a sharp rise during 1951-1960, which reached a peak in 1981-1990.

Highest numbers of periodicals published in India are in the discipline of medical and health sciences (23%) followed by agricultural sciences (20%). Share of publications in other disciplines are engineering and technology (14%), life sciences (12%), environmental sciences (6%), physical and earth sciences (7%), chemical and mathematical sciences each 5%, and the rest are in the category of general S&T, psychology, information & communication technology and energy.

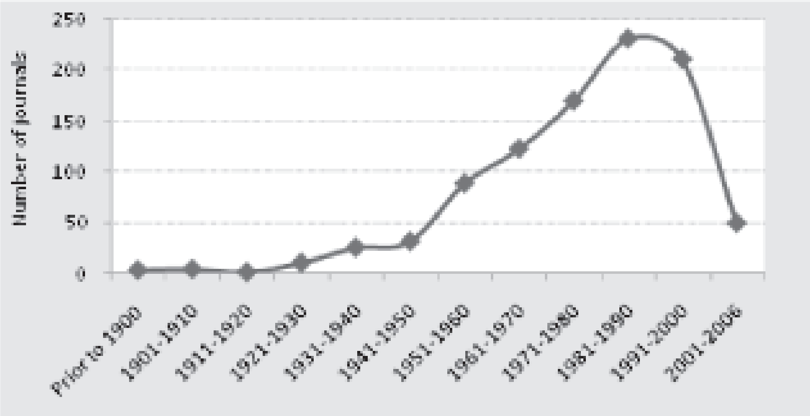


Fig 5-05.01: Growth of Indian science journals

Membership of Editorial Boards of US and UK Journals in Clinical Medicine Field

This box presents country-wise distribution of editorial boards in the field of clinical medicine. The data for this was collected from ISI Web of Knowledge Current Contents – Clinical Medicine, available at http://www.thomsonscientific.com.

The dataset contains 1359 journals, of which the journals published from USA and UK were subjected to analysis. The present analysis is based on data for 700 journals. Table 5-06.01 presents the number of editorial board members from different countries which indicate that highest number of editorial board members was from USA followed by UK. 76 researchers from India were members of the editorial board of different journals.

Table 5-06.01: Number of editorial board members in clinical medicine from different countries

Country	# of editorial board members	Country	# of editorial board members
US	5971	Switzerland	244
UK	1158	Sweden	198
Germany	514	Spain	177
Italy	450	Belgium	160
Australia	421	China	106
Japan	419	Israel	106
Canada	409	Austria	112
France	361	Denmark	112
Netherlands	328	India	76

Source: *http://www.thomsonscientific.com.*

Most of these periodicals are published as monthly, quarterly, or half-yearly publications. Publications in these three categories constitute about 75% of periodicals. Only miniscule portion of periodicals are published weekly and fortnightly. Societies and associations publish the maximum number of periodicals. Private publishers also contributed significantly to the publication of S&T periodicals.

Appropriation and Value of Publications, the Knowledge Assets

The value of published papers as assets lies in size of the asset-class, herd-beliefs and herd-betting of publishing population, and the presence of credible index journals which together make or unmake the value of both a knowledge asset and a class of knowledge assets. Citation is an important indicator reflecting this process of valuing. Higher citation to a paper increases the asset value, and the higher citations that all papers receive in a journal increase the credibility of the journal.

The different types of knowledge institutions, say from the areas under the knowledge of biomedical-university and hospitals are in general norm-following. The institution of organized research especially from the private business does not follow norms in general. To take up cross-country comparisons, countries with organized exchange mechanisms such as journals, editorial boards and the peer reviewers would be accessing more assets generated in several other countries, while the others not having similar institutions of journal-based exchanges would face difficulty in terms of higher costs of appropriation of knowledge assets as also in accessing rights to prior arts.

Citation patterns to research assets generated in India, China, Singapore and Israel support this point when we look at the knowledge asset classes of microbiology for India and China, and bioinformatics for all four countries and nano (including nanotechnology, nanomaterial and nanoparticle) for India, China and Israel (Fig 5-07.01).

India does not publish global journals of high standing, and as appears Indian publications cite Indian papers less and are in turn cited lesser, compared to China. China very actively cites domestic publications and is accepted as more worthy of citations by all countries in these areas.

Average citation for a single paper from China though is comparable to what on average an Indian paper would receive. Citations that a Chinese paper receives from several countries are also closely linked with the large number of inter-country collaborative researches going on in China. Reading these together, one gathers that China has been able to organize its research-assets production and valuation more intensively than accomplished by India.

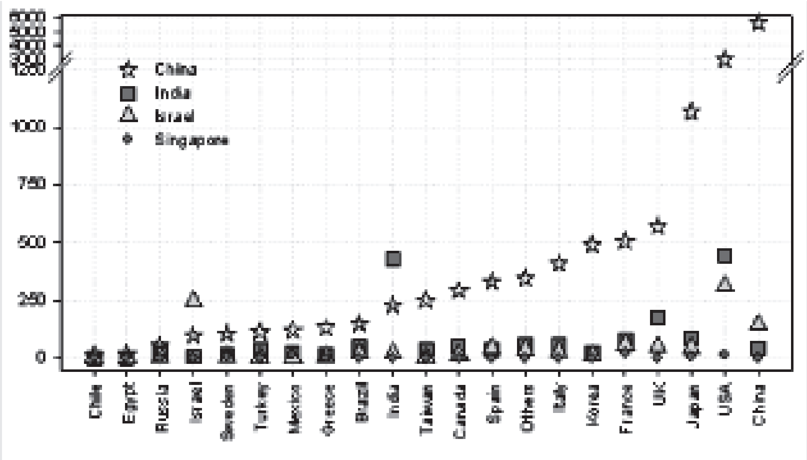


Fig 5-07.01: Number of citations received by papers from different countries

Source: *Scirus database*

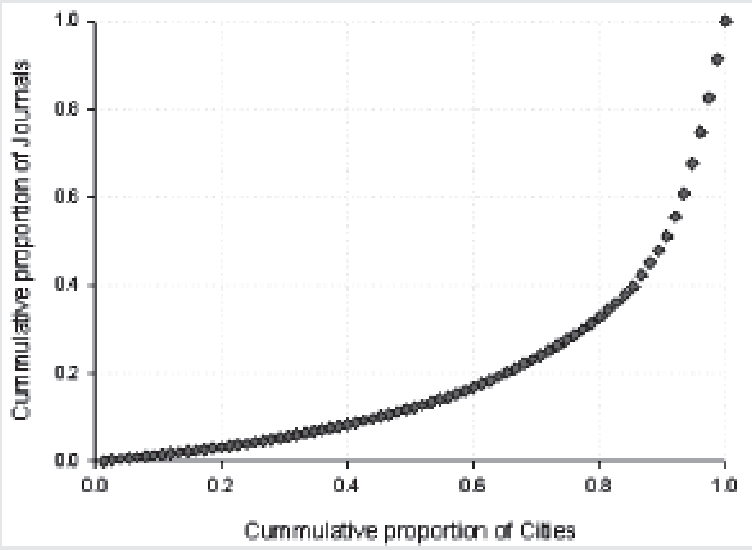


Fig 5-07.02: Lorenz Curve for Journals having ten or more papers across different cities of country (Gini Coefficient = 0.605)

Source: *Scirus Database*

Citation and capability to appropriate valuation also depends on the country's capacity. One measure of capacity is the access to journals by the publishing/researchers community. The fig 5-07.02 exhibits this dimension through the Lorenz curve estimation of the distribution of citation patterns and hence access across publishing cities from India. No wonder, the skewed up right side of the curve evidences metropolitan cities of Bangalore, Chennai, Delhi, Pune, Mumbai, Calcutta and a few large other cities.

Access to International Journals using Citations: a case study of Medical Science Research in India

Citation analysis is based on the basic assumption that the practice of quoting an author in a scientific communication is always very meaningful. However, use of citation data in understanding the access of journals by different countries, cities or institutions remains unexplored. Here citation data has been used to map how different Indian cities or institutions access international journals in the field of medicine.

The data is from Science Citation Index-Expanded for the year 2007. Analysis of 7,726 papers published in 2007 and originated from 257 cities scattered in different states of India indicates that maximum number of papers (21%) originated from Delhi followed by Tamil Nadu (11.6%). The share of papers from the North Eastern region was meagre as these states contributed only 28 papers. Distribution of the output for 257 different cities indicates that 46 cities contributed 20 or more papers and the rest less than 20 papers. 90 cities published only one paper each. Number of cited references appended to these papers was 19,512. Table 5-08.01 below gives distribution of output and the number of journals cited by each Indian State contributing 1% or more papers. It has been observed that States/cities publishing more papers are accessing more journals.

Table 5-08.01: Distribution of output and the number of journals cited by each State

State	# of papers	% of papers	Journals referred by corresponding papers
Delhi	1640	21.2	6844
Tamil Nadu	895	11.6	4884
Maharashtra	880	11.4	4380
Uttar Pradesh	836	10.8	4881
Karnataka	711	9.2	4593
Chandigarh	517	6.7	3099
West Bengal	406	5.3	3007
Andhra Pradesh	401	5.2	3140
Kerala	284	3.7	2217
Gujarat	246	3.2	1690
Madhya Pradesh	139	1.8	1362
Punjab	122	1.6	1275
Rajasthan	109	1.4	985
Haryana	105	1.4	1077
Pondicherry	93	1.2	922

Indian Patent Output 1990-2007

Patents are one of the key outputs of the science and technology system, and an important link between research & development and the marketplace. The quantitative analysis of the grant or applications for patents may provide significant insights into the inventiveness of a nation and its key performers of research and development. Indian patenting activity grew amidst changes taking place in its domestic and global economic policy environment. The twin objectives of the post-1991 economic reforms of the Government of India were to promote competition and simultaneously increase the ability of producers to meet such competition, by removing policy barriers and distortions. The Government of India launched a national campaign for creating awareness about patents and intellectual property rights (IPR) in the country in 1995 which may have impacted the generation of patents by R&D institutions in the country.

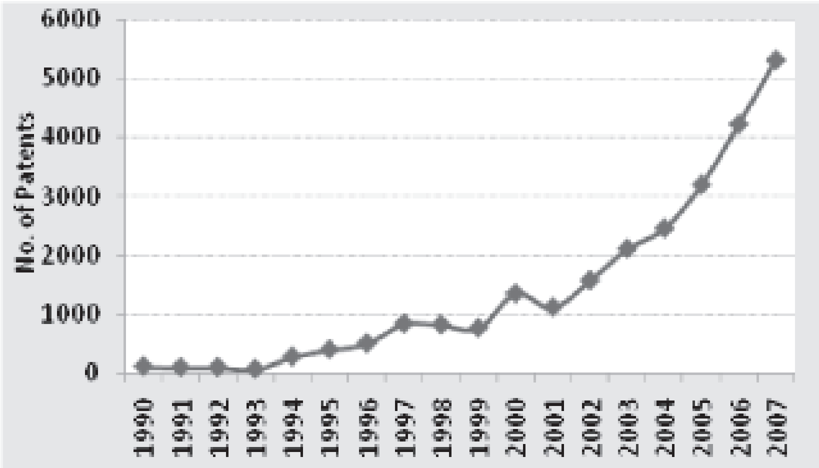


Fig 5-09.01 : India's growth in patenting

The data for analyzing the Indian patent output was extracted from the patent collections of United States Patent Office – granted patents, European Patent Office – granted patents, German patents granted, Patent Abstracts of Japan – unexamined patent applications, WIPO.

PCT publications and INPADOC patent collections (granted or filed) covering data from 42 different countries including India. The Delphion patent database (https://www.delphion.com/) was used and a search was made to obtain patents owned by Indian assignees for the period 1990 to 2007. The Delphion database included data of patents granted by India to Indian assignees, up to 2004 only. This data for the period 2005–2007 was taken from the website of Indian Patent Office which included the data on patents granted by India. The data was cleaned and analyzed. Fig 5-09.01 gives the pattern of growth of Indian patenting output.

Salient Highlights of the Findings

- The spurt in growth of the Indian patent output may be directly attributed to Indian industry's growing inventiveness and competitiveness, as its share in patenting grew from about 40% patents in 1990-1999 to around 60% patents in 2000–2007.

- The leading assignees from the domestic private sector include mostly firms belonging to the drugs and pharmaceuticals sector, which together obtained more than 3,600 patents during 2000-2007 as against just around 100 patents during 1990-1999 indicating a direct response of the Indian pharmaceuticals industry to the global challenge and competition in the field.

- Indian firms have increasingly been penetrating foreign markets and taking patents abroad since the initiation of economic reforms in early 1990s. The number of countries in which Indian firms have sought patents rose from 29 countries in 1990-1994 to 52 countries in 2000-2004 – a growth of 79%; and another 49 countries in the following three year period 2005-2007. The Indian assignees had maximum interest in protecting their inventions in North America, viz. USA and Canada till 2000-2004, after which their patenting activity expanded significantly in Europe, Asia and Latin America (Fig 5-09.02).

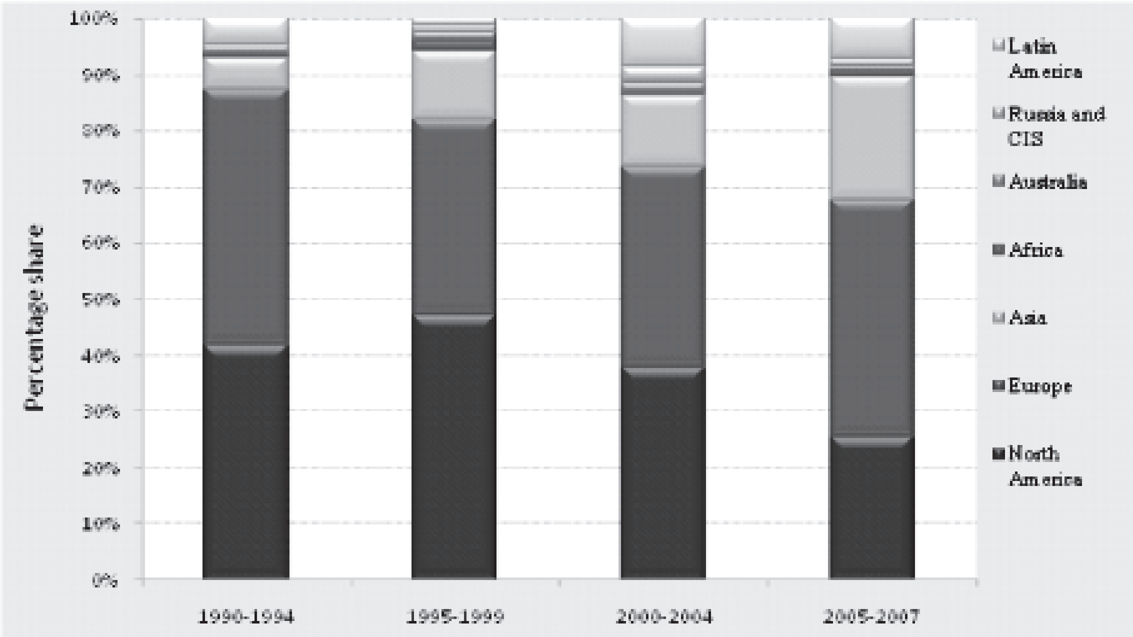


Fig 5-09.02: Region-wise spread of India's patenting activity

- The Council of Scientific and Industrial Research pioneered the Indian patenting activity during 1990-2007 and is the leading patent assignee with more than four thousand patents to its credit during this period. Many other government S&T departments and institutions increased their patenting activity particularly after 2000. These include Defence Research and Development Organization, Department of Biotechnology, Department of Science and Technology, National Institute of Immunology, Sree Chitra Tirunal Institute for Medical Science & Technology, Jawaharlal Nehru Centre for Advanced Scientific Research, Centre for DNA Fingerprinting and Diagnostics, and the Department of Atomic Energy.
- Indian patent output is significantly high in the areas of chemistry, chemical technology and related areas, and drugs and pharmaceuticals. Indian patenting activity also established itself in newer areas like food products and technology, micro-organism and genetic engineering, information and communication technologies including computer and automated business equipment, optical computing devices, electrical digital data processing and telecommunication.
- Of the total patents obtained by Indian assignees during 1990-2007, about 15% patents were jointly owned by performers in industry, university or government sectors. The joint ownership of patents between government institutions shows an increase, while that between universities it is almost negligible. Foreign firms have played a positive role in the growth of Indian patenting activity wherein their joint patents with domestic Indian firms, as well as with their affiliates, have increased significantly during the period.
- The overall pattern of citations received by Indian patents during 1990 to 2007 indicates that of the total 2,132 patents, 764 patents (36%) received one or more citations, indicating their high value and continued technological significance. There were 179 patents (23% of the total) that received 1,494 citations (49% of the total), while the remaining 585 patents (76% of 764) received 1,076 citations (35% of the total).

Indian Publications and Patents Output in Information and Communication Technology

Information and Communication Technology (ICT) is one of the vibrant sectors of the economy, which plays significant role in promoting economic growth, expanding economic opportunities and providing employment. The industry displays considerable variations in terms of technological development and performance. Here an analysis of the Indian contributions in the field of ICT as reflected in terms of the publications and patents output is presented. The source of data is the Scopus database (http://www.scopus.com) and on patents it is Delphion patent database (http://www.delphion.com), searches made using keywords and other relevant features. A set of 4,438 publications data and a set of 742 patents were taken for the purpose of present analysis.

Growth in Publications

The Indian publication activity in the field of Information and Communication Technology (ICT) grew slowly during 1990 to 2001 and gradually picked up, thereafter, during 2002–2006 and showed a significant rise during 2007. The highly productive areas of Indian publications in the field of ICT include communication systems, cyber security systems and network management; while its core strengths as indicated by patenting activity are in the areas of digital computing devices, transmission of digital information, computing, calculating and counting. The most productive academic institutions that have published nearly nine hundred publications (20% of the total) include Indian Institutes of Technology (Delhi, Kharagpur, Kanpur, Bombay, Roorkee, Chennai and Guwahati) and Indian Institute of Science. Government institutions and the firms in the industry have also made publications in the field. Indian authors have joint publications with authors from foreign academic or industrial firms.

Growth in Patenting

The Indian patenting activity in the field of ICT has also grown slowly since 1990, but indicates a sudden spurt in growth during 2002-2007. The major contributions to patents (40% of the total) have come from domestic Indian industries that include key players like Vaman Technologies, Sasken Communication Technologies, Tata Consultancy Services Ltd., Reliance Infocomm and Satyam Computer services Ltd. The analysis of publication and patenting activity indicates the growing Indian R&D and technological capacity in the field of ICT. Industrial firms have also made contributions to the field of ICT through publications, but they are more active in patenting activity.

Indian Publications and Patents Output in Nanotechnology

The creation of R&D capacity for the development of new technologies and products in the field of nanotechnology are of key importance for a developing country like India. India launched its national nanotechnology initiative in 2001. Indian contributions in the field of nanotechnology as reflected in publications and patents output is analysed here based upon data on publications from Scopus database (http://www.scopus.com) and data on patents from the Delphion database (http://www.delphion.com). A set of 11,000 publications were taken for analysis. Counting the contribution of each author as one publication, the total number of publications rose to nearly 21,000, implying multiple contributions from a single institute. A set of 167 patents was taken for analysis.

Salient Results

Growth in publications: The rate of growth of Indian publications in the field of nanotechnology is much higher during 1998-2007 in comparison to that of 1990-1997 (Fig 5-11.01). The analysis indicates that publication activity accelerated after the launch of the national nanotechnology initiative in 2001. Major contributions to these 21,000 publications, nearly 48% of the total, have come from the academia; 28% from government R&D institutions; and 1.3% by industrial firms. Of the share of industrial firms, nearly 80% is contributed by domestic firms and 20% by foreign firms operating in India. Foreign academic institutions contribute/collaborate in nearly 22% of these publications.

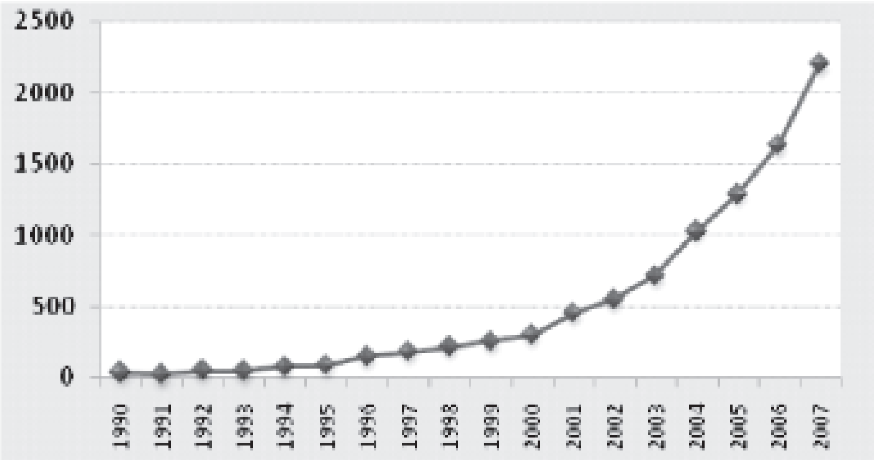


Fig 5-11.01: Indian publications in nanotechnology for the period 1990-2007

The highly productive academic institutions in the field of nanotechnology include Indian Institutes of Technology (Kharagpur, Kanpur, Delhi, Mumbai, Chennai, Roorkee, and Guwahati), Indian Institute of Science, Tata Institute of Fundamental Research, Jadavpur University, University of Delhi, and University of Pune. Of the government institutions, the most productive contributions have come from Bhaba Atomic Research Centre, Indian Association for the Cultivation of Science, Indira Gandhi Centre for Advanced Research, Kalpakkam, Saha Institute of Nuclear Physics, and the Centre for Materials for Electronics Technology. Productive contributions have also come from the Laboratories of CSIR that include National Chemical Laboratory, National Physical Laboratory, National Institute for Interdisciplinary Science and Technology (formerly Regional Research Laboratory, Trivandrum), Indian Institute of Chemical Technology, National Metallurgical Laboratory, and Central Electrochemical Research Institute.

Growth in patenting: The growth of patenting activity in the field of nanotechnology by Indian inventors indicates that the intensity of patenting grew slowly during 1990 to 2000 but rose suddenly during 2001 to 2007; almost exponentially. Of the total 167 patents, 64 patents (39% of the total patents) are owned by the government institutions, 45 patents (27% of the total) by firms in the industry, and 10 patents (6% of the total) by academic institutions. There are 37 patents (22% of the total) that are owned by individual inventors.

The major technological areas of patenting in the field of nanotechnology include its applications related to drugs and pharmaceuticals, chemical sciences and technologies e.g. catalysis, colloid chemistry, separation and non-metallic elements and materials, analyzing materials by determining their chemical or physical properties and methods/filters implantable into blood vessels.

The analysis indicates growing Indian competence in the field of nanotechnology, particularly since 2001 onwards. There is significantly more number of publications than patents. The academic institutions have made significant contribution in terms of publications. In contrast they have limited patenting activity. Although firms from industry have been active in taking patents, there is almost negligible publication activity by them. In an emerging field like nanoscience and nanotechnology, competence in basic research plays a significant role in developing new technologies. Therefore, it is essential for the firms in the industry to develop basic research capacity and contribute more towards publications. The analysis indicates that institutions in each of the sectors of academia, government and industry should complement their R&D capacity and technological strengths by enhancing greater collaboration amongst them.

Indian Patents in Biotechnology

Indian patenting in biotechnology (BT) is exhibited here through analyses of data from the Indian Patent Office journal 2001-07, falling under IPC codes pertaining to BT as per OECD, 2004. The data for 2004 was not available.

Salient Features

1. No. of Patents filed, published and granted in all fields have increased continuously during 2001-07 (Table5-12.01)

Table 5-12.01: Patents Filed, Published and Granted during 2001-07

Status of Patents	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Filed	-	11466	12613	17466	24505	28940
Published	-	9538	10709	14813	11569	14119
Granted	-	1379	2469	1911	4320	7539

Source: *Annual Report 2007 of Indian Patent Office*

2. Among fields related to Biotechnology there is no general increase in food patents, unlike the scenario for chemicals and drugs. (Table 5-12.02)

3. The proportion of biotech patents in all patents published is < 3%. There is an increase in the number of BT patents during 01-07. But increase of Indian component is not significant (Fig 5-12.01).

Table 5-12.02: Patents Published during 2002-03 to 2006-07, in Various Fields

Year	Chemical	Drugs	Food
2002-03	776	966	119
2003-04	2952	2525	123
2004-05	3916	2316	190
2005-06	5810	2211	101
2006-07	6350	3239	101

Source: *Annual Report 2007 of Indian Patent Office*

Number of domestic patents in BT has increased from 126 during 2001-03 to 181 during 2005-07. The BT patents by domestic applicants were ~ 3 times more than patents by foreign applicants during 2001-03. The trend reversed during 2005-07, during which BT patents by Indians formed only 12% of all patents. This drastic change in the proportion of Indian compared to foreign patents in BT can be seen in Table 5-12.03.

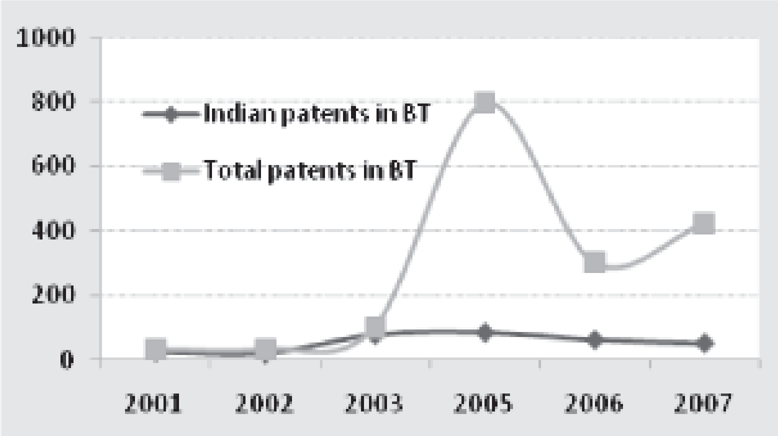


Fig 5-12.01: Number of Patents and Indian Contribution in Biotechnology

Source: Issues of relevant years of Journal of Indian Patent Office

Table 5-12.03: Proportion of Indian/Foreign BT Patents 2001-07

Year	Indian	Foreign	Total
2001-2003	126	47	173
2005-2007	181	1302	1530
Total	307	1349	1656

4. The Number of countries contributing has increased over the years during 2001-07. This fact explains the increase in number of patents during this period to a limited extent (Fig 5-12.02).

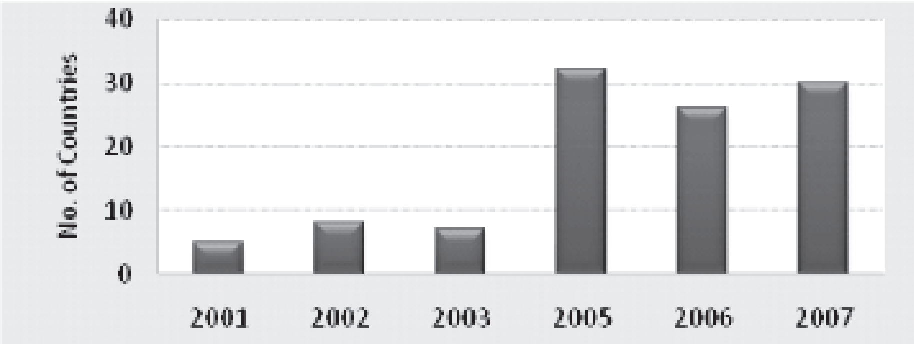


Fig 5-12.02: Number of Countries involved in Patenting in BT in India, every year

Source: Issues of relevant years of Journal of Indian Patent Office

5. Major countries applying for Indian BT patents were led by USA. India occupies 2nd position. These two were followed by Germany, UK, Denmark, Switzerland and Netherlands.

Nature of Applicants for Indian BT Patents

Basically three types of institutions apply for patents in biotechnology: universities & public research institutions, private (profit oriented) companies, and non-profit organizations & research foundations. Their behavior, during the period 2001-2007, can be observed in Table 5-12.04.

6. The contribution of public vs. private institutions among Indian and foreign applicants for 2001-07, is given below:

Table 5-12.04: Nature of Institutions from India and abroad contributing to BT Patents in India

Year	Domestic				Foreign			
	Private	Public	Others	Total	Private	Public	Others	Total
2001	9	17	0	26	3	1	0	4
2002	3	14	3	20	17	2	0	19
2003	16	61	3	80	22	1	1	24
2005	27	34	7	68	627	56	20	703
2006	15	36	7	58	204	25	14	243
2007	18	24	13	55	316	39	1	356
Total	98	176	33	307	1189	124	36	1349

Source: Issues of relevant years of Journal of Indian Patent Office

- *Indian* Public:Private: 68:32
- *Foreign* Public:Private: 12:8

Of the total patents, 77% come from the private applicants, while public research institutions contribute a mere 19%. Remaining 4% patents are applied for by individuals and nonprofit organizations.

The countries that contribute in a big way together have a share of 80% of all patents published in BT during the period under study. Of these, top five countries (USA, India, Germany, UK and Denmark) have 73% contribution. When the contributions from Switzerland and the Netherlands are added to the contribution by the top five countries, 81% of patents in BT are covered (Fig 5-12.03).

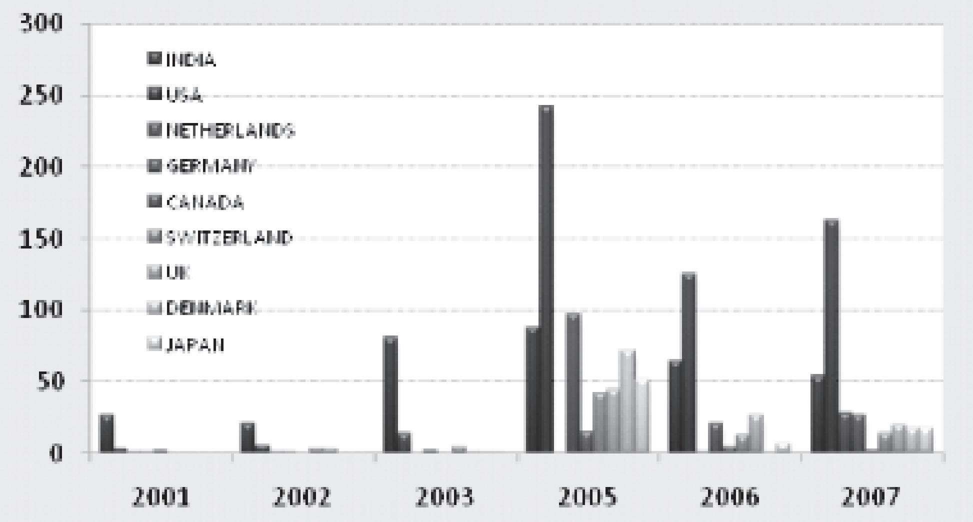


Fig 5-12.03: Country wise applications for patents in India in Biotechnology

Source: Issues of relevant years of Journal of Indian Patent Office

7. During 2001-07 the largest and consistent contributor from India is CSIR. The trend of Indian applicants is presented in Fig 5-12.01. There is an increase in the number of applicants from India in this period. Increased interest of Indian companies in going for patents becomes evident when figures for 2005-07 are compared to those for 2001-03 (Fig 5-12.04).

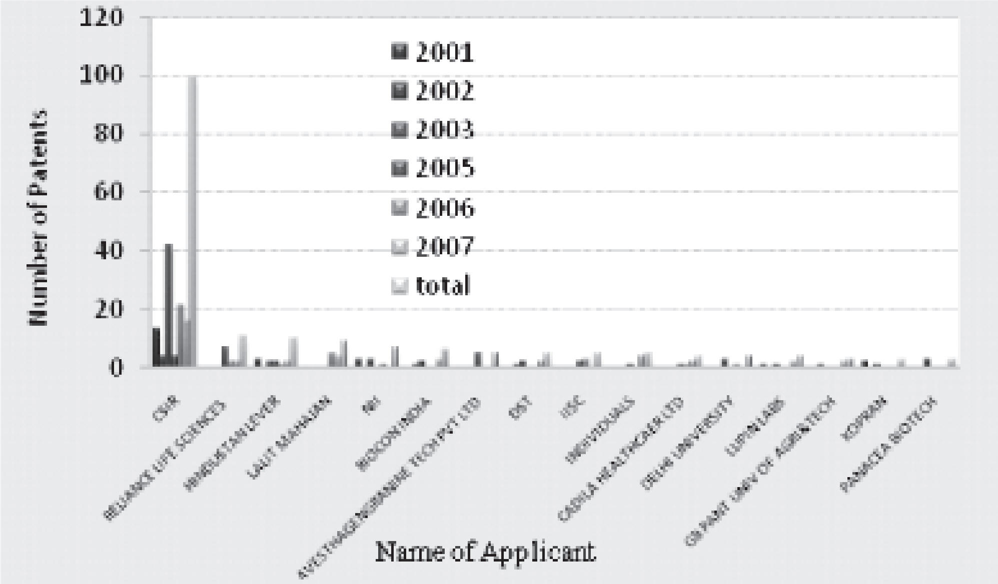


Fig 5-12.04: Patent Publication Performance of Top 16 Indian Applicants

Source: *Issues of relevant years of Journal of Indian Patent Office*

Focus of Indian Biotech Patents

8. Codes based distribution of patents published during 2001-07 show that there is an increase in the number of patents that come under the IPC codes A61K. The codes C07K, C12Q have made significant and consistent appearance in the period 2005-07. This would mean that production related patents have increased in 2005-07. This corroborates with the observation that during this period more private industry applicants have applied for patents with Indian Patent Office (Fig 5-12.05).

9. Based on the major codes of IPC relevant for Biotechnology we find that the focus is more in A61K, C07K, C12N and C12Q. There is a slight shift in the focus from 90's during 2000's; A61K which was

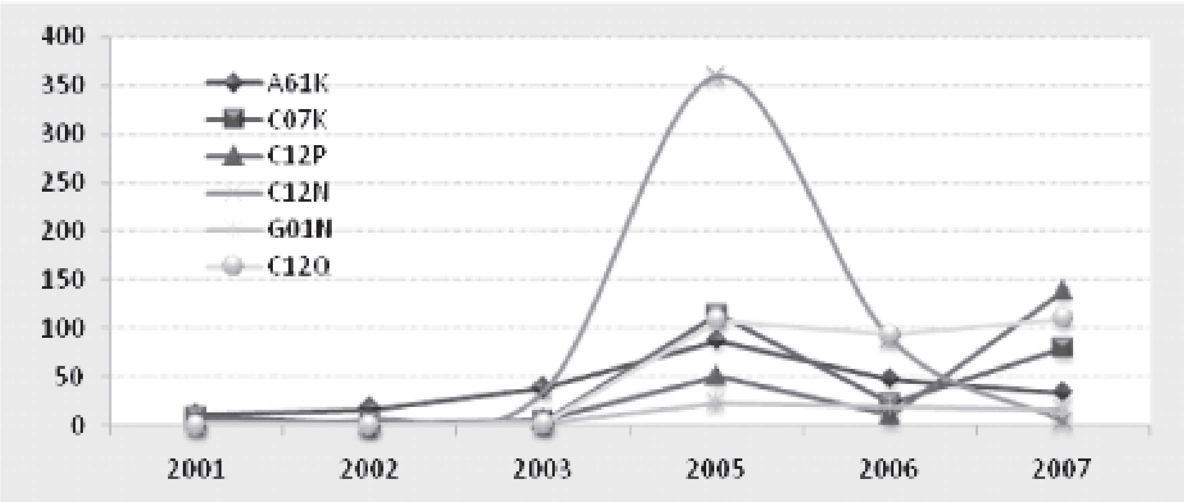


Fig 5-12.05: IPC Codes wise distribution of patent applications in India in Biotechnology

Source: *Issues of relevant years of Journal of Indian Patent Office* very prominent and the only prominent specialization of focus during the 90's has become less prominent during 2000 and its place is occupied by C12N, C12Q and C07K (Fig 5-12.05).

10. Focus in terms of applications in various areas like agriculture, industrial enzymes, healthcare and environment during 90's and 2000 has shown that environmental BT patents (C20F) are very few and the importance given has not changed in the two periods. Health care BT patents, indicated by A61K, C07K, C12N, C12Q and G01N have been in focus. Though there is a change in their performance, between them and during 90's and 2000's – prominence of codes C12N, C12Q, C12M, C12S indicate focus on Industrial BT involving enzymes. Of these C12S could also indicate healthcare related products; focus on this area has also increased nominally. The codes indicating AO1H, agriculture process of obtaining new plants and modifying genotypes have not increased from the 90's (Fig 5-12.06).

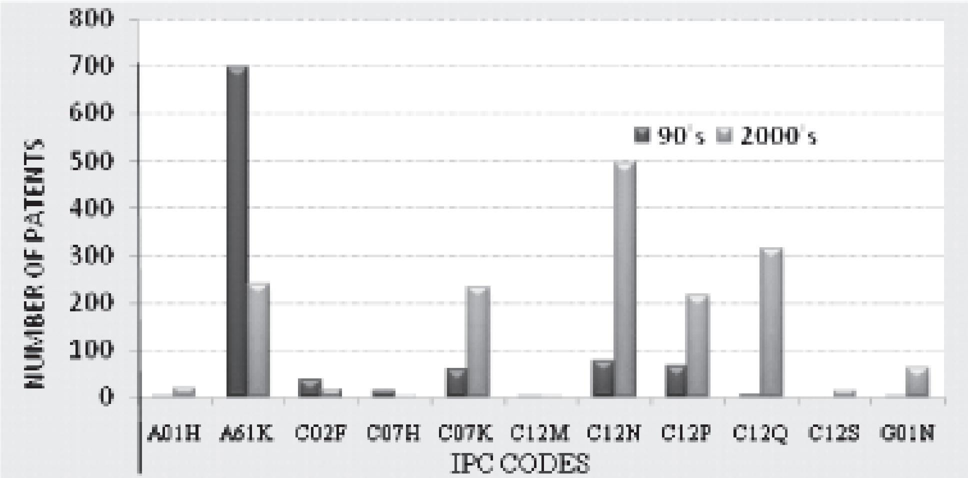


Fig 5-12.06: India BT Patents by IPC in 90'S & 2000'S
Source: Issues of relevant years of Journal of Indian Patent Office

11. From this trend it appears, Indian institutions as well as foreign applicants feel that there is a larger opportunity for health care BT related patents to be worked in India compared to industrial BT or Agri-biotechnology. Environmental Biotechnology does not seem to be in focus of applicants from India or abroad.

Conclusion

Patenting activity in India in BT has increased from 90's and significant increase in the number of patents has been observed during 05-07. Patenting activity by a number of countries from outside India plays a dominant role, accounting for ~70% of BT patents. Then there is an increasing patent activity by Indian private sector as well. Significant increase in number of institutions both private and public from foreign countries has also been observed. The focus of patenting activity seems to be healthcare, followed by Industrial enzymes. Low level patenting activity is observed in the area of agriculture and environment.

Citation reflects the strength of herding and organized betting. This increases value of assets. Therefore citation can be considered as dummy of strategic worth or value of an asset. Patent portfolio strategy is also captured through citations. This value becomes more important when we consider patents in lieu of research publications. Further, strategic worth of patents that reflects rights to excludability is often more significant than the licensing values.

Data from USPTO on Indian patents in USA in areas such as protein, polymer, drugs and similar others since 1976 (up to 2004) were considered. We looked for citations to patents in patent applications by Indian organizations and individuals.

Some Observations

- Nearly 80% Indian patents did not cite any other Indian patents, and then only a handful cited Indian patents alone. Such absence shows that there are little or no relations between patents filed by even the same organization (Fig 5-13.01).
- Significant numbers of these organizations are private and corporate.
- The explanation for this may be due to the fact that prior arts from India did not have any relevance. Assets in an Indian undertaking failed to garner the minimally required domestic mass behind it and failing that the value of patents, very similar to the fate of research papers, nose-dived.
- Indian patents appear to have little worth for litigation and turf-protection.
- Only patents from drugs-pharmaceuticals sector received any citations, and out of such 225 drug patents only 30 had positive values of SI (Fig 5-13.02).

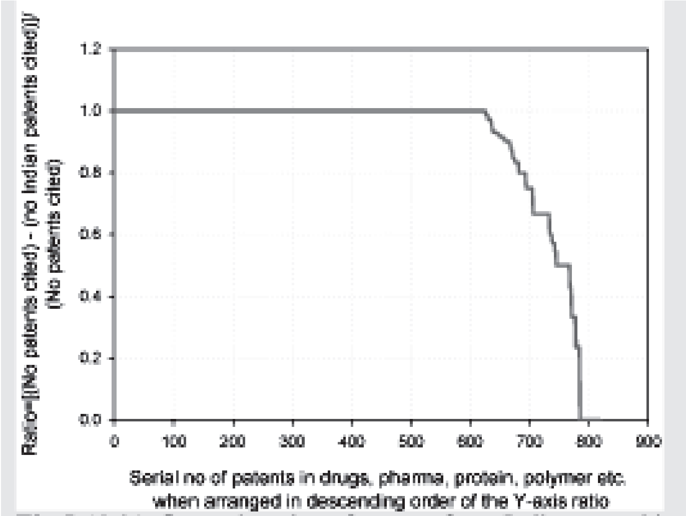


Fig 5-13.01: Strategic value of patents from India granted in USA

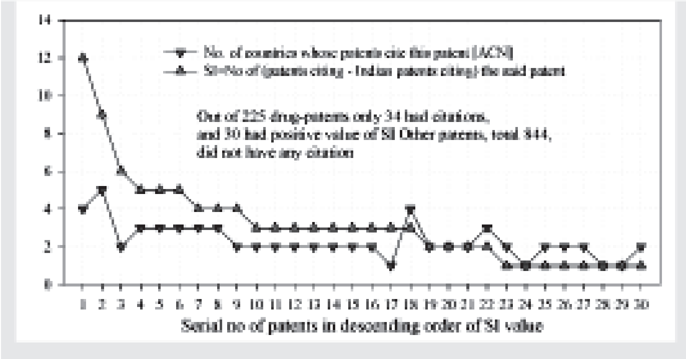


Fig 5-13.02: Strategic importance of Indian drug patents granted by USPTO
Where SI = [(Number of patents from any country citing an Indian patent) – (number of Indian patents citing that Indian patent)].

Conclusion: In this context, absence of citations to any Indian patents from any other country for such a large group of Indian patents definitely raises doubt on the market worth or strategic worth. It appears that prior art from India does not evoke responses from patents being filed later. These assets therefore fail to attain value because of the absence of herd betting.

S&T for Rural India and Inclusive Growth

Overview

S&T perhaps can empower best the poor most of whom stay in rural India. Such a dimension of S&T is likely to demand radical departures from the contemporary modes of organizing sciences and technologies, including even their contents. A crucial aspect enabling this departure would be how S&T integrates with and remains answerable to or is governed by the rural people of poor disposition. The urban-based supply side and linear approach (from the concept to technology use) to pushing S&T - needs a serious relooking. S&T research problems formulation and technological solutions are currently organized around the industrial model. The supportive institutions of law, banking and regulations, including that of the executive, have been designed primarily for volume-based energy and materials intensive, low-employing and often unsustainable economically and environmentally, modes of high-growth production. Such production modes when simply scaled down for rural production, especially of manufacturing types, bring about breaks in the integrated living of rural communities. Life in rural India as it is elsewhere has an integrative approach to the agricultural and other than agricultural modes of wealth creation. This latter is our focus. Prosperity in India can come primarily from rural capacities and capabilities to manufacture, value add, innovate and remain sustained with agricultural production. The new role of S&T to empower rural poor could be addressed, in the immediate, by focusing on non-farm earth resources sustaining modes of production.

Innovation, to recall, is a mode of redistribution. Innovation redistributes assets, capacities, capabilities, earnings and consumptions. Empowering rural poor through manufacturing within rural areas could thus be brought about only by innovation, however, of a variety that is very different from the high growth oriented often unsustainable and high resource-consuming as well as waste generating modes of innovation. Most of our institutions including of the S&T have been designed for the latter variety of innovation. Therefore, in order for S&T to be innovative for rural living – institutions and structures of not only S&T but others as well, need restructuring and refocusing. Over the last six decades the democratic governance system of the country has created a very large number of structures and institutions whose original purpose very often was to address the innovation befitting rural India. However, the agenda capturing power of the dominant urban institutions appears to have taken over much of the original intent and today S&T for rural manufacturing has virtually been reduced to a subset.

S&T for the rural non-farm sector requires most immediate attention. Such a refocus could target amongst others creation and sustenance of assets, capacities and capabilities; in particular the ‘concentric circles’ model of Mahatma Gandhi would inform us that refocused S&T and institutions could especially address inter-rural markets for expansion and commerce. A moot question would be around coordination and governance. The country has a very large S&T infrastructure devoted to rural areas; change in coordination and governance with special emphases on local government could bring about miracles. The great resources of diversity, earth resources, knowledge and skills that rural India possess could thus be greatly enhanced through innovations in and brought about by S&T. This theme has been partially explored by looking into several facets of potential areas where S&T could bring very important changes in the lives, health and economics of the rural Indian.

Rural development in India has evidenced several changes over the years in its emphasis, approaches, strategies and programmes with a view to improving the socio-economic conditions of the people: in providing good infrastructural facilities, support services and employment opportunities. Many organizations of the government like Khadi and Village Industries Commission (KVIC), Council for Advancement of People's Action and Rural Technology (CAPART), National Institute of Rural Development (NIRD), Department of Science and Technology (DST), National Research Development Corporation (NRDC), Council of Scientific and Industrial Research (CSIR) and Indian Council of Agricultural Research (ICAR) support the generation and promotion of appropriate technologies under various schemes. In addition, engineering based educational institutions, state government organizations, non-government organizations, voluntary agencies and private establishments augment these efforts. In spite of the advances made, there still remains much to be done to bring prosperity in the lives of the people in the rural areas, thus ending the so-called divide between Bharat and India.

In the present *theme,* an attempt is made to document briefly the approaches and strategies adopted by the government in the field of rural development, the recent trends and the programmes implemented under the restructured departments of Ministry of Rural Development. The scope of non-farm activities in rural areas is huge and can effectively be exploited as potent stimulator for economic growth. A short review of the rural non-farm sector (RNFS) has been made focusing briefly on the structure, growth and trends in employment and income generation. Management and distribution of safe drinking water are essential and critical for better livelihood. Power is a key requirement in rural areas, for agricultural as well as non-agricultural and domestic uses. Technology is now capable of providing reliable power at comparatively low cost in a decentralized manner. It needs to be upgraded and scaled-up in a big way with emphasis on renewable and non-polluting technologies. Deployment of technologies for post-harvest processing, cold storage and cold-chains for transportation to market and other means of adding value are required to enhance rural employment and incomes. In this theme, various issues in the field of rural development like shelter, food grains, sanitation, energy, medicine, post harvest management, livestock mixed farming system, bio-pesticides and genetically modified crops etc have been discussed. In addition to this some sectors like fisheries, mushroom culture, horticulture and sericulture were identified as ideal and potential avenues for socio-economic development of the rural communities. The role of information technology in agriculture marketing i.e. in providing information related to commodity prices, transportation, agricultural practices, weather, etc. to the farmer has also been discussed. The scope for application of Geospatial information technologies for rural development, strategies for alleviation of rural poverty, a review of the use of tools and modern implements, an appraisal of rural artisans, of the mechanisms and standards for developing and fixing food standards and a proposal for an agricultural innovation policy are some other things that the theme explores.

The full text of these extended summaries is available at *http:www.nistads.res.in*

Science and Technology for Rural Development: a synergy approach

Presently in India, around 58% of the work force and nearly 70% of the population still continues to depend on agriculture and allied sectors. However, share of agriculture and allied sectors in GDP has declined from 24.02% in 2000-01 to 18.6% in the current year. This reflects a huge divide in rural and urban incomes, social and physical infrastructure, quality of life, and consequently in human capabilities and entitlements. In fact, the rural economy in India has been contending with a complex set of adverse factors like poor infrastructure, insufficient capital and investment, inadequate farm infrastructure and limited access to information, health, education and markets etc. Although some developmental initiatives under 'Bharat Nirman' and 'PM's Gram Sadak Yojna' and in Health, Education and Agriculture do facilitate greater access to markets and inputs, by upgrading capabilities of the rural people, there is however, still a big gap to be bridged in order to wipe out developmental imbalances between rural and urban economy. Therefore, it is imperative to look into the present pattern of rural technology development, its systemic deficiencies and the factors for poor dissemination of technologies with a view to putting in place a reformed S&T system for rural development, ensuring full participation of stakeholders in the technology development process. We undertake a short appraisal, and it contains suggestions, for re-structuring the system of technology development and dissemination.

S&T System for Rural Technology Development and Dissemination – its present set up

Council of Scientific and Industrial Research (CSIR): Mainly laboratories like NCL, NPL, CLRI and CGCRI *et al* involve in developing technologies for rural application.

District Industries Centers (DICs): Provide financial and technological support, including training. They coordinate their activities with KVIB and State Small Scale Industries Corporations. The technology development Research and Training Centers under KVIC and State Khadi Board and institutions such as the Indian Institute for Handloom Technology primarily work for rural-non-farm sector (RNFS) and rural industries under household, tiny and small sector engaged in value addition activities.

Indian Council of Agricultural Research (ICAR): A national grid comprising 46 Institutes including 4 deemed universities, 4 National bureaus, 81 All India Coordinated Research Projects (AICRP), 31 State Agricultural Universities and Central Agricultural University at Imphal. ICAR is engaged in strategic research, location specific agricultural research e.g. ICAR, NE Hill Complex at Shillong, Vivekananda Institute for Hill Agriculture, Almora, etc.

Universities: The university system in states, set up with support from UGC and the state governments is also equipped with the capacity for basic, applied and adaptive research. However, much of this capacity is unutilized due to lack of linkages with State Agricultural Universities and their concerned faculties.

Problems in Technology Dissemination

- S&T System is central government driven, as practically all major institutions for S&T education, research and training are funded and managed by the central government, with little S&T capacity in the states, both at the departmental and state university levels.

- Scientific Research is taken up by the Central S&T system on its own volition and priorities. Therefore, few local research-needs are identified and consequently, development of technology solutions is not really demand driven due to near absence of interface with the states.
- State S&T Councils are mostly ineffective except in a few states such as Madhya Pradesh, Uttarakhand, Tamil Nadu and Karnataka. They are not geared to integrate S&T system into the development activities and to create state or region specific S&T capability, which is so vital for a country of India's size & diversity.
- A kind of central technology dependency syndrome is prevailing because the line departments of the states implement only those technologies which are sponsored and built into the Plan/Central Sector/ CSS or externally assisted programmes and lean on the central nodal ministries for technology assistance.
- Various coordination committees at the district level deal with sectoral implementation issues and not technological issues and do not add up to a District level S&T forum capable of taking a view on technology gaps and needs of the District in a comprehensive manner.
- The University system in states has long ceased to be providers of technologies or partners in development; societal S&T capacity at the district level and below at the community level is virtually absent primarily because the civil society has been weak in S&T and has not forged a partnership with S&T institutions located in the state except in few areas.
- Centrally funded agencies like the District Rural Development Agencies (DRDA) set up in every district for carrying out poverty alleviation programmes have not been provided with S&T back up to look into the technology aspects of anti-poverty programmes.

Suggested Approach (A Framework of Synergistic Mechanism)

- The S&T Council should be restructured to function as the Science and Technology Advisory Group (STAG) responsible for integrating S&T inputs from all S&T institutions located in the state, by making them partners in development. The activities of the partnership mode may include identifying technologies already developed for dissemination and prioritizing research work with emphasis on problems emerging from the field.

- Technological empowerment of the communities to assess their problems and participate in the process of choosing of technologies. For this, a consultative Group of Local S&T institutions comprising of concerned department officials and S&T capable NGOs may be formed by the collector with the involvement of PRI's; one of the S&T institutions may be selected as the nodal agency.

- In line with the concept of Mother NGO, a NGO may be selected to conduct survey of S&T needs and technology gaps sector wise, especially non-farm sector and identify areas for entrepreneurship development; assess need for field trials and adaptive research; select field NGO's who could be trained and supported to develop competency in S&T intervention and to act as incubators for enterprise growth; arrange training for NGO partners in project activities in the area; collaborate with the nodal S&T Institutions and to act as a clearing house for rural technology related information and also with NABARD and institutional financial agencies; mobilize expertise from the state S&T system including Universities on consultancy basis for S&T intervention and to provide S&T support to District Plan.

- The consultative body with three wings like Nodal S&T Agency, Local Department and Lead S&T capable NGO backed by a network of field S&T NGO's may emerge as Technology Coordination and Action Group (TCAG); to serve as a Scientific Advisory Body to the Collector and the Zilla Parishad. The incremental non-recurring and recurring costs in setting up TCAG in the District may be supported financially by the state DST and a local official of DST may be nominated as Member Secretary.

- Technology Coordination and Action Group (TCAG) may be registered as a society to give it the necessary authority and flexibility with a broad charter so that it could lead all S&T interventions and bring the departments, S&T institutions and the committees under one forum, which does not exist at present.

  The institutional reform proposed here would be a means towards achieving the national goal of "harnessing S&T for improvement of livelihood, employment generation, environment prediction and ecological security" (Tenth Plan Document). Our S&T system is not, as the cliché goes, a giant with a feet of clay, but is rather like giant with a strong feet but suffering from weak joints which could be remedied to enable it to take India on a 'peoples' science based development path.

Non-Farm Occupation in Rural India

Rural non-farm economy in recent times is considered as an effectual strategy for decentralization of economic activities to rural India. Rural-Non-Farm-Sector (RNFS) includes all economic activities *viz.,* household and non-household manufacturing, handicrafts, processing, repairs, construction, mining and quarrying, transport, trade, communication, community and personal services etc. in rural areas. The Economic Census of India estimates that around 41.89 million of rural people are employed in non-agricultural establishments, which registered a growth rate of 4.56 % during 1998-2005 (Table 6-02.01). This section

Table 6-02.01: Non-agricultural establishments and employment in rural India (Figures in absolute number)

Own account establishments				Establishments with hired workers				
No. of establishments	Employment			No. of establishments	Employment			
	Total	Female	Child		Total	Hired	Female	Child
Economic Census 1998								
107145	158121 (1.5)	30112 ((19.0))	6002 ((3.8))	37923	179557 (4.7)	156085 ((86.9))	38522 ((21.5))	4707 ((2.6))
Economic Census 2005								
13262173	17302128 (1.3)	3216655 ((18.6))	326967 ((1.9))	6564894	24592025 (3.8)	21122316 (85.9)	5981652 ((24.3))	700709 ((2.9))

Note: Figures in single and double brackets indicate average number of persons per establishment and percentage of female / hired worker to total employment respectively.
Source: *Economic Census All-India Report (1998; 2005), Govt. of India, Ministry of Statistics and Programme Implementation.*

reviews the strengths and weaknesses of the rural-non-farm-sector in India, analyzing the structure and growth of rural-non-farm-sector and potentiality of the sector towards employment and income generation, to arrive at certain inferences like formulation of possible approaches with a view to promote rural-non-farm-sector as a self-sustaining entity in the changing competitive environment.

Structure and growth of rural-non-farm-sector: The non-agricultural establishments accounted 19.83 million in the rural area. Out of 19.83 million, 13.26 million (66.89%) were own account establishments and remaining 6.56 million (33.11%) were establishments with hired workers. Retail trade (39.28%) was the dominant activity followed by manufacturing (26.02%) and other community, social and personal services (8.15%) of the non-farm establishments (Fig 6-02.01).

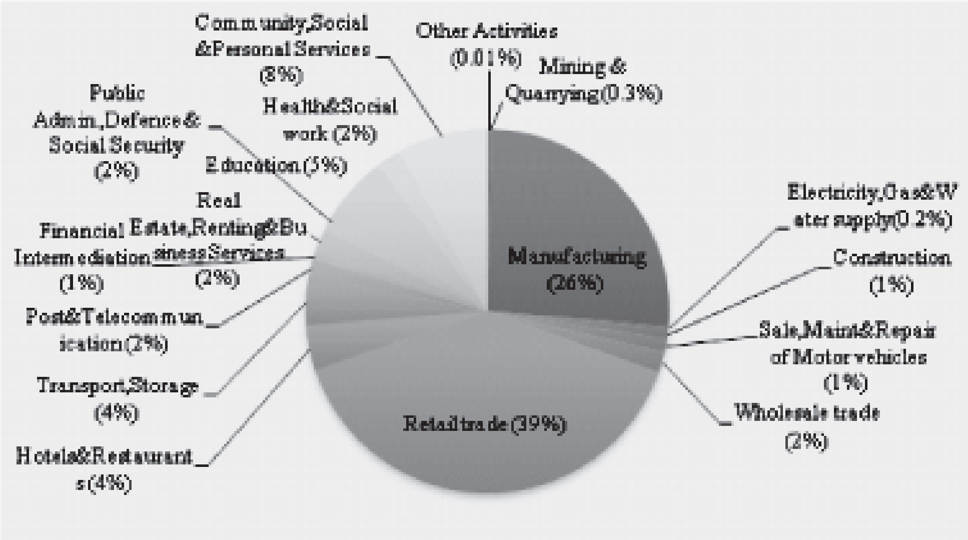


Fig 6-02.01: Distribution of major Non-agricultural establishments in rural India during 2005
Source: Economic Census of India 2005

Trends of non-farm employment and income: There were 41.89 million people working in non-agricultural establishments (Economic Census of India, 2005). Of these, 17.30 million persons (41.30%) were employed in own account establishments and the remaining 24.59 million (58.70%) in establishments with hired workers. Female workers constituted 21.96% of total employment in rural non-farm sectors and proportion of female employment was found comparatively higher (24.32%) in establishments

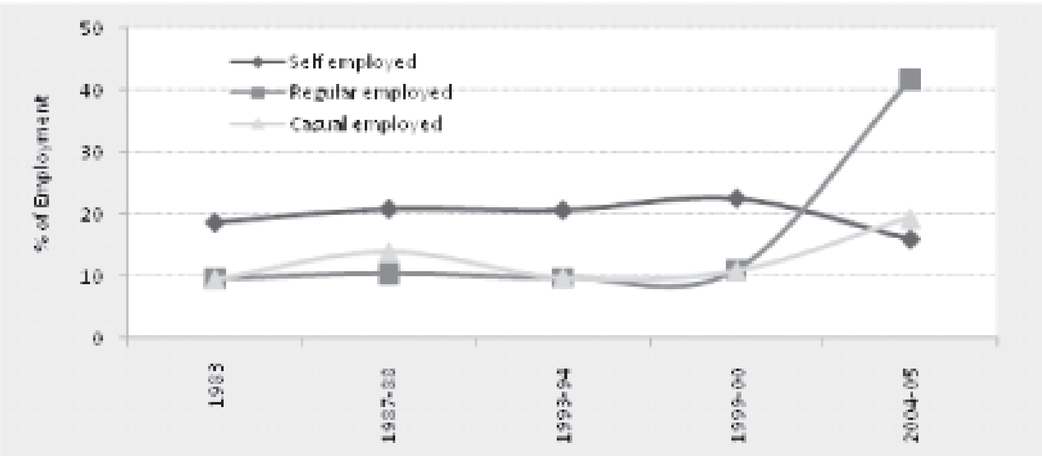


Fig 6-02.02: Trends in employment status in rural labour force (male + female) by sector
Source: NSS Report No. 522 (62/10/01) Employment and unempolyment situation in India, July, 2005 - June, 2006

with hired workers than own account establishments (18.59%). A trend in employment status of rural labour in India is presented in Fig 6-02.02.

Labour force growth and employment requirements: The labour force projected to increase by 40.02 million in special group and 55.82 million in working age group (15+) during the period of 2007-12 implies the need for an increase in the pace of creation of additional work opportunities commensurate with the growth of labour force (Table 6-02.02). Unemployment is estimated at 21.15 million, 5.11% of the total population (Table 6-02.03). To achieve full employment by 2011-12, it is estimated that employment should grow at 2.7% per annum based on the proposed policy and programmes in the Tenth Plans. This would require GDP to grow at 8% per annum.

Quality of employment: Surveys revealed substantial increase of illiterates among the unemployed persons (Table 6-02.04). Over the period of 1993-2005, the proportion of those with educational level up to primary among the unemployed increased from 1.9-3.0% and 2.6-3.1% in case of male and female respectively, while unemployment decreased from 8.3 to 6.5% among those at secondary school or higher educational level and increased from 9.8 to 18.2% in case of females.

Table 6-02.02: Increase in Labour Force and Working Age Population (in millions)

Basis of scenario	2002-2007	2007-2012
Increase in labour force (Specific group)	35.29	40.02
Increase in working age population (15+)	55.25	55.82

Source: *Report of Planning Commission; Special Group on creation of 10 million employment opportunities per year since 2002.*

Table 6-02.03: Labour Force, Employment and Unemployment (in million)

Parameter	1999-2000	2001-2002	2006-2007	2011-2012	% per annum
Labour force	363.33	378.21	413.50	453.52	1.80
Employed	336.75	343.36	392.35	451.53	2.70
Unemployed	26.58	34.85	21.15	1.99	-9.50
Unemployed rate (%)	7.32	9.21	5.11	0.44	-

Source: *Planning commission, Govt. of India, Tenth five year plan 2002-07; Special group estimates on CDS basis*

Non-farm activities are either detrimental to keep the poor falling into deeper poverty or advantageous to lift the poor above the poverty line. Keeping this in view, it becomes imperative to identify the strengths and weaknesses of the non-farm sector in India to focus on, in order to alleviate poverty.

Strengths

Institutional basis: In India, the institutions underlying the development of the rural non-farm sector are very strong. These include secure property rights; a well-developed financial system with preferential access to credit for the sector; supporting institutions such as the KVIC, State Khadi Board, NHHDC, Small Industries Development Bank of India (SIDBI), State industrial corporations; policies and programs promoting linkages with agriculture, especially agro-industries; domestic marketing channels for rural non-farm production; as well as government support in export promotion.

Decentralization process: Over the last two decades the State governments in India have been able to exercise far more independence in decision-making than in the pre-1980 period. Regional parties are an

Table 6-02.04: Education Profile of the Unemployed in Rural India (Unit in percent)

Year	Illiterate	Literate		Total
		Up to Primary	Secondary and above	
Rural male				
1993-94	1.8	1.9	8.3	3.1
1999-00	3.0	3.0	7.3	3.9
2004-05	2.7	3.0	6.5	3.8
Rural Female				
1993-94	2.2	2.6	9.8	2.9
1999-00	2.7	2.6	16.9	3.7
2004-05	2.5	3.1	18.2	4.2

Source: NSSO report NO. 515 (61/10/1)

integral part in coalition governments at the Centre. In turn, they have negotiated economic autonomy in the formation of state specific policies for development.

Weaknesses

Infrastructure: The most significant bottleneck in generating higher levels of rural non-farm activity in India is the quantity, quality and reliability of infrastructure. Power outages appear to be one of the most serious obstacles to the development of the non-farm sector.

Regulatory restrictions: Regulation of the small-scale sector constitutes an important aspect of non-farm development policy in India. In the initial stages, capital investment restrictions were imposed to protect the small-scale sector, especially in rural areas, from predation by large industry. Reservation of products for the sector was initiated to create a domestic market and quantitative restrictions imposed to protect them from competition from imports. At the end of the 1990s, however, these very policies have become detrimental to the dynamism of the small-scale sector, especially in the rural areas. Capital investment limits have discouraged economies of scale, and concessions offered to small industry have created adverse incentives against re-investment.

Quality of manpower: High levels of illiteracy in rural India have hampered the growth of the rural non-farm sector. In the rural areas, lack of education leads to labour being stagnant in agriculture, or moving to casual work occupations in the non-farm sector, and not to salaried employment with higher wages and benefits. Together with lack of technical skills, there is little incentive for rural forms to invest in technology, leading to low levels of labour productivity in the rural manufacturing sector compared to urban manufacturing.

Forward and backward linkages: Absence of appropriate forward and backward integration greatly affects performance of non-farm activities in rural areas. In case of forward linkages, the RNFS serve as inputs to other sectors, whereas in backward linkages the RNF sector demands the outputs of other sectors. Gaps in the integration of the production linkages brought about by poor infrastructure, low accessibility of market, support service and skewed intervention of middle men have constrained the development of non-farm-enterprises in India.

The rural non-farm sector is increasingly playing an important role in the development of rural areas in terms of its contribution in employment and income generation for rural folk. Efforts are needed to identify appropriate and effective institutional vehicles for development of non-farm sector policy and interventions for creating employment opportunities. China's labour-intensive township and village enterprises (TVEs) often described as the "engine of growth" behind that country's remarkable growth during the past decades represents the vanguard in China's new capitalism. The TVEs are hybrid institutions, generally unusual alliances between TVE entrepreneurs and local government officials (acting in the capacity of "owners" of TVE enterprises). In this regard, the role of government is crucial especially in the provision of necessary infrastructure and other support services in the country. It is also vital to improve the market links between the village entrepreneurs and the larger business firms located in the towns/cities. Such strategic alliances or partnerships can contribute to enhance the sustainability of small village and tiny enterprises in the rural areas. Other important considerations that need to be focused on may include human resource development, financial/credit facilities, research and development and women's participation with a view to making these activities self-sustaining in the changing competitive environment.

Rural Development: A strategy for poverty alleviation in India

Of late, rural development has assumed global attention especially among the developing nations. A country like India where majority of the population (around 65% of the people) lives in rural areas has great significance. This section overviews the role and function of the Government and its' programmes for rural development in India. In addition, some important science and technological achievements in the field of rural development have been highlighted briefly.

The aims and objectives of rural development are alleviating poverty, improving the livelihoods of rural people in an equitable and sustainable manner both socially and environmentally through better access to assets, services and control over productive capital. The Ministry of Rural Development, comprising of three departments *viz.,* Department of Rural Development, Department of Land Resources and Department of Drinking Water Supply is the apex body for formulating policies, regulations and acts pertaining to the development of the rural sector in India. The primary responsibilities assigned to the Ministry are to encourage, promote and assist voluntary action in the implementation of projects for the enhancement of rural prosperity, strengthen and promote voluntary efforts in rural development with focus on injecting new technological inputs, act as the national nodal point for co-ordination of all efforts at generation and dissemination of technologies relevant to rural development and promote programmes aimed at conservation of the environment and natural resources. However, several other ministries in the central government are also engaged directly or indirectly in implementation of many programs and schemes for the development of rural areas. Various strategies and programs of the Government of India for rural development has been briefly presented in Box.

Programmes / Schemes	Aims and Objectives
Integrated Rural Development Program Training of Rural Youth for Self Employment (TRYSEM) Development of Women and Children in Rural Areas (DWCRA) Supply of Improved Tool Kits to Rural Artisans (SITRA) Ganga Kalyan Yojana (GKY)	Assistance to rural poor in the form of subsidy and bank credit for productive employment opportunities through successive plan periods.
Wage Employment Programs Swarnjayanti Gram Swarozgar Yojana (SGSY) Sampoorna Grameen Rozgar Yojana (SGRY) National Rural Employment Guarantee Act (NREGA)	Anti-poverty strategies, like assistance to the rural poor families to bring them above the poverty line by ensuring appreciable sustained level of income through the process of social mobilization, training and capacity building. NREGA is an act of parliament. It is not merely a scheme or policy. It aims at enhancing the livelihood security of the people in rural areas by guaranteeing hundred days of wage employment in a financial year, to a rural household whose members volunteer to do unskilled manual work. The objective of the Act is to create durable assets and strengthen the livelihood resource base of the rural poor.
Employment Assurance Scheme	Providing employment in the form of manual work in the lean agricultural season leading to creation of durable economic and social infrastructure addressing the felt-needs of the people.
Food for Work Program	Food provision through wage employment started in 2000-01 as a component of the EAS in eight notified drought-affected states of Chhattisgarh, Gujarat, Himachal Pradesh, Madhya Pradesh, Orissa, Rajasthan, Maharashtra and Uttarakhand.
Rural Housing • Indira Awas Yojana • Samagra Awas Yojana (SAY)	Providing free housing to families in rural areas, mainly to SC/ST households and freed bonded labourers, loans at a concessional rate of interest to low-income group households for construction of houses with provision of safe drinking water, sanitation and common drainage facilities.
Social Security Programs • National Social Assistance Program (NSAP) National Old Age Pension Scheme (NOAPS) National Family Benefit Scheme (NFBS) National Maternity Benefit Scheme (NMBS) • Annapurna	Social assistance programs initiated to ensure minimum national standard of social assistance over and above the assistance that states provide from their own resources and food security assurance to senior citizens eligible for pension under NOAPS but could not receive it due to budget constraints.
Land Reforms	Strengthening Revenue Administration and Updating of Land Records (SRA and ULR).

Source: *Ministry of Rural Development, Govt. of India*

The thrust of these programmes is economical and social transformation of rural India through a multi pronged strategy aiming to reach the most disadvantaged sections of the society. In addition, several new schemes *viz.,* State Rural Road Connectivity, State Rural Housing, State SGSY, Training, Master Plan and Sutradhar are proposed for XIth Five Year Plan and given below in short-

- *State Rural Connectivity*: Under Pradhan Mantri Gram Sadak Yojana, construction of all weather roads is not permitted if the villages are less than 500 meter away from the main road. Such left out roads and bridges can be covered and connected under the scheme with state support.

- *Mukhya Mantri Awas Yojana*: The Scheme is being under the Bharat Nirman with the main objective to accelerate the rate of diffusion and provide housing to the houseless SC/ST families.

- *State SGSY*: An initiative to constitute SHG Federation based on activity and geographical location to strengthen SHG movement.

- *Training IEC Scheme*: A scheme for training on project implementation and its monitoring.

- *Working Plan for Water Storage*: It is plan on the basis of survey of the catchment areas and flow of water direction on the basis of watershed area and then identification and cost estimation of the probable water harvesting structures.

- *Sutradhar Yojana*: Establishment of kiosks to facilitate access in rural areas to electronic communication and information and government schemes and programmes.

Ministry of Science and Technology plays a pivotal role in the promotion of science & technology in the country. Some of the important initiatives undertaken by this ministry are-

- *S&T Application for Rural Development (STARD)*: Aims to facilitate development of promising S & T based field groups and innovative technologies related to rural development.

- *S&T for Women*: Aims to promote research, development and adaptation of technology, improve the life, working conditions and opportunities for gainful employment of women especially in rural areas.

- *S&T Application for Weaker Sections (STAWS)*: Aims to develop economically weaker sections of the society in rural and urban areas.

- *Tribal sub-plan*: Aims to improve living conditions of scheduled tribes based on sustainable science and technology activities.

- *Special Component Plan (SCP)*: Aims to improve lot of the poor sections of SC community through intervention of Science & Technology.

Appropriate rural technology focuses mainly on those technologies which are simple and within the reach of the ordinary people for their own benefit and the benefit of their community and harness the local or regional capacity to meet local needs without increasing dependence on external factors. A large number of organizations *viz.,* NRDC, CAPART, TRCS, NIRD, DST / DBT, CSIR, ICAR, IITs, IIMs, KVKs and voluntary organizations etc. are involved in developing technologies for rural areas. Some of the important S&T achievements in the field of rural development are summarized below-

- Swaraj - India first indigenous tractor to facilitate mechanized agriculture.
- Value addition through post-harvest technologies like essential oil/ menthol production.
- Cheapest water purification technology including terracotta purification disc, portable arsenic detection kit, ultrapore membrane-based purifiers for removing virus & bacteria.
- Over 365 technologies passed on to the rural masses through publications, training sessions, etc.
- Construction of around 30,000 dwelling units using cost-effective construction technologies.
- Reverse Osmosis plant for desalination in Andaman & Nicobar Islands, Gujarat and Tamil Nadu.

Such concerted efforts initiated by the Government of India through several plans and measures to alleviate poverty in rural India need even greater attention to the core issue of rural prosperity. At present technology dissemination is uneven and slow in the rural areas. Good efforts of organizations developing technologies, devices and products for rural areas could not yield high success. Experiences of many countries suggest that technological development fuelled by demand has a higher dissemination rate. However, in India, technology developers for rural areas have been catering for needs (with small improvement), rather than creating demand. There is no industry linkage institution that can create demand-based-technology market for rural communities. Besides, there is also an imbalance between strategies and effective management programmes. Propagation of technology/schemes for rural development is slow, lacking a wider participation of different stakeholders. An ideal approach may therefore, include the government, panchayats, village personnel, researchers, industries, NGOs and private companies to not only help in reducing this imbalance, but also to have a multiplier effect on the overall economy.

National Innovation Foundation

The National Innovation Foundation (NIF, www.nif.org.in), Ahmedabad, Gujarat is an autonomous organization established under Department of Science and Technology, Government of India on Feb 28th 2000, with the main goal of providing institutional support in scouting, spawning, sustaining and scaling up grassroots green innovations and helping their transition to self supporting activities.

The main network partners of NIF are Honey Bee network, Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) and Grassroots Innovation Augmentation Networks (GIAN). NIF known for its passion for producing an environment congenial for grassroots innovations strives to support innovative minds and their creations. It conducts pollens for documenting and spreading these innovations through its network. It even selects and supports innovations both financially and intellectually for patenting and trademarks by involving project/ technology disseminating agencies for selective transfer of technology.

Till date more than 100,000 innovations and traditional knowledge practices have been scouted from over 500 districts of the country during its six national campaigns (Shodhyatras). NIF has filed 184 patent applications in India, 7 patent applications in US and 1 in PCT. Out of these, 33 patents have been granted in India and 4 patents in USA. Besides the above patent applications, 1 Design and 10 Trademark Applications and one farmer variety in PPVFRA have also been filed by NIF. It is also developing and maintaining National Grassroots Innovation and Traditional Knowledge Management Information System. The areas covered in the innovation database include plant variety, utilities and general machinery, farm implements, energy devices, agricultural and traditional knowledge practices, livestock management, herbal remedies, biodiversity examples, innovation concepts and ideas.

Status of use of Modern Implements, Farm Machinery and Hand Tools

Information Source for Rural People

An authentic source of information regarding new tools and techniques can enhance the applicability of the modern tools in rural areas. In the light of the National Sample Survey Reports, we outlined the flow of information about the new technology. As per National Sample Survey Organization (Report *No*. 499(59/33/2), 59th round 2003) data, only 40% of farmer households are concerned about access to information on modern farming technologies. The most popular source of information was 'other progressive farmers' with percentage of farmer households accessing information through this source being 16.7%, followed by input

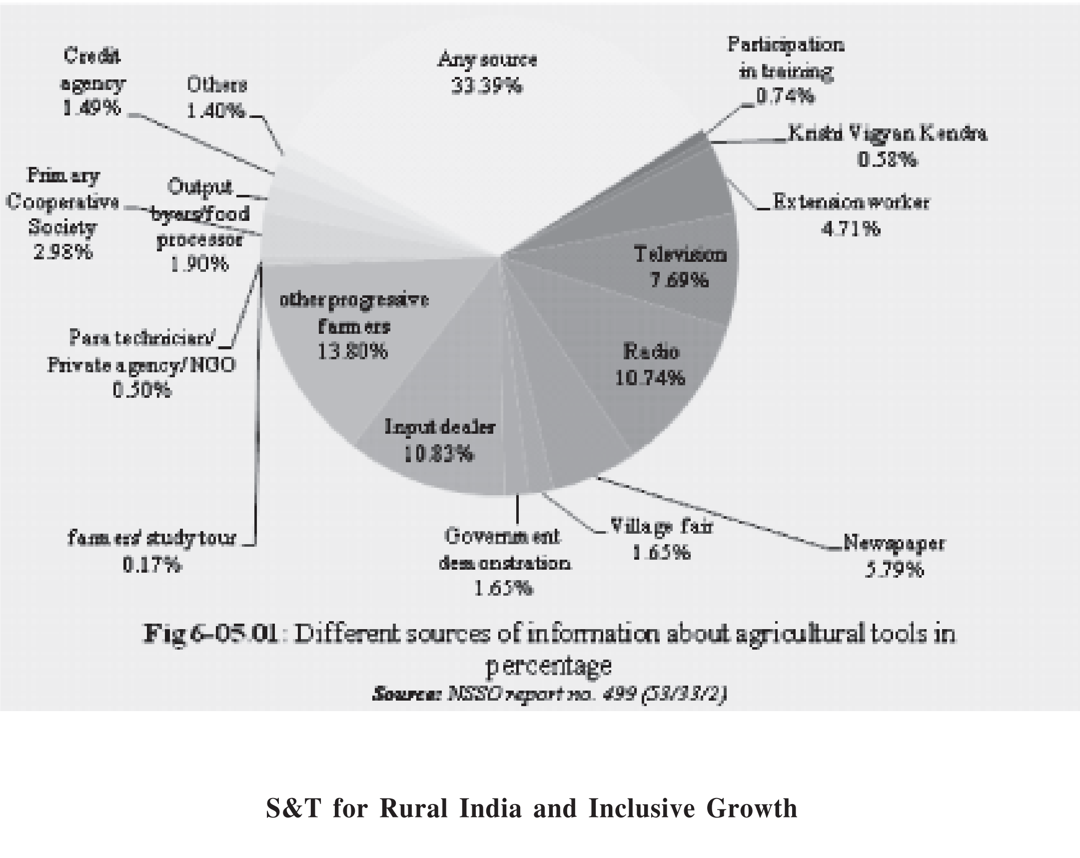


Fig 6-05.01 : Different sources of information about agricultural tools in percentage
Source: *NSSO report no. 499 (53/33/2)*

dealer (10.83%) and radio (10.74%). Percentage of farmer households accessing information through 'other progressive farmers' was highest in Andhra Pradesh (34%), followed by Gujarat (30%) and West Bengal (25%). In the case of accessing information through 'input dealers' it was higher in West Bengal (36%), Andhra Pradesh (30%) and Gujarat (24%). 'Radio' was highest in Jammu & Kashmir (36%), followed by Kerala (31%) and Assam (29%). It is also indicated that the two most popular sources namely, 'other progressive farmers' and 'input dealer' were contacted by the farmer households mainly on 'need basis' or 'seasonally'. The overall picture of India regarding sources of information is represented in the following Fig 6-05.01.

Finance for Farmers

According to the report from NABARD, GoI set a target of Rs. 1,75,000 crore for credit flow to agriculture for 2006-07 against which disbursements by all agencies stood at Rs. 2,03,296 crore, exceeding the target by 16 per cent. Commercial banks, co-operative banks and Regional Rural Banks disbursed Rs. 1,40,382; 42,480 and 20,434 crore achieving 118, 104 and 136 per cent of their targets, respectively. During the same year, 83.50 lakh new farmers were brought under the institutional fold, 74.70 lakh fresh KCCs were issued, 631 agri-clinics financed, debt relief worth Rs. 4,873.37 and. 673.90 crore was provided to farmers in distress and in arrears, respectively. An amount of Rs. 460.06 crore was provided by banks to small/marginal farmers under one time settlement scheme. Banks also extended loans to the extent of Rs. 73.41 crore to 27,810 farmers, to redeem their past debts availed from informal sources. In some cases, subsidy is also available for the purchase of agricultural equipments. Agricultural equipments namely, tractors, power tillers, power threshers, sprinklers, drip irrigation, self propelled reapers, rotavators etc. are available on subsidy under Central Sector Plan Schemes. The subsidy is available to the farmers @ 25% of the cost of equipment, subject to certain ceiling limits.

Most recently, Government of India released a debt waiver scheme in 2008 to the farmers for the welfare of poor farmers. This may be a short-term relief for the small and marginal farmers. But for the long-term gain we need to focus on capacity building of these farmers to sustain on adverse condition with more credit solution.

Major Farm Machinery Training and Testing Institutes in India

The Farm Machinery Training & Testing Institutes (FMTTI) at Budni (M.P.), Hissar (Haryana), Garladinne (A.P.) and Bishwanath Chariali (Assam) established by the Government of India have been playing a vital role in promoting agricultural mechanization.

The numbers of central farm machinery testing and training centre are less compared to the agricultural area of India. It is obvious that to enhance the facility there is a need to create more centers in India. To aware rural marginal farmers we need to decentralize the training and certification system. In fact, another gateway of job creation in rural India by imparting training to some nodal rural persons about standards and give them rights to certified the rural unorganizedly made small agri-machinery and tools on reasonable payment basis. In this way we may think of inclusion of large unorganized hand tool and agri-machinery industry into our organized system with proper safety measures and global acceptance.

Usage of Modern Farm Implements

It is clear from the Fig 6-05.02 that the tendency of utilization of wooden plough is higher than the iron plough. The other Fig 6-05.03 clearly reveals that use of indigenous water lifting device is much more than the use of mechanized pumps except in case of the large farmers.

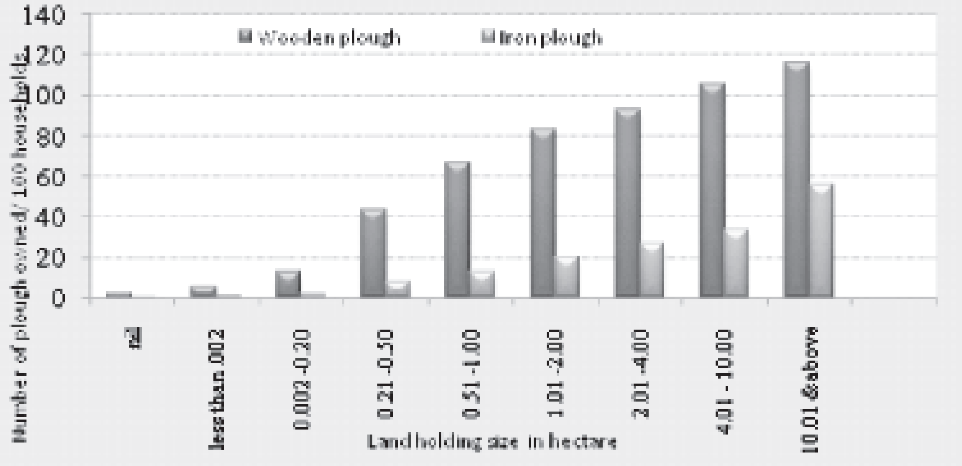


Fig 6-05.02: Number of different kind of plough owner in rural India
***Source:** NSSO Report No. 408, 1991-92*

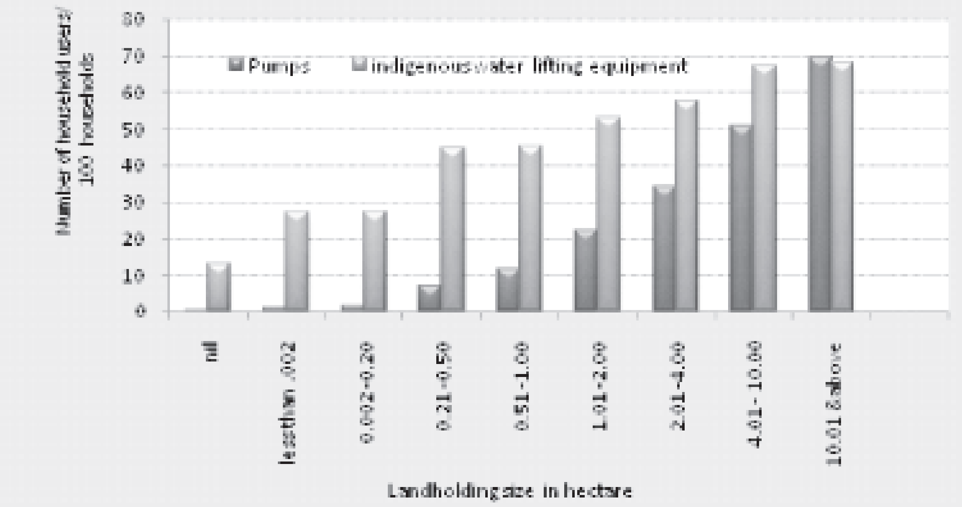


Fig 6-05.03: Number of different kind of pump user in rural India
***Source:** NSSO Report No. 408, 1991-92*

The above figures show the pattern of the usage of modern farm implements in rural India. The pattern shows that farmers with larger land holdings are the ones who mainly use the improved farm implements.

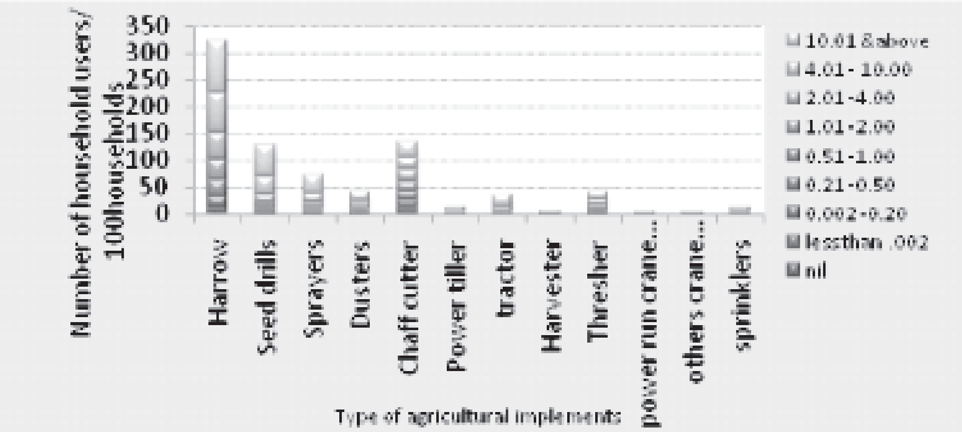


Fig 6-05.04: Users of mechanized agricultural implements in rural India
***Source:** NSSO Report No. 408, 1991-92*

Agricultural equipment based market basically for tractors in India is dominated by private players like Mahindra & Mahindra (M&M) and TAFE which constitutes for around 40% (out of which 75% is occupied by M&M)

of the total market, Escorts and PTL together occupy 25%, while others hold 35% of total market share (Tractor manufactures association 2004-05). These players not only do well in national market but also in international market. According to United Nation ESCAP report, the present requirement is about 2.75 million additional tractors. The average annual demand will be about 3.43 lakh tractors over the next 8 years. For intensive cropping, farm power availability needs to be increased from 1.35 kW/ha to 2 kW/ha by 2010, mainly due to increased use of tractors and power tillers and by 2010, the tractor population needs to be increased from 2.76 to 4.13 million tractors. Approximately annual use (in hours) of tractors is currently between 600-700 h/year.

Export Import Scenario

The following graphs show the trend of export-import data for soil machinery, dairy and milking machines and for the tractors over last 12 years. It is based on the values (in 1000$) of the particular item imported or exported as reported in FAOSTAT. These trends show the revenue generation through the export of agriculture machineries.

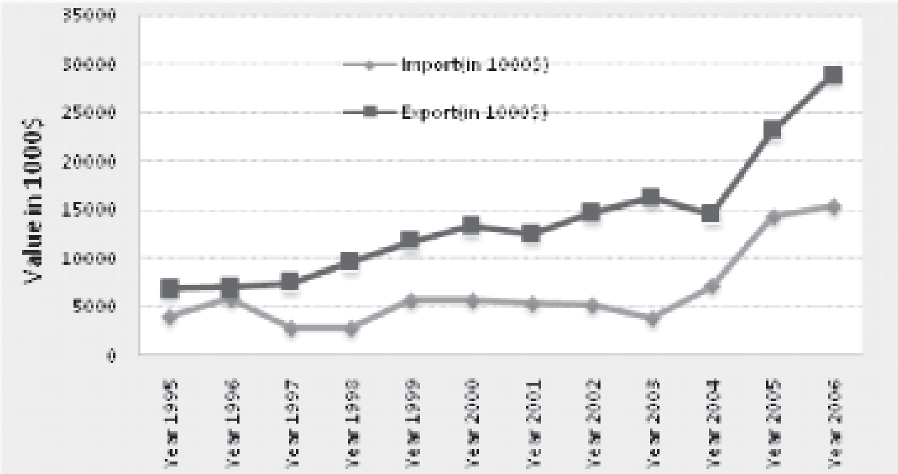


Fig 6-05.05: Import export value of soil machinery
Source: http://faostat.fao.org/site/576

Status of Hand Tools

There are an estimated 2500 small scale and tiny units in India, of which around 350 units are concentrated in Jalandhar and more than 100 in Ludhiana, besides 7 large units. The small-scale industry for

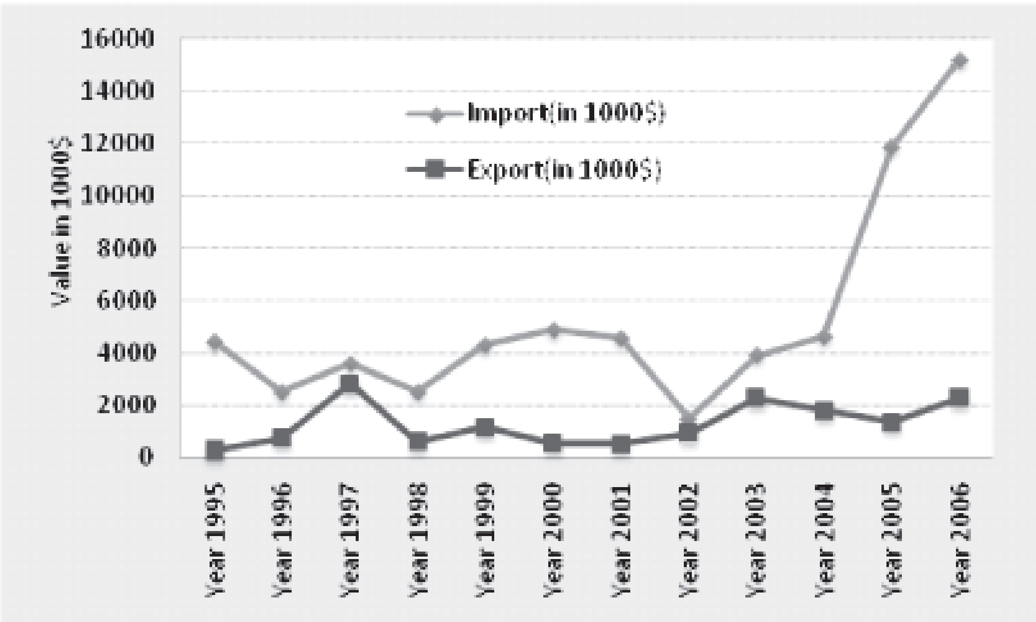


Fig 6-05.06: Import export value of dairy and milking machinery
Source: http://faostat.fao.org/site/576

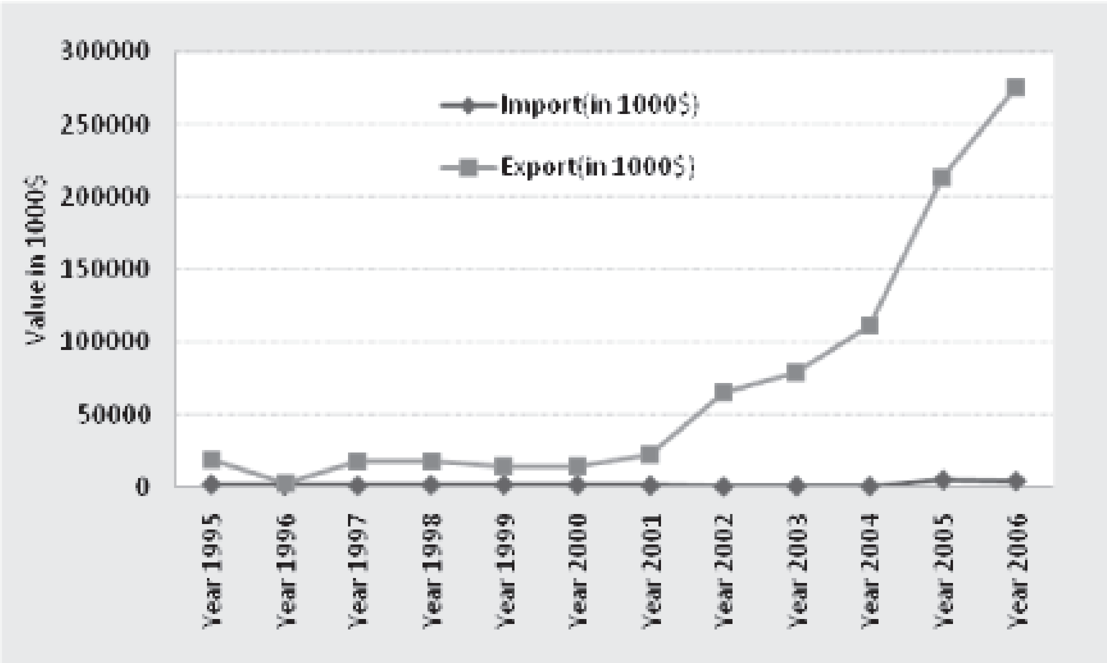


Fig 6-05.07: Import export value of Agricultural tractors (all values in USD)
Source: *http://faostat.fao.org/site/576*

hand tools employs an estimated 25000 workers. India's share is more than Rs. 5 billion in global hand tool market. Manufactured hand tools include hand tools like spades, shovels, mattocks, hand saws, files, rasps, pliers, pipe cutters, spanners and wrenches, goldsmith tools, vices and clamps, anvils, tools for turning, milling, grinding, sharp edge tools, etc. Hand Tool industry is an energy intensive industry with high scope for improving energy efficiency and saving. Different state governments have several schemes for the industry related to agricultural implements and hand tools.

Key points to focus on

- Dissemination of knowledge of modern farm implements among rural farmers still depends mostly on 'progressive farmers'. More intervention is needed by KVK and Government agricultural departments.
- Intervention micro credit system is one of the essential components for the small land holding farmers in rural India for using improved farm implements.
- There is a need to increase the number of public farm machinery training institutes for low paying farmers.
- We need more focus to do more R&D in sophisticated agri-machinery like milking machines, so that we can export more.
- Hand tool industry is still neglected in India. This industry is basically unorganized in nature. We must lay emphasis on the standardization, up-gradation and also on the marketing part of the small scale based hand tool industry.

One Segment of Unorganized Sector Workers: Rural Artisans

An important component of non-farm segment is the unorganized sector of workers, especially rural artisans in the village areas. These artisans comprise blacksmiths, carpenters, weavers (of carpets, durries, khesh, sarees, etc.), potters, mudha makers, hand tool makers, farm implement makers, metal ware (sliver, brass, copper) makers, sculptors (wood, metal, clay, stone), handicraft makers, etc. These artisans, on one hand, are regarded as custodians of the heritage of India, and on the other, play an important role in the village life through their repair and maintenance services. This informal sector possesses vast potential for opening-up employment opportunities, generation of rural income, and strengthening of purchasing power of the rural people. A special feature of these artisans is that they live in clusters, some of which are:

Potters: Nawalgarh & Dundlod (Rajashan), Narola & Dhulkari (Himachal Pradesh), Khandwa & Khadgao Kalan (Madhya Pradesh), Ranibandh (West Bengal), Thozukkal (Kerala) and Kasharipara (Meghalaya)

Blacksmiths: Loharpura (Rajasthan) and Sampla (Haryana)

Carpenters: Landnu (Rajasthan) and Chhuchhukwas (Haryana)

Present Scenario

The skill of rural artisans continues to be old and technology traditional. Their economic status is far from satisfactory, which makes their marketing power also weak at both selling and buying levels. Their education level is low and their linkages with rural developmental institutions are either non-existent or weak. Their shyness, weak communication power, and tendency to remain 'small' and 'satisfied' are some of their other problems. It has been found that the main reason behind the fruits of S&T developments not reaching these artisans is their non-involvement in rural development programs. In most cases, the technologies remain confined to R&D institutions. As a result, the overall goal of improving the quality of life of rural people remains far from being satisfactorily realized.

Some Insights from Rural Artisans

- Neglect by State and Central Governments
- Non-Involvement in Rural Developmental Programs
- Lack of Skill Improvement and Technology Up-gradation
- Lack of Specialized Markets
- Non-existence of Infrastructural Facilities
- Non-Availability of Quality Raw Materials

- Weak Financial Power
- Inability to Get Bank Loans
- Poor Access to Information
- Lack of Linkages with different Developmental Institutions
- Need of Social Security Mechanism

A survey of the felt-needs of rural artisans revealed the requisites of awareness generation, linkages development, training and confidence development in them. Following strategies were adopted:

i) Study of techno-economic status of artisans

ii) Awareness generation meetings

iii) Visits of R&D scientists to the workshops of artisans

iv) Organization of trainings

Organization of Trainings

To upgrade the skill of artisans and to innovate on their technologies, technical trainings were organized for them in the appropriate technical training institutions, such as Division of Agricultural Engineering, Indian Agricultural Research Institute (IARI), New Delhi. In these trainings, artisans could get exposure to different machines used in the manufacture of agricultural implements. They also received a chance to get acquainted with and work on some of the latest machines.

Impact: A comparative survey of the levels of awareness among artisans on various aspects having a direct relation with them in 2004 and 2007 clearly depicts the significant rise in their awareness levels.

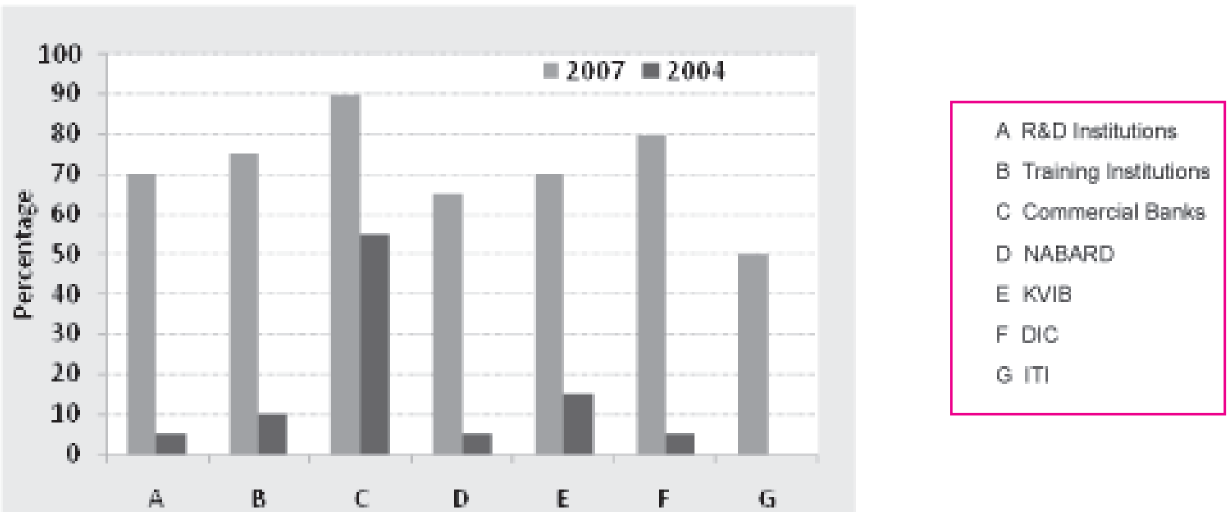


Fig 6-06.01: Change in awareness level of artisans in 2004 & 2007

Policy Implications

On the basis of the study carried out in different clusters of artisans following policy implications have been suggested:

- Trainings: Based on the predominant trade in a cluster
- Awareness Generation Meets
- Collateral-Free Loan Facilities
- Artisan Credit Cards
- Participatory Approach in all rural development programs
- Cluster–based Technical Education
- Marketing: Specific markets for artisans on the model of *Anaaj Mandies*
- Easy Access to Information
- Social Security Support

These will lead to skill up-gradation of rural artisans, which will help in income and employment generation and also stop migration of rural artisans to urban centers.

Shelter: A Big Challenge for Rural India

Owning a house ensures certain degree of economic as well as social security to a citizen. Providing weather resistant and hygienic accommodation to its citizens remains one of the most serious challenges India is facing today. The problem of inadequate housing is more acute in the rural areas where bulk of the BPL population lives. Our focus is on the requirements of housing in rural India, present government initiatives and most importantly the technological requirements for constructing low-cost sustainable houses. At the end deliberations are made on the possible future course of action for ensuring shelter to all. Throughout the discussion, a person without a permanent house (as defined in Census of India 2001) is referred to as homeless.

Present Scenario of Housing

The world's homeless population is estimated to be around 1 billion people. In India, around 1% of the total population is without a home (2001 Census). Approximately 60% of the homeless population is from the rural areas. In terms of housing units, the housing shortage is estimated to be 148.33 lakh houses as per the 2001 Census. The housing shortage has increased @ 0.89 million houses per year during 1991-2002.

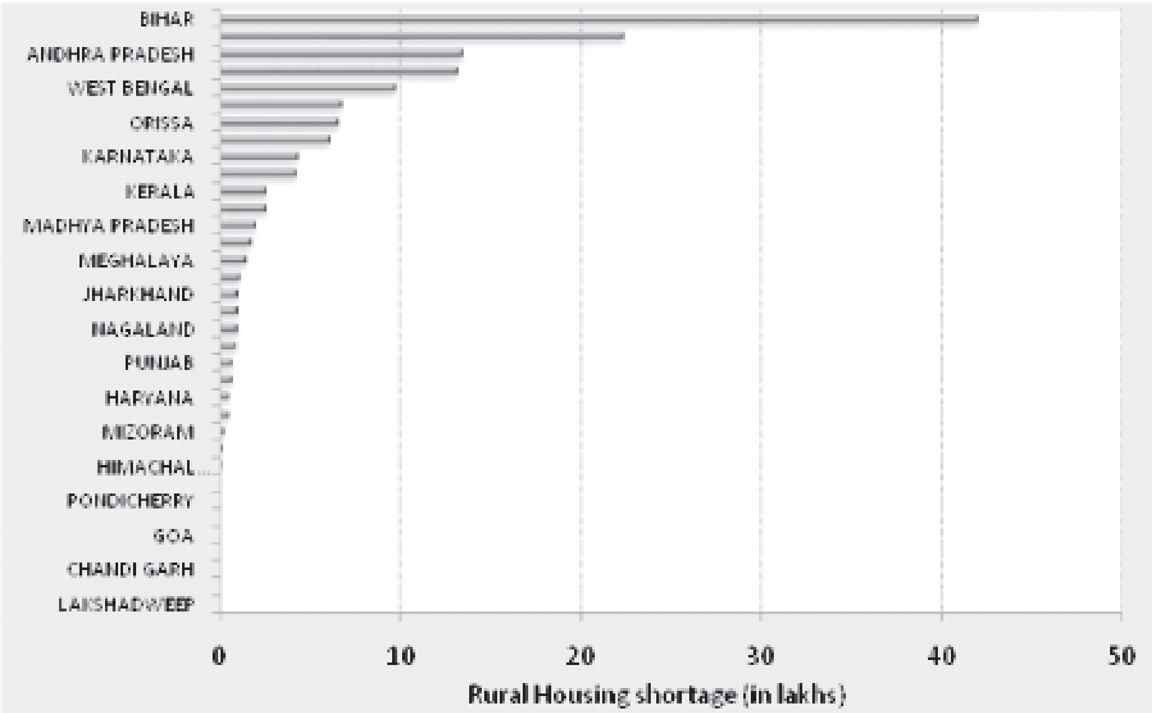


Fig 6-07.01: State wise shortage of housing in rural areas

Source: *Census of India, 2001*

The Working Group on Rural Housing for the 11th Five Year Plan estimated the total rural housing shortage during 2007-12 at 47.43 million houses. Of these 42.69 million or 90% of the total shortage pertains to BPL families. It is a matter of grave concern that even in advanced states like Gujarat and Maharashtra the extent of housing shortage is still very serious.

Government Efforts in Rural Shelter

The earliest known government initiative for housing was for rehabilitation of refugees immediately after the partition of the country. But, rural housing initiatives in its true sense and vigor in India began with the Indira Awaas Yojana (IAY) during 1985-86.

Indira Awaas Yojana (IAY)

The initial objective of the scheme was to provide dwelling units free of cost to the members of Scheduled Castes, Scheduled Tribes and freed bonded laborers living BPL. In 1993-94, its scope was extended to cover non-scheduled castes and tribes and later on the scheme was extended to families of servicemen of the armed and paramilitary forces killed in action. Since the time of inception, the number of houses constructed under the IAY has increased constantly over the years. During the financial year 2006-07, around 14.5 lakh houses were constructed and the achievement is 93.6% of target.

Technological components in IAY: If the beneficiaries' desire, government departments can provide technical assistance or arrange for coordinated supply of raw materials like cement, bricks etc, but it is not innate with the scheme itself. Though, 85 Rural Building Centers (RBCs) set up by the Ministry to enable people in different parts of the country to access appropriate technologies and aid capacity building at the grassroots level, were delinked from the scheme after 2004, these centers are expected to continue to support technology transfer and produce cost-effective material.

Recent developments in IAY: Since August 2005, the scheme has been brought under the ambitious Bharat Nirman Programme and has been set the target of constructing 60 lakh houses during the period 2005-09. Recently, the unit cost of IAY houses has been increased from Rs. 25,000 to Rs. 35,000 w.e.f. from 1st April 2008.

State-run Housing Schemes

Long before the Central government introduced any scheme for rural housing some state governments had rural housing programs. Currently, around 15 States/UTs like Andhra Pradesh and Tamil Nadu have their own schemes, whose scope extends much beyond than those of the IAY. These states through their own schemes have together constructed 27 lakh houses in rural areas during 2001-05.

Financing Rural Housing

In addition to the government undertaken fully subsidized IAY, there are other national as well as regional financial institutions which provide loans at concessional rates.

Housing and Urban Development Corporation Limited (HUDCO)

HUDCO provides housing loans mainly to Economically Weaker Sections (EWS) whose monthly household income is less than Rs. 2500. Another feature of HUDCO's work is assistance for reconstruction of rural houses in natural calamity affected areas.

National Housing Bank (NHB)

It promotes housing finance institutions at the local and regional levels by providing financial support in the form of equity and refinances to cater to the housing credit needs of all segments of population through primary lending institutions like commercial banks, housing finance companies (HFCs) and cooperative institutions.

Research Agencies in Rural Housing

This sub-section highlights some institutions working in developing suitable building materials and designs

Central Building Research Institute (CBRI), Roorkee: The institute has developed a number of technologies for making housing materials like clay bricks, machines for making the materials like brick making machine etc. Most of these technologies are under commercial use, while some are ready for commercialization.

National Institute of Rural Development (NIRD), Hyderabad: A recent initiative by the institute is the establishment of a National Rural Building Centre within the Rural Technology Park. This centre showcases the technologies of constructing region-specific affordable houses with eco-friendly local materials rather than conventional concrete and steel.

Advanced Materials and Processes Research Institute (AMPRI), Bhopal: The institute has developed a number of innovative, cost-effective alternative building construction materials using industrial wastes like Fly-ash and organic fibre like Sisal fibre as reinforcement in polymer matrix. The salient features of the products are:

- High strength and durability
- Cost effective
- Versatile technology for building industry

National Building Construction Corporation Limited: NBCC was established in 1960 as wholly owned Government enterprise to implement management practices that encourage value-added, innovative construction services delivery.

Building Materials and Technology Promotion Council: The BMTPC was set up in 1990 in order to bridge the gap between research and development and large scale application of new building material technologies especially promotion of low-cost, new waste based building materials and components.

Creating a Market for Innovation in Housing – a Push and Pull Approach

What is perhaps required is the creation of a demand (market) for the technologies developed by the research organizations. It can be created through the instrument of "*Public Procurement*" much in the line suggested by the Aho Committee in Europe. The Aho Committee suggested, providing an innovation-friendly market for Europe to be innovative.

The government may ensure public procurement by linking it with publicly funded housing schemes like IAY with necessary riders on standards and designs, and especially linking procurement to local raw materials, local standards, and local masonry skill.

This creation of demand through public procurement will push up enterprises in taking up ventures in low-cost innovative building materials which in turn will push the R&D institutes to be more innovative. The developed products will be pulled, in turn, through the public procurement system.

This push and pull strategy could be best executed through the creation of a new technology based business model.

Drinking Water Supply vis-a-vis Technological Interventions for Social Empowerment of Rural India

India has the largest rural drinking water supply program in the world serving about 1.6 million habitations spread over 15 diverse ecological regions and 742 million people. The provision of clean drinking water has been given priority in the Constitution of India, with Article 47 conferring the duty of providing clean drinking water and improving public health standards to the State. According to the National Water Policy for ensuring sustainability of the systems, steps were initiated in 1999 to institutionalize community participation in the implementation of rural drinking water supply schemes.

Ensuring water quality in the Rural Drinking Water Supply has remained the major bottleneck. The Government of India had launched the National Rural Drinking Water Quality Monitoring and Surveillance Program in February 2006. Moreover, in view of the problems of pollution of national water resources, the Ministry of Environment & Forests has constituted the "Water Quality Assessment Authority" (WQAA). The Ministry of Water Resources is assisting the WQAA in carrying out and coordinating its functions.

The States implement drinking water supply schemes. The Government of India supplements the efforts of the States by providing financial assistance under the Accelerated Rural Water Supply Program (ARWSP). Additional assistance is also available to the States for Rural Water Supply Program under various externally aided projects. The entire program (ARWSP) was given a mission approach when the Technology Mission on Drinking Water Management, called the National Drinking Water Mission (NDWM) was introduced as one of the five Societal Missions in 1986. NDWM was renamed as Rajiv Gandhi National Drinking Water Mission (RGNDWM) in 1991. The efforts of the Central and State governments are also backed by international organizations such as the bilateral agencies of Japan, the United Kingdom, the United States, Denmark, Sweden, Germany, Australia, Netherlands, etc., and multilaterals such as the World Bank, WHO, UNICEF (Water and sanitation program-South Asia), UNDP and the European Union.

Progress achieved so far

As reported in a background paper by Water Aid, according to latest estimates, 94 per cent of the rural population has access to safe drinking water. Data available with the Department of Drinking Water Supply (DDWS), Ministry of Rural Development shows that of the 1.6 million rural habitations in the country, 1.06 million are fully covered (FC), 0.34 million are partially covered (PC) and 0.19 million are not covered (NC). However, coverage refers to installed capacity, and not average actual supply over a sustained period or the quality of water being supplied which is the most essential part (*Water aid background paper, 2008*). Moreover, large incidences of slippage from "fully covered" to "partially/not covered" categories are another issue. The per capita water supply also ranges from a low of 9 lpcd to a high of 584 lpcd. Till the 10th plan, an estimated total of Rs. 1,105 billion was spent on providing safe drinking water. Thus, one would argue that the expenditure is huge but despite such expenditure lack of safe and secure drinking water continues to be a major hurdle and a national economic burden. Based on various gaps existing in the present rural drinking water supply system in the country, the DDWS has very recently come up with a paradigm shift in policy under which the ARWSP has been renamed as "National Rural Water Supply Program (NRWSP)".

Providing access to water has been considered primarily important and thus water quality remained secondary. As a result monitoring of the impact on habitations affected by poor water quality "is not happening".

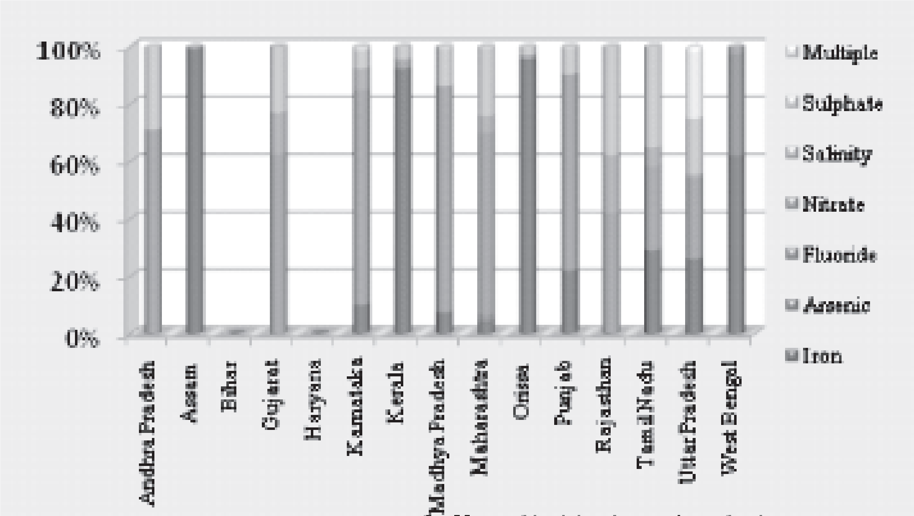


Fig 6-08.01: Percentage of affected habitations chemical contamination wise (as per ARWSP Norms)
Source: *http:www.ddws.nic.in*

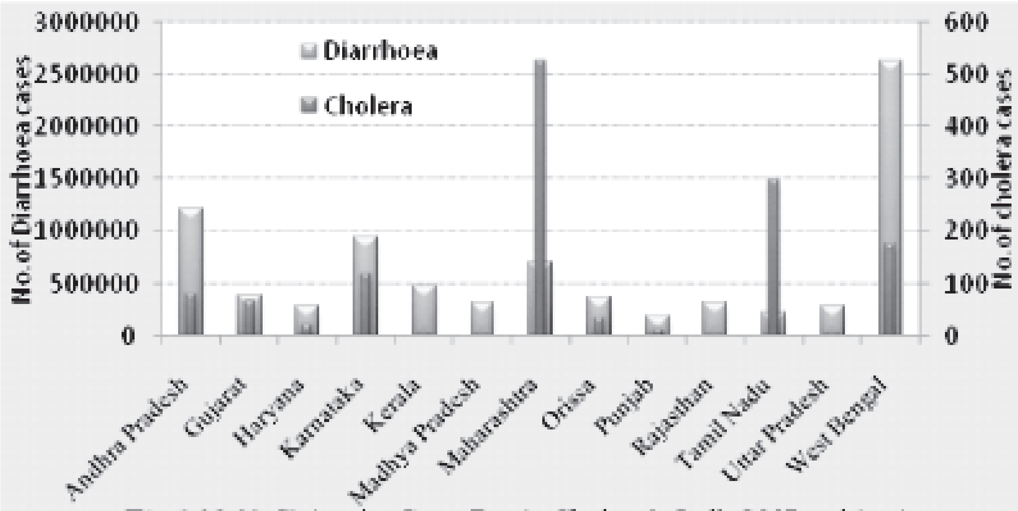


Fig 6-08.02: State wise Cases Due to Cholera in India 2007 and Acute Diarrhoeal Disease in 2006
Source: *National Health Profile, 2007, Report from Ministry of Health and Family Welfare*

The most serious malfunction in India's water-supply system is its hazardous quality and gigantic cost to human health. India ranks 120th out 122 countries monitored, in poor potable water-quality. Groundwater is the major source of water in our country with 85% of the population dependent on it. Even 80 % of the government's supply is dependent on groundwater. Arsenic contamination is now grim reality in almost the entire Gangetic belt while fluoride contaminated drinking-water similarly affects 20 States. The problems of chemical contamination are prevalent in India, with 1,95,813 habitations in the country affected by poor water quality (*Water aid background paper, 2008*). For surface water the major quality problem is seasonal turbidity owing to bacteriological contamination, reasons being anthropogenic. In 2005, a Central Pollution Control Board countrywide survey found 66 per cent of samples had unacceptable organic values, while 44 per cent had coliform, occurring generally from faeces. Fig 6-08.01 indicates the crisis that exits in safe drinking water supply in terms of quality. It is surprising to note that states like Bihar and Haryana does not have any problem related to chemical contamination.

Health Cost

The health burden of poor water quality is enormous. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually (viral hepatitis, cholera, jaundice, typhoid are examples), 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease each year. The resulting economic burden is estimated at $600 million a year. Ten million people are vulnerable to cancers from excessive arsenic and another 66 million are facing risk of fluorosis, now endemic in 17 States. Fluorosis is affecting future generations too through pregnant mothers whose anaemia is caused by fluorosis. Anaemia produces low birth-weight babies who in turn manifest their mothers' nutritional deficiencies through physical and mental deformities. Besides, there prevail health impacts of drinking-water with other environmental pollutants such as industrial wastes. Fig 6-08.02 reflects on the cases of water borne diseases like cholera and acute diarrhoea occurring in various states of India.

Role of Technology in Rural Water Supply

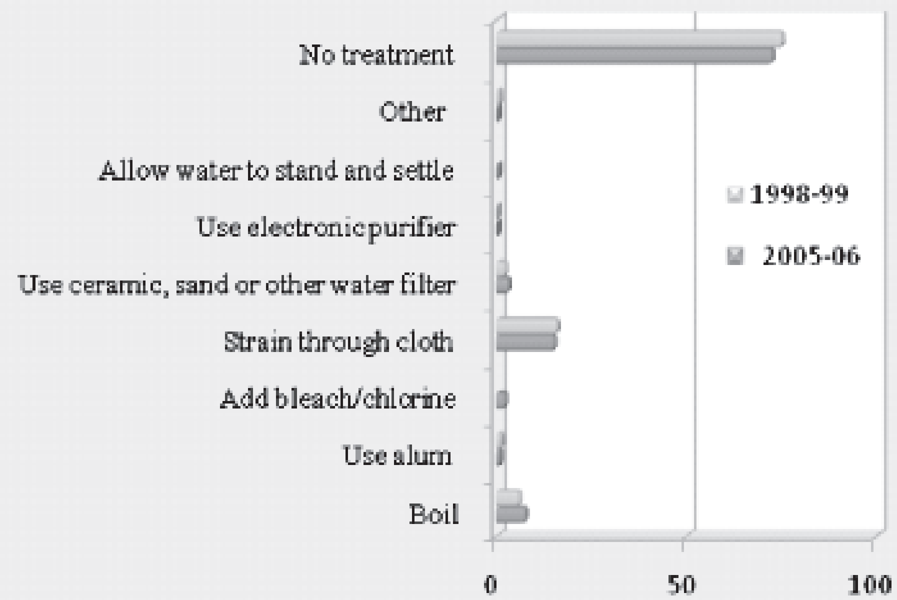


Fig 6-08.03: Percent distribution of rural households by treatment of drinking water in 1998-99 and 2005-06 respectively
Source: NFHS 2&3

History stands witness to man's use of varied forms of technology and science, ranging from the simplest to the most complicated, for storing and extracting water. India has a particularly strong tradition of water harvesting – communities have met their minimum water requirements effectively by collecting rainwater locally, diverting and storing water from local streams and springs and tapping sub-surface water. However, these traditional technologies and methods have fallen prey to inattention and ignorance over time, and need to be revived and rejuvenated. On the other hand are the most modern, state-of-the-art technologies and practices which could make a lot of difference in these water-stressed times.

Fig 6-08.03 and 6-08.04 provide an insight of how the S&T factor has grown in a span interval of six years and also that across different states while treating the drinking water.

It is found that technology penetration has rarely taken place in rural India. On the contrary, the role of technology is very significant in the expansion of drinking water supply coverage in rural India and to fulfill

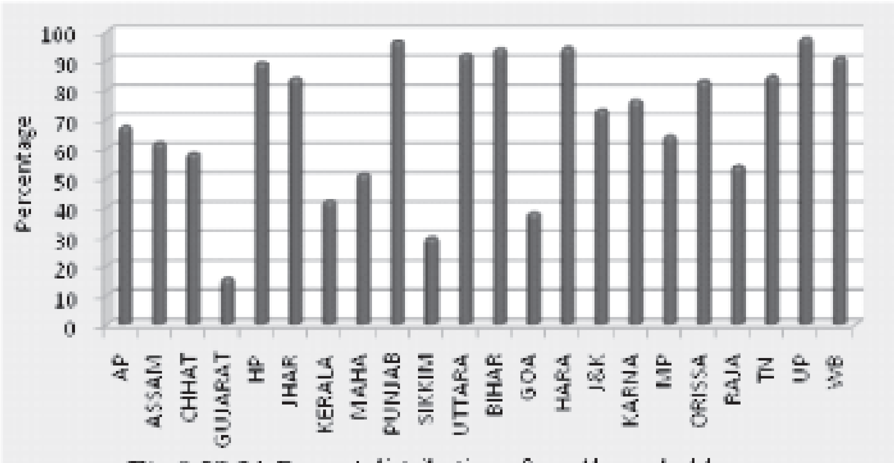


Fig 6-08.04: Percent distribution of rural households across states not treating the drinking water in 1998-99

the vision of making safe drinking water available to all people. Our scientists have done monumental works but very few know about it. Therefore social engineering is required to enable technology to deliver the desired results. For water quality affected habitations low cost technologies are available in the country and can be employed for tackling chemical and biological contamination problems. The Public Health Engineering Departments have to be regularly updated on the knowledge of technologies, areas for R&D have to be identified and engineers trained for successful implementation of technologies. There is also a need to enable them to formulate projects in a better manner and seek release of funds from GoI.

In order to ensure sustainability of such technological innovations of public funded research organizations, the financial participation of the user group is very essential. Depending on the site specific factors the cost of water may vary. Subsidies may have to be provided depending on the economic conditions of the local population. Sustainability emanates from acceptability which in turn is dependent on reliability, affordability and adequacy. A DAE-CSIR program has been envisaged which involves deployment of technologies developed by respective laboratories in a reliable and sustainable manner. The implementation involves synergistic participation of DAE-CSIR laboratories, executing agencies and users, each with financial contribution and commitment to ensure self-sustenance preferably with a multiplier effect.

Some Technological Success Stories

Many State Governments have reported success stories on ground water recharge, roof-water harvesting and surface water collection. For example, in Gujarat, through various programs 87,179 check dams, 35,479 boriband and 1,71,400 khet-talavadi (farm ponds) have been constructed for ground water recharge and dilution of contaminants. During the last 7 years, the State has built and taken up 3,585 recharge structures which have resulted in rise of ground water levels from 0.5m to 12m in the vicinity of recharge structures. Roof-water harvesting has been made compulsory for all government buildings in Tamil Nadu. In Karnataka, roof-water harvesting is successfully implemented by an organization called BAIF in fluoride affected habitations of Kolar and two other districts. Andhra Pradesh has enacted the AP Water, Land and Tree Act in 2003, which specifies that permission is required to be taken to drill a bore hole if drilling is within 250m radius of a drinking water source. Tie up with National Geophysical Research Institute (CSIR) is being done for creation of water sanctuary. Restoration of one water tank in each village under National Rural Employment Guarantee Act is proposed to ensure multiple sources of water and lead to drinking water security. Mizoram and Lakshadweep are amongst the pioneers in roof-water harvesting structures. Roof-water harvesting has also started in other States like Kerala, Bihar, Madhya Pradesh, etc. Maharashtra has come up with unique methods of unconventional blasting like bore blasting, stream blasting, etc. in order to enhance the percolation rate of soils, enhance the aquifer capacity and/or create a secondary aquifer for ground water recharge.

The Government has also launched the 'National Water Award' and 'Bhumijal Samvardhan Award' to encourage NGOs, Gram Panchayats/Urban Local Bodies for adopting innovative practices of ground water augmentation through people's participation. Moreover, the Government has constituted Advisory Council for Artificial Recharge of Ground Water in April, 2006 to popularize the concept of Artificial Recharge among all stake holders.

In summing up, one major problem is that the provisions for water are distributed across various ministries and institutions. With several institutions involved in water supply, inter-sector coordination becomes critical for the success of any program. The ownership of water is the core challenge of water management posed at different scales: between the state and communities in general, between the Central government and respective states or provinces and between local and state governments. When it comes to dealing with maintaining water quality, the users and the communities have to play a key role in maintaining hygiene near water sources.

Thus, policy issues to be addressed to improve rural drinking water supply scenario are:

i) To strengthen state-level institutions thus enabling more cost-effective rural-based services.

ii) Introducing a number of important innovations in technology, public administration, and policy, e.g. Integrated Watershed Development Program (IWDP) is an important step in harvesting rainwater in rural India.

iii) Good interdepartmental coordination by the project's monitoring and coordination cell.

iv) Water augmentation: A combined strategy of reviving our water bodies and supplying treated sewage for industrial use will more than adequately address the artificial water shortage.

The rural water supply component represents an effective marriage of initiatives from government departments and beneficiaries: locally elected governing bodies identify groups of villagers who need improved water supplies, and these groups take ownership of and maintain the completed hand-pumps. The government departments provide key technical expertise to locate the best sites, supervise construction, certify the water as satisfactory for drinking purposes, and provide spare parts. Several private bodies, NGOs are contributing significantly to the development of this sector. Organizations like Water Aid, Water Partners, World Bank, UNESCO, The Aga Khan Foundation, Naandi Foundation, Centre for Science and Environment have played an important role in shaping the drinking water scenario of the country. Naandi Foundation has developed and is implementing a holistic model that recognizes that demand for quality water exists and that by capitalizing on communities' willingness to pay, accountability can be enforced through a contractual relationship between service providers and the local government. Water partner's projects are funded through grant, loans or a combination of grants and loans. Their loan program is the first of its kind with the idea of community based water supply projects. By offering innovative financing methods through its Water Credit Initiative, Water

Partners empowers local communities to develop and sustain solutions to their own water needs. Taking lessons from such initiatives, there is need to look at traditional ways of life and wisdom in water management that have sustained over years and try to refine and upgrade the same with new scientific knowledge. Neither the public nor the private sector can alone meet access, quality, financing and policy gaps. Government institutions remain central but private sector should be a key partner. There is an urgent need to engage along a spectrum of public private solutions. The National Rural Water Supply Program (NRWSP) to be effective from April, 2009 onwards comes with lots of expectations.

Rural Sanitation: A step towards achieving the Millennium Development Goal No 7, Target 10

If water is life, sanitation is surely a 'way of life' and access to such facilities surely has an impact on the quality of human life and health. Environmental cleanliness and sanitation were subjects closest to Mahatma Gandhi's heart who proclaimed that "cleanliness is next only to godliness". Lack of adequate sanitation is a pressing challenge in rural India. Another major problem that the country faces today is the practice of scavenging, which mostly engages women. There are 7,70,338 scavengers and their dependents in India. They are the most suppressed class of the society, considered as untouchables and avoided by other communities.

The first national program aimed at improving rural sanitation on a large scale, the Central Rural Sanitation Program, was launched in 1986. Despite considerable investment, this approach failed to motivate and sustain high levels of sanitation as it was based on the assumption that mere provision of sanitary facilities would lead to increased coverage and usage. Recognizing the limitations of this approach, the Total Sanitation Campaign (TSC) was launched in 1999. The TSC moves away from the infrastructure focused approach of earlier programs and concentrates on promoting behavior changes. To add vigor to the TSC, in June 2003,

Table 6-09.01: Incentive pattern under Nirmal Gram Puraskar (in Rs. lakh)

Particulars	Gram Panchayat					Block		District	
Population Criteria	Less than 1000	1000 to 1999	2000 to 4999	5000 to 9999	10000 and above	Up to 50000	50001 and above	Up to 10 lakhs	Above 10 lakhs
Panchayat Raj Institutions (PRI)	0.50	1.00	2.00	4.00	5.00	10.00	20.00	30.00	50.00
Individuals	0.10					0.20		0.30	
Organization/s other than PRIs	0.20					0.35		0.50	

Source: www.ddws.nic.in

GoI initiated an incentive scheme for fully sanitized and open defecation free Gram Panchayats, Blocks, and Districts called the 'Nirmal Gram Puraskar'. The incentive pattern is based on population criteria given in Table 6-09.01. The incentive provision is for Panchayat Raj Institutions (PRI) as well as individuals and organizations that are the driving force for full sanitation coverage.

Since its launch, the Nirmal Gram Puraskar (NGP) has been very successful as a fiscal incentive for achievement of sanitation standards. From merely 40 Gram Panchayats from 6 states that received the prize in 2005, the number went up to 4959 Panchayats from 22 states in 2007. In 2008, more than 30,000 Panchayats were nominated for this prize and more 11,000 Panchayats have been selected for the award in 2008. NGPs are popular, and the numbers have risen significantly over the past two years. However, issues of sustainability need to be addressed, for the study shows that NGPs of Year 1 and 2 are slipping on a large scale. Reasons included poor construction, construction under peer pressure, and minimal emphasis on behavior change. The suggestions were that monitoring needs to be stronger and awards could be staggered.

The TSC is being implemented at a huge scale; 590 districts of 30 States/Union Territories (UTs). Against a target of 108.5 million individual household toilets, as of October 2008 the number of toilets reported completed is about 57 million. In addition, about 0.68 million school toilets, 14,540 sanitary complexes for women, and 222,267 *anganwadi* (pre-school) toilets have been constructed. The figures below give an idea of the release of funds vis-à-vis coverage status of sanitation.

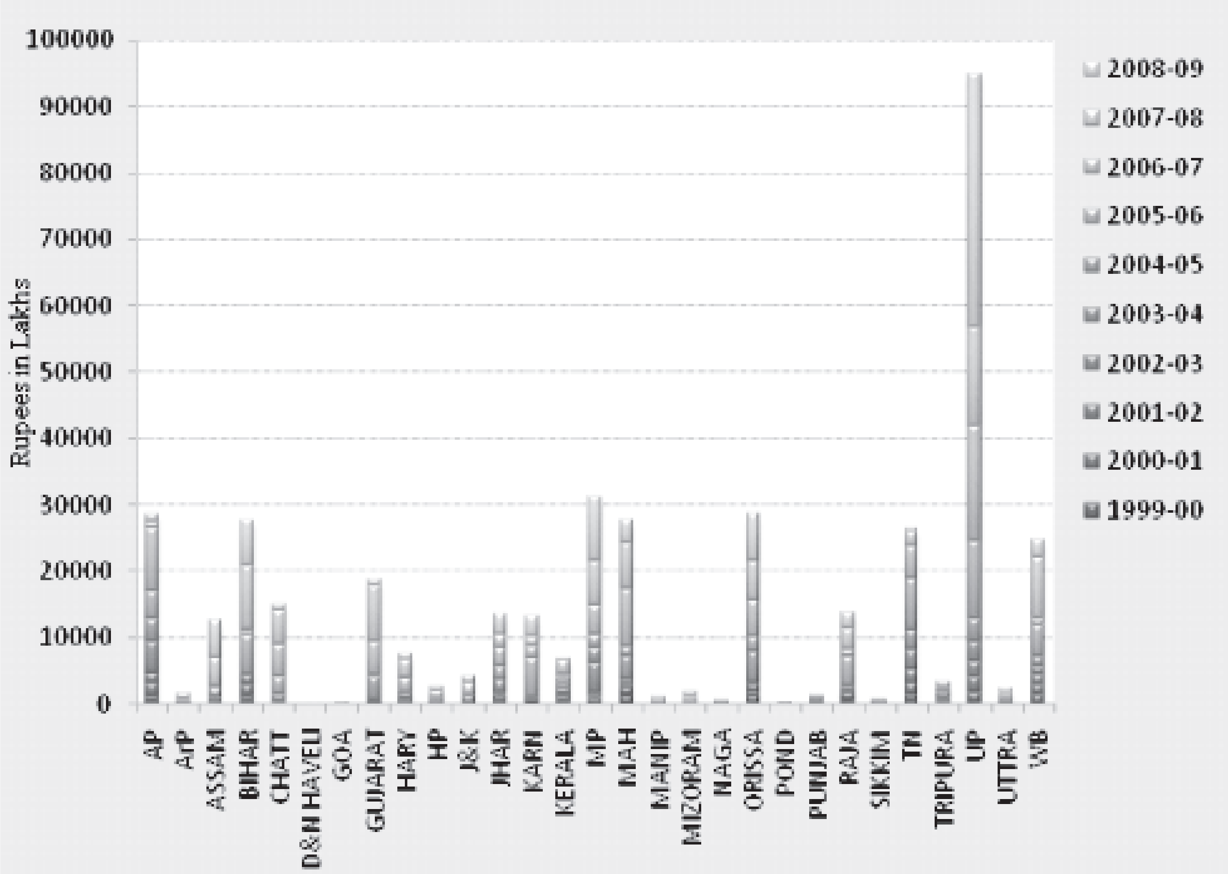


Fig 6-09.01: State-wise allocation released on TSC from Centre share

Source: www.ddws.nic.in

The TSC strategy is to make the campaign community based i.e. led through leadership by local bodies, youth and women organizations, schools in implementing the campaign. Open defecation is one of the greatest challenges in the region and needs to be addressed as a priority through greater emphasis on community partnerships. While Community Led Total Sanitation is a good approach, it requires some improvements for sustaining the momentum, behavior change and overall sustainability. These include actions at the community level (e.g., inclusion of the poorest in mapping and design; gender sensitive technologies; inclusion of schools) and district level (monitoring of usage, maintenance and hygiene practices, capacity building for facilitators etc). In rural sanitation, 'encouraging cost-effective and appropriate technologies for ecologically safe and sustainable sanitation' has been one of the main objectives of the approach. The implication for technology is that this should be improvised to meet consumer preferences 'in an affordable and accessible manner by offering a range of technological choices'.

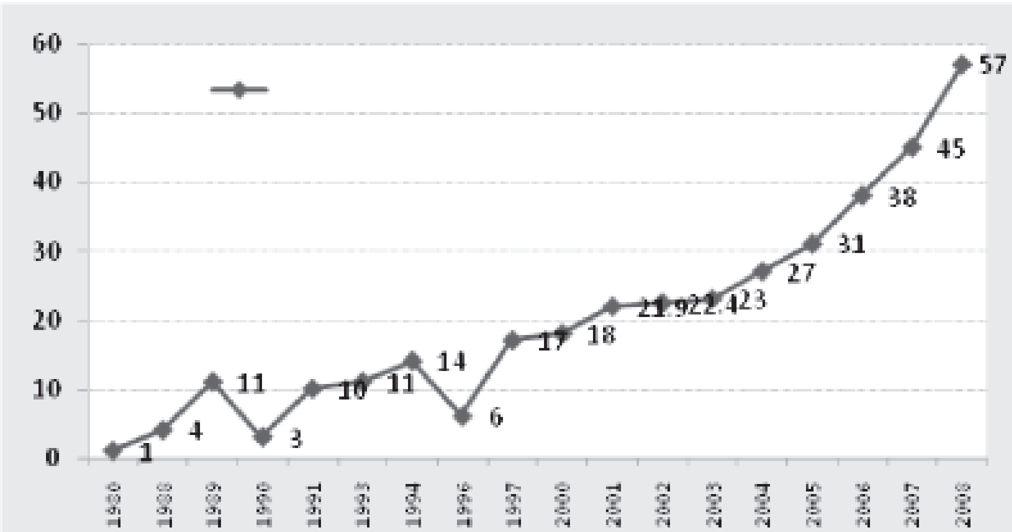


Fig 6-09.02: Trend of increase in % of rural individual household latrine

Source: Sustaining the Sanitation Revolution, India Country Paper, SACOSAN III, 2008

However, rural sanitation coverage has received a flip under the TSC, increasing from just 22 per cent in 2001 to nearly 57 per cent in 2008. While the TSC has been successful in scaling up rural sanitation, the program has also faced challenges in implementation. Some of the lessons learnt from this implementation experience are outlined using the framework of 4i's i.e. Role of *Institutions*, *Incentives, Information* and *Inclination*.

While talking of sanitation Mahatma Gandhi was of the idea that 'no one should clean and carry human excreta of others just to earn one's livelihood. There must be some scientific method of human waste disposal." Low sanitation coverage is also coupled with lack of affordable sanitation technology! There are several designs and technologies available for installing a household type sanitary latrine. But several inter-related factors play important roles in installing a sanitary latrine in a rural household. Therefore, it is important to give several technological options or informed choices to the user to choose from in order to own and maintain a sanitary latrine without much external support. These options must be of a kind that helps the user to select the most suitable amongst them in terms of cost as well as design without compromising the criteria of sanitary latrines. For example, between indiscriminate open defecation and water seal latrine, one can identify several options by applying the sanitation up-gradation approach – a movement from one alternative to another alternative, which is better than the previous one. At this point the role played by Sulabh Souchalay, needs a special mention. The organization had developed new technologies for production of biogas from human waste: a method of treatment of the biogas to make it pathogen free, duckweed-based waste water

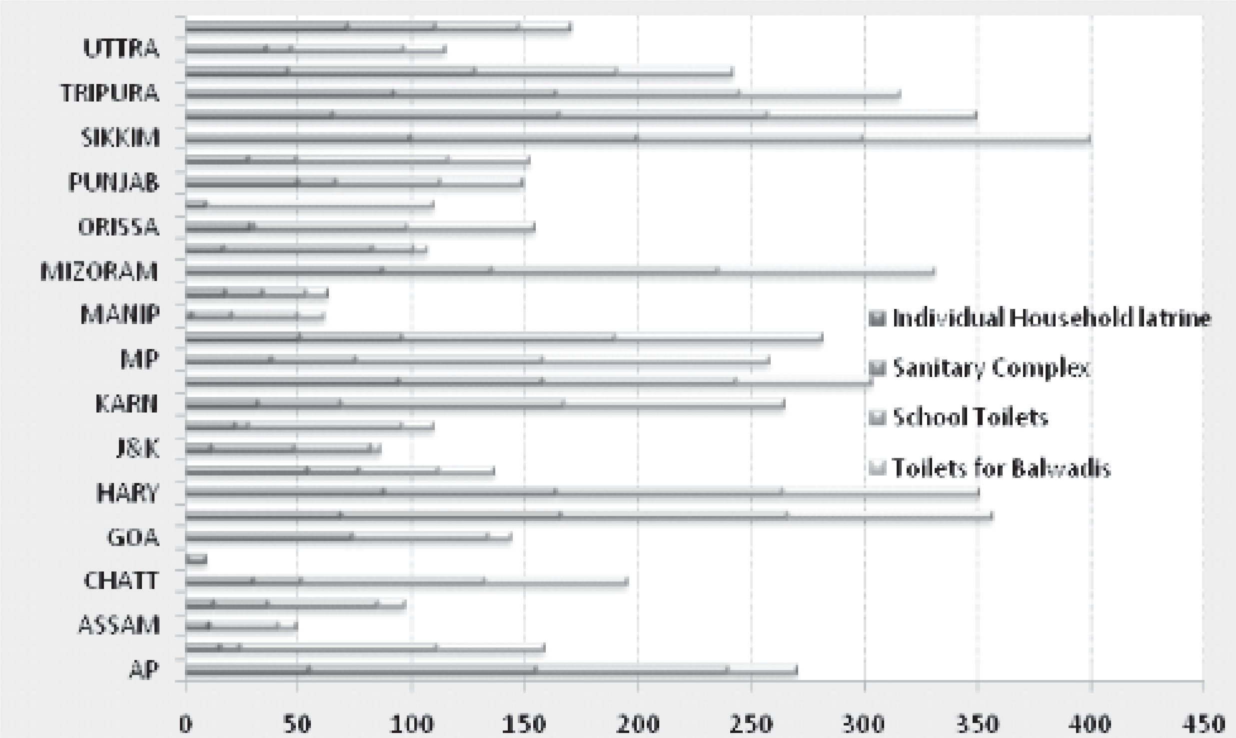


Fig 6-09.03: Statewise Percentage of sanitation coverage achieved till march 2009

Source: www.ddws.nic.in

treatment, Thermophilic Aerobic Composting etc. Sulabh has built over 7,500 community toilets with bath, laundry and urinal facilities. Sulabh is now operating in 27 states and 5 union territories with over 50,000 trained and experienced workers. Moreover, for sustainable rehabilitation of liberated scavengers, the programme 'Nai Disha'- an innovative model for the liberated and rehabilitated women scavengers was started by Sulabh.

To achieve on the holistic definition of sanitation issues related to solid and liquid waste management, use of waste (human and animal) for generating power, awareness generation and capacity building on innovative clean technologies need utmost importance. There is enough traditional knowledge on waste management in the country and it is high time proper attention was given to initiatives that have been successful in creating 'wealth' from 'waste'. There is a need to deepen our understanding about the linkages between climate change and sanitation and to use the same for advocating policy change on sanitation. Here comes the role of S&T in this sector. Ecological Sanitation which aims to promote the development, implementation and dissemination of socially and culturally acceptable, sustainable, hygienically safe and ecologically sound sanitation approaches can be applied (i) to identify appropriate wastewater handling approaches that satisfy technology, cost and institutional framework requirements and enable maximizing the utilization of existing pipelines and treatment facilities (ii) to recover nutrients from urine and faeces for agricultural purposes and (iii) to contribute to the reduction of wastewater discharged to sewers through recycling of grey water. The alternative paradigm of ecological sanitation offers the potential of sustainable sanitation for developing countries. Thus, "sanitation" cannot be limited to toilets. The current mindset of "flush and forget" has to be transformed into "wealth from waste". This would require sustained capacity building inputs for all stakeholders and awareness generation among the public. Convergence of several efforts of the Government, private bodies and NGOs could probably help us to achieve the Millennium Development Goal to: "Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation."

Rural Energy Security in India: Reality Checks

Access to a steady supply of sufficient and clean energy is critical for all round development of every person, irrespective of social and/or economic status and geographic location. However, one needs to differentiate between the energy security of rural and urban areas because energy dynamics of both the areas are quite different. Energy security perhaps is more important for the rural people because they are very vulnerable, marginalized and lack access to most of the basic resources. Majority of rural households in developing countries like India depend on traditional fuels like firewood to meet most of their energy requirements, supplemented by small amounts of kerosene and electricity for lighting.

Energy Scenario in Rural India

- About 70% of the Indians live in rural areas and use animal dung, agricultural waste and fuel wood as fuel for cooking,
- Particulate matter in the Indian rural households is 2000 μg/cubic m which is much higher than the permissible 150 μg/cubic m,
- Use of traditional fuel is estimated to cause around 400,000 premature annual deaths due to various respiratory problems.
- 75% of rural households depend on firewood for cooking, 9% each on dung-cake and on LPG as against 22% of urban households using firewood for cooking, another 10% on kerosene and about 57% on LPG.
- 44% of rural households depend on kerosene and another 55% on electricity, while in urban areas dependency is 89% on electricity and 10% on Kerosene for domestic lighting.

Two Perceptions that Need Attention

The adopted definition of electrification: According to the new definition (MOP, 2004), a village will be considered electrified if 10% of the total number of households in the village use electricity, in addition to other two criteria like availability of transformer in the village and electricity is provided to public places like schools etc.

- The scope of the definition of an electrified village needs to be broadened further.

Misinterpretation of the rural energy needs: 'Rural' is usually equated with 'agriculture' and 'rural energy' with 'cooking and lighting'; which certainly misses out the energy requirements of various other rural facets like rural schools and rural enterprises etc. Most neglected policy dimension has been energy for manufacturing in rural areas.

- About 87% of the schools in the country are located in the rural areas.
- About 25.81 million or (61.3%) of the enterprises in India are located in the rural areas (Economic Census 2005).
- Among Micro, Small and Medium Enterprises (MSME) alone, around 44.52% of the registered units and around 54.68% unregistered units are in rural areas.
- Besides, there are thousands of rural artisans who operate as Own Account Enterprises (OAEs) e.g. weavers whose productivity could be enhanced by supply of clean energy on a regular basis.

In a nutshell, there needs to be a paradigm shift especially,

- in the perception of rural energy needs,
- defining the goals as well as strategies of India's energy security,
- shift from the centralized mega-thermal/hydro/nuclear plants etc. and
- more importantly concentrating in renewable and sustainable sources of energy

Pattern of Rural Energy Consumption

In rural areas, three major types of power consumption are prevalent:

1. *Domestic consumption*
   - For cooking
   - For lightening
2. *Industrial consumption*
   - For Micro, Small and Medium Enterprises
   - For Big Industry
3. *On-farm energy consumption*
   - Energy consumption for farming

Consumption of energy in rural MSMEs: Two types of MSME units are available in India, Registered and Un-Registered Units. Approximately 46% of un-registered and 35% of registered rural MSME have no access to power. Further, the application of non-conventional energy (0.64-0.65%) in rural MSMEs is very meagre.

Consumption of energy in Agriculture (rural): 'Agriculture' is always considered to be synonymous with '*rural*', especially in countries like India. Agriculture consumes power both in the animate and non-animate

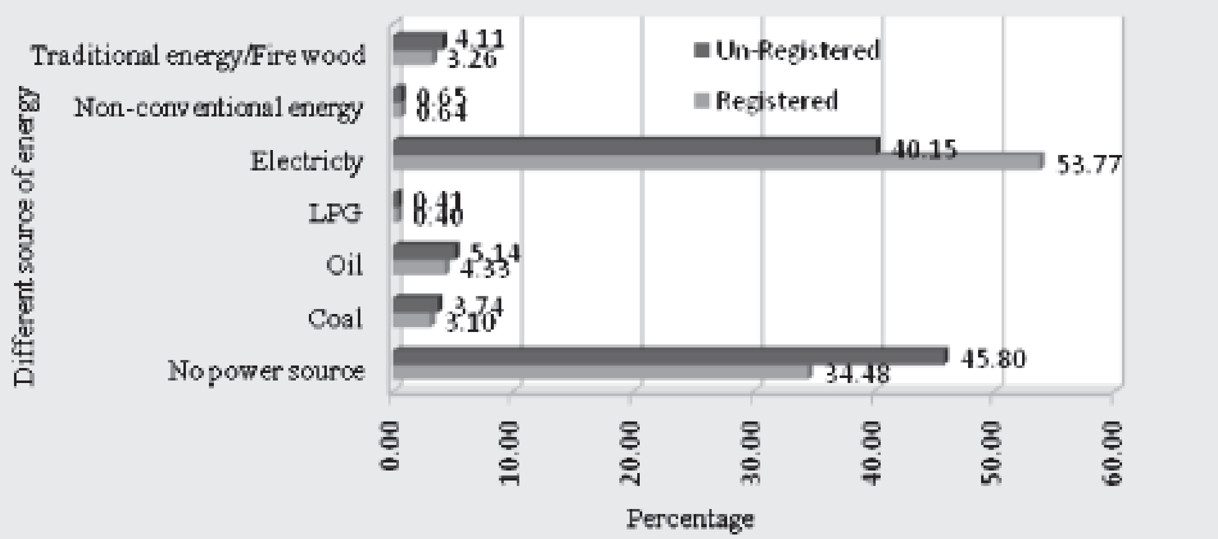


Fig 6-10.01 : Sources of energy for Indian Rural MSMEs
Source: MSME 3rd Census, 2001-02

forms. During the first five year plan power consumption in Indian agriculture was 316 GWh (3.97% of total power consumption in India). In 2005 total power consumption in agriculture stood at 88,555 GWh, which is approximately 22.93% of total energy consumption in India. Gujarat (46%), Andhra Pradesh (43%) and Haryana (45%) are the leading states regarding electricity power consumption in Agriculture (*TERI energy data directory & yearbook, 2005, P: 240*).

Government Initiatives

Some of the government initiatives for rural energy security are:

National Rural Electrification Policy, 2006: It aims to provide electricity to all households by 2009, though the time lag has been extended to 2012.

Integrated Rural Energy Program: It promotes applications of Renewable Energy technologies for cooking, heating and lighting in the rural sector.

Rural Electrification Corporation (REC) Limited: It finances and promotes rural electrification projects all over the country.

Sources for Rural Energy

Agri-waste: About 350 million tons of agricultural waste is produced every year which has a potential of generating 17,000 MWe of power and can eventually save roughly an amount of Rs. 20,000 crores every year. It has been estimated that the power potential has increased @ 8.75% during the period 1998 to 2003 (http://cgpl.iisc.ernet.in). Of the total power potential from agricultural waste, only 656.6 MW has been harnessed as on 30.09.2008 (http://www.mnes.nic.in).

As paddy, cotton and wheat are the major residue generating crops, large agri-waste based biogas plants should be set up in the areas growing these crops.

Other biomass based energy: Biomass based energy generation has a good potential for our country because of the rich biodiversity and a huge population. The potential sources of biomass energy are:

- Non-edible oil producing plants/trees-biofuel/bioenergy
- Wood biomass-lignocellulosic
- Forest litter biomass
- Bamboo energy
- Household/domestic waste
- Daily/weekly market waste
- Wastes from rural based industries
- Algal Energy

The Government of India through the Ministry of New and Renewable Energy Sources is implementing several schemes to harness the potential of different types of renewable energy sources. Considerable achievements have been made to generating power from non-edible oil producing plants and cogeneration bagasse (994 MW). But more efforts are needed to explore potentiality of indigenous non-edible oil producing trees for production of bio-fuel and bio-ethanol.

Virtually, no initiatives have been made to harness the energy potential of wood biomass, forest litter biomass, bamboo energy and domestic & market waste; though some small scale take-ups are reported from different parts of the country.

Solar Energy: Present state of exploitation of solar energy is insignificant in comparison to the estimated potential in the country. One of the issues that need immediate and serious attention is the improvement of efficiency and reduction of cost of solar energy devices and most importantly the search for alternative materials/devices of trapping solar energy.

Wind Energy: The present installed capacity of wind power under the grid-interactive power system is around 9,522 MW. In addition, 1,342 wind pumps have been installed. This installed capacity is far below the estimated potential of about 45,000 MW. Small scale community level wind turbines can be set up with government subsidy for the use of rural people.

Micro-Hydel Systems: Small hydro power projects are very viable especially in hilly areas like the North East, Himachal Pradesh and Uttarakhand where the natural downward flow of water can be easily trapped for generating power. The installed capacity of small hydro power projects of up to 25 MW capacities is around 2221 MW. However, hydro power projects of smaller capacity (up to 3MW) are installed only for about 240 MW. For the benefit of rural and remote areas there should be more projects of this kind. It is important to mention here that the estimated potential of Small Hydro Power in the country is about 15,000 MW.

The Way Ahead

It is apparent that there is a stark difference between the energy requirements of rural and urban areas. It is also evident that even after initiatives by the government; there still remains a gloomy scenario of energy in the rural areas. To cover the gaps of energy requirements of all the rural sectors like domestic consumption, agriculture, small scale industries (MSMEs) - demand-driven S&T interventions are essential. Moreover all the initiatives should involve full community participation to ensure the success of the endeavours.

Applications of Geospatial Information Technologies for Rural Development & Inclusive Growth in India

The advent of geospatial information technologies including Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS), individually as well as jointly, are playing a significant role in development and inclusive growth in India. The applications of remote sensing include forest and wastelands mapping, land-use/land-cover mapping , land-form and land-degradation studies, agriculture and soil mapping, ecology and geo-sciences and geo-morphologic mapping, and mineral, oil and water explorations, coastal and ocean resources studies, environmental monitoring, disaster management, urban area studies and environmental impact assessment, etc.

The Government of India had set-up the National Natural Resources Management System (NNRMS) in 1983, after recognizing the need and importance of natural resources management. The Indian Remote Sensing (IRS) satellite system was India's first domestic dedicated earth resources satellite program. The IRS-P4 satellite (also known as the Oceansat-1), launched on 26 May 1999, is currently in orbit. It has a Multi-frequency Scanning Microwave Radiometer (MSMR) and a nine-band Ocean Color Monitor (OCM) which has opened new vistas in ocean studies. The data collected from ocean color monitoring is used for conducting fisheries surveys and development of a fisheries forecast model. The satellite records the chlorophyll concentrations in the oceans which help predict biological productivity in the oceans. The monitoring has proved quite useful in coastal processes like sediment dynamics, dynamics of estuaries and tidal inlets, prediction of shore time changes, circulation & dispersal pattern, up-welling of coastal and oceanic fronts and surface currents. The satellite has had a great impact on environment studies as it has proved to be of great use in learning about marine pollution and oil slicks. Also important is its use in coral reef studies. Subsequently, IRS-P6 (Resourcesat-1) was launched in October 2003 and high resolution satellite IRS-P5 (Cartosat-1) on May 5, 2005. Thus, over the years, Department of Space (DOS) has built-up a strong R&D and technological base for implementing the space program.

Some Applications of Geospatial Technologies

GIS technology has become an integral tool in a number of applications, including land use, wastelands, urban planning, water exploration, environmental conservation & management, eco-system studies, etc. The GPS has helped improve the accuracy of data, as the availability of useful digital data, remote sensing or otherwise, is often limited and quite costly. Geo-spatial information technologies have applications in various sectors and an example of *water sector* is explained below:

- *Water Resources:* The two most important areas for GIS applications are:
  - o Hydrological studies which include rainfall estimation, forecasting and monitoring, hydrological modeling, urban hydrology and water balance models, and
  - o Watershed conservation, planning and management, including watershed delineation, quantitative analysis of drainage network, watershed, geology, soil mapping, lake and reservoir sedimentation studies.
- *Drinking Water:* Geospatial Technologies have emerged as powerful technological tools to identify the location of drinking water wells and also rainwater harvesting structures.
- *Water Quantity:* The remote sensing / GIS investigations can narrow down the region of high-yielding aquifers up to a minimum of 12 km, the exact location of bore-wells within that area has to be identified by geophysical surveys and studies. Similarly, it can also be applied for studies on water quality including Eradication of Guinea-Worm, Control of Brackishness in Water, Control of Iron, Control of Fluoride, Control of Arsenic and Control of Nitrate.

Some Policy Implications

The Information Technology (IT) Policy of Government of India, adopted in 1999 emphasizes the availability of spatial data to geospatial technologists, user community and industry. The areas which are receiving priority attention include natural resources assessment, monitoring and management; watershed development, environmental planning, urban services and land use planning.

Most states in India and several ministries and departments of the central and state governments have initiated special Geo-spatial information technologies applications relating to ground-water studies, cadastral mapping, power transmission and transportation infrastructure. The integration of socio-economic data with spatial data is increasing. The implementation of GIS in research programme has raised a variety of conceptual questions for both ecological and socio-economic sectors. In addition to these basic units of research, spatial links between the two sectors and levels of data abstraction for the spatial database have to be defined. Using the theoretical background of the hierarchical system approach and valuable experiences of spatial data handling, a consistent spatial information database needs to be created. Despite problems with data accuracy, logical consistency and completeness of data, a powerful tool for regional and local planning should be developed which may serve as a framework for a variety of planning programmes at the local and regional levels, as well as the transfer of know-how between governmental agencies and institutions using an interactive approach.

Government Intervention in Focal Areas of Traditional System of Medicine

In Indian traditional system of medicine, the knowledge about the drugs is largely centered on plants. At present, about 90% collection of medicinal plants is from the wild source and 70% of the plant collections involve destructive harvesting. Due to this, many useful plant species are becoming endangered or threatened. The government is presently emphasizing on two basic essentials i.e. firstly on conservation, secondly on cultivation so as to increase the production of raw materials without destroying the natural habitat.

Conservation

The raw materials for these traditional systems are largely native plant species growing in the forests (about 95%). So in order to maintain a sustainable supply of the raw materials from the forests, overharvesting has to be stopped and conservation of forests has to be done.

Acts safeguarding the forests

- Forest (Conservation) Act, 1980 with amendments made in 1988
- National Forest Policy, 1988
- The National Bio-diversity Act, 2002
- Convention on International Trade in Endangered Species of wild fauna a nd flora (CITES) and the negative list of exports notified by Government of India.
- Schemes (in situ conservation) for supporting projects on conservation of some specific medicinal plants by setting up Medicinal Plants Conservation Areas (MPCAs) which are primarily located in forest areas
- The Botanical Survey of India carries out surveys and also conserves rare and threatened medicinal plants in its gardens.
- The scheduled tribes and other traditional forest dwellers (recognition of forest rights) act,2006

Cultivation

Cultivation of medicinal plants is also of critical importance to offset the uncontrolled collection of large quantities leading to destruction of many forest medicinal plants. It is the only method of choice for long term management and ex situ conservation of medicinal plants. The cultivation can be done through herbal gardens, nurseries, cultivation in fields, tissue culture etc.

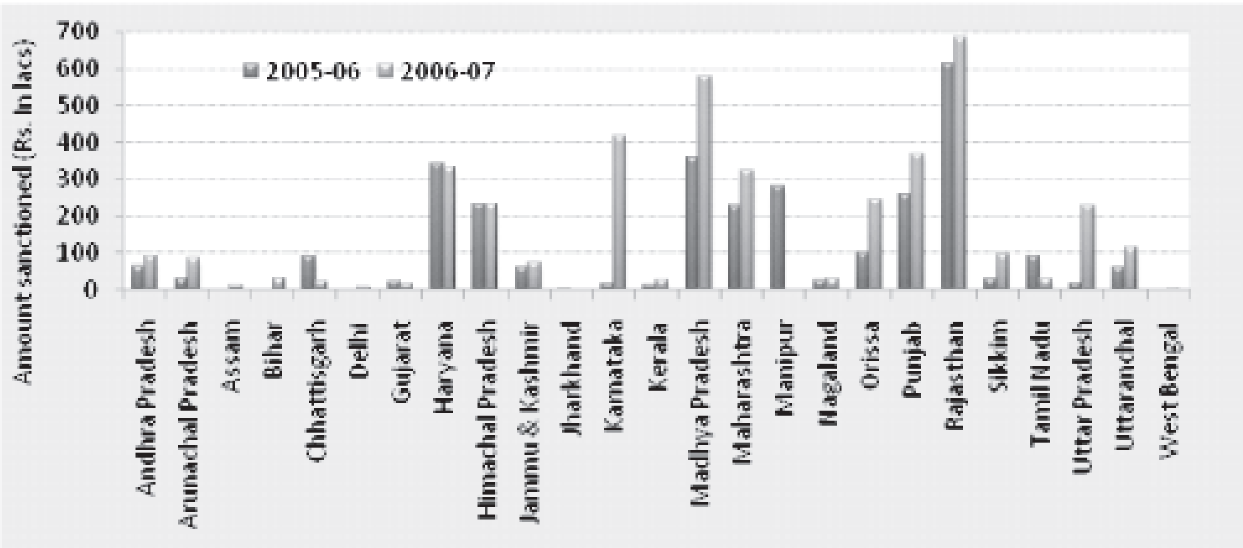
XI Five Year Plan

Key interventions and strategies in the Eleventh Five Year Plan are

- Ensuring conservation of medicinal plants, gene pools as well as promoting cultivation of species used in high trade and establishment of medicinal plants processing zones.
- Strengthening regulatory mechanism for ensuring quality control, R&D, and processing technology involving accredited laboratories in the government and non-government sector.

NMPB

- In the Tenth Plan, a National Medicinal Plants Board (NMPB) was established for supporting conservation of gene pools and large scale cultivation of medicinal plants.
- To ensure and enhance the quality of ASU medicines, the Government of India has scripted a GAP manual. The guidelines for Good Agricultural Practices (GAP) seek to lay down a cultivation programme designed to ensure optimal yield in terms of both quality and quantity of any crop intended for health purposes.
- Incentives: NMPB since its inception has been granting incentives in the form of funds to farmers and NGO's who want to take up cultivation of medicinal plants. During 2006-07, it sanctioned, all over India, around 1805 projects costing Rs. 4,044 lakhs as compared to 1,222 costing Rs. 2,954 lakhs in 2005-06.



Existing R & D Infrastructure

Various central institutions, state agricultural universities and NGO's are involved in R&D activities related to improvement of cultivation practices of herbal plants. Some of them are CSIR Labs (CIMAP, NBRI, IIIM), NBPGR, State Agricultural Universities, FRLHT etc.

Inferences

The primary focus in herbal sector should be:

a) To assess the abundance of medicinal flora. Emphasis on improved agro-technologies and that too preferably organic in nature. Encouraging organic cultivation, will not only reduce the levels of toxic/ metallic content (which are basically a result of excessive use of pesticides and fertilizers) but in all likelihood that it will help retain the original curing powers.

b) A manual on 'collection practices from wild' has to be prepared urgently and distributed to state departments.

c) There should be stringent rules on storing of raw materials according to the shelf life and other characteristics of the bio-product.

d) In current scenario when the number of medicinal plants is declining in their natural habitat because of over collection from the wild, it needs to be thought over and discussed whether 'forest rights act 2006' is practicable? Won't it accelerate the depletion of already endangered plants?

It can be construed that improper and unscientific method of collection, indiscriminate and over exploitation, shrinking homelands for the herbs, their conservation and sustainable use are the major problems plaguing this sector. Indeed the government is catching up on solving these existing problems of the herbal industry; but with mounting universal interest, increasing potential and prospects in herbal industry, some urgent initiatives need to be taken otherwise the situation will deteriorate further.

Impact of Science & Technology on Indian Fisheries Sector

Fisheries sector, a sunrise sector in India, has recorded faster growth than that of crop and livestock sectors. The sector contributes to the livelihood of a large section of economically-underprivileged population of the country. It has been recognized as a powerful income and employment generator as it stimulates growth of a number of subsidiary industries and is a source of cheap and nutritious food besides being a foreign exchange earner. With the changing consumption pattern, emerging market forces and technological developments, it has assumed added importance in India. It is undergoing rapid transformation and the policy support, production strategies, public investment in infrastructure, and research and extension for fisheries have significantly contributed to the increased fish production. Particularly, after the mid-1980s, the development of carp poly-culture technology has completely transformed the traditional backyard activity into a booming commercial enterprise.

Fish production in India has touched 6.87 million tonnes in 2006-07 from a mere 0.75 million tonnes in 1950-1951. The share of India in global fish production has grown gradually from about 2.66% during the 1960s and 1970s to 4.58% in 2006-07. It shows that growth in fish production in India has been at a faster rate than in world; mainly due to increasing contribution from inland fisheries. In the initial years, marine sector used to contribute more to total fish production then inland sector. In the 1950-51, marine production contributed about 71.01%, which fell gradually to 42.77% in 2005-06, while inland sector started contributing from 28.99 in 1950-51 to about 57.23% in 2005-06. In fact, by the year 2000, its share crossed 50% and continues to improve.

With fisheries sector comprising marine fisheries, freshwater and brackish water aquaculture and inland fisheries consisting of tanks and reservoir, the potentiality of this sector as a whole remains to be fully tapped and it remains a sector of much promise. The fisheries sector is a complex enterprise that functions under integrated networks of natural resources, other enterprises with forward and backward linkages with fisheries and other socio-political variables. The major functions of fisheries enterprises, viz., production, transportation, storage and processing involve value addition from labour, capital and management, which significantly influence the rapid economic development of the country.

In the last 25 years, unlike agriculture, the contribution of fisheries sector to GDP continued to grow at a rapid pace because of the expansion of culture fisheries enterprise. The contribution of fisheries sector to the total GDP has gone up from 0.75% in 1980-81 to 1.04% in 2004-05 (at current prices). Similarly, the share of fisheries in agriculture GDP (AgGDP) has increased robustly from 2.17% in 1980-81 to 5.93% in 2004-05. This sector is in fact pushing the agricultural growth upward for the past 5 and half decades.

Expansion of fleet capacity, technological innovation, and increases in investment all led to explosive growth in the exploitation of marine fisheries through the 1960s, 1970s and 1980s. But from the late 90s onwards, marine fisheries production has reached a plateau and it seems that it can register only marginal increase in the near future. With most wild fisheries near maximum sustainable exploitation levels, capture fishing will most likely grow slowly.

On the other hand, inland fish production has been constantly rising. The inland fisheries include both capture and culture fisheries. Capture fisheries were the major sources of inland fish production till mid-1980s. But the fish production from natural waters like rivers, lakes, etc. followed a declining trend, primarily, due to proliferation of water control structures such as dam and habitat destruction due to human interference and settlement near and surrounding water bodies. Depleting resources, energy crisis and resultant high cost of fishing etc. have led to increased realization of the potential and versatility of aquaculture on a sustainable and cost-effective alternative to capture fisheries. Inland aquaculture activities are gaining importance in some states like Uttar Pradesh, Andhra Pradesh, and Punjab etc. in recent years.

In the coming decades, aquaculture will most likely be the greatest source of increased fish production, as fish farmers expand the water surface area under cultivation and increase yields per unit of area cultivated. Greater use of compounded aquaculture feeds along with improvements in rearing technology and selective breeding have the potential to significantly increase the productivity of many forms of aquaculture.

But the sector must overcome several major challenges, if it has to sustain the rapid growth of the past years.

- Aquaculture has to face competition from other user of land and water, as these resources would become more scarce in future
- Marine sector would face energy crisis as it would need fossil fuels for further expansion.
- Aquaculture production would be restrained by diseases as the sector expands.
- The availability of fish meal, fish oil and wild caught trash fish as feed inputs may also become a limiting factor.

The growth rate analysis for various states from 1990-91 to 2005-06 shows that fish production had a significant growth in all states and Union Territories except Goa, Karnataka and Tripura in case of states and Andaman & Nicobar Islands, Dadar & Nagar Haveli, Daman & Diu and Puducherry in case of Union Territories. In some of the states like Andhra Pradesh, Maharashtra, Orissa, Tamil Nadu and West Bengal, the growth of inland fisheries was found to be higher than that of marine fisheries. But in Gujarat and Tamil Nadu, marine fisheries growth was observed to be more than that of inland fisheries, though the latter is negative and non-significant.

Allocation of funds to a particular sector is an indication of a push given for development of the sector. The outlay for fisheries sector was about Rs. 5.13 crore in the I Five Year Plan and it went up to Rs. 2,060.54 crore in the X plan. Its share in the total plan outlay was hovering from 0.26% in I Plan to 0.52% in IV Plan and decreasing thereafter continuously and it received only 0.14% of total outlays in X Plan. In spite of this, the sector has been growing at an annual growth rate of about 5% over the last two and half decades. Considering the general importance given to agricultural sector, the preference received by the fisheries sub-sector in the plan outlays is still reasonable.

Fisheries sector witnessed a spectacular growth of over 800% in last five and half decades of planning & development, for which technologies were the main drivers of growth. At present, fisheries research is carried out by a huge network of institutes under different organizations, viz., ICAR, SAUs, CSIR, DOD, DST, DBT, UGC, IITs, IIMs, Ministry of Agriculture, Ministry of Commerce, Ministry of Food Processing Industries, several voluntary agencies / private industries etc. Most of the productivity enhancing technologies have largely come from the research investment made by ICAR/DARE, which is the main agency responsible for developing & disseminating technically feasible, economically viable & environmentally sustainable technologies for the development of agricultural & allied sectors, including fisheries in our country. The outlay for fisheries research in total agricultural research has grown from 2.7% in IV Five Year Plan to 6 % in IX Five Year Plan, though it again dropped to 3.1% in X Plan. Overall, this showed the increasing importance accorded to this sector to exploit the still under-exploited areas.

Among the two major sub-sector of fisheries sector, it was found that the importance accorded to research is more than that of development over different plan periods. The share of research allocation rose from 3% in IV Plan to about 7% in X Plan. Increasing importance accorded to research over development programmes by the Government, shows that the planners are convinced that technologies are driving the growth in this sector, which need to be nurtured to achieve the desired 4% growth in agriculture in the XI Plan.

It was found that investment on both fisheries research and development would be financially feasible and beneficial to the society. An earlier study conducted by ICAR and World Fish Centre showed that the net present value (NPV) was estimated to be Rs. 82 to 176 billion under various TFP scenarios. The internal rate of return (IRR) from investment would be in the range of 42 to 55 percent. The benefit-cost ratio would vary between 2.1 and 3.4.

To sustain this growth of the sector in general, technology, infrastructure and market would play a major role apart from enhanced investment in research and development. Technology had been the main factors responsible for the phenomenal growth of the aquaculture, particularly after the advent of carp poly-culture and composite fish culture in the late 70s. Similarly, major investments on infrastructure such as construction of mini harbors, jetties, landing centers, introduction of trawlers and mechanized vessels, supply of nets, etc. led to increased catch and contribution from capture fisheries sector. However, market has not been able to play a major driver for the growth of the sector so far. To un-tap the potential of the sector, market may take the lead in furthering the growth, especially in the emergence of aquaculture sector.

Mushrooms: The vegetable of future

In India, mushroom is a unique non-traditional cash crop grown indoors, both as a seasonal crop and round-the-year under controlled environmental conditions. About 2000 species of fungi are used as food by tribes and societies, however, only a few are cultivated. Climatic conditions in India are favorable for natural occurrence of mushrooms and some of them are regularly collected and used as food by natives, particularly those belonging to tribes. Common mushrooms collected from nature are species of *Astraeus, Auricularia, Calvatia, Cantharellus, Lycoperdon, Morchella, Schizophyllum, Termitomyces, Tuber* etc.

Value added products that can use Mushrooms

Bakery products (biscuits, bread, cakes), pickles, chutneys, nuggets, papads & fast food items like burgers, cutlets and pizza etc.

Sustenance from Wild Collection

There is a wide scope to tap the potential in and outside our forests for providing sustained livelihood and profit to the people through systematic collection and processing of wild mushrooms, which is till today limited to the collection of morels only.

World

World production: 3 million tones

Market value: US $ 10 billion

Major Exporting countries

a) Fresh Mushrooms: Netherland, Poland, Ireland, Belgium

b) Preserved Mushrooms: China (41.82%), Netherland, Spain

Major Importing countries

a) Fresh Mushrooms: U.K., Germany, USA, France

b) Preserved Mushrooms: Germany, USA, France

India

- India ranks 54th in world production & 6th as exporter
- Per capita consumption: 25g/year
- Production: 48000 tonnes /annum
- Major states: Punjab, H.P., Haryana
- Three varieties: Button, Paddy Straw & Oyster
- Value of Export of preserved Mushrooms (2006-07): Rs 108 Crores
- Value of Export of fresh Mushrooms (2006-07): Rs 4.2 Crores
- Largest market of Indian Mushrooms: USA (69.52 %)

Medicinal properties

- Rich in Folic acid, polysachharides, ergosterol, higher K:Na ratio & fibre content
- Antitumour, anticancer, antimalarial, antifungal & antiviral
- Counteracts pernicious anemia & hypertension
- Delight for diabetics

Sustenance from Cultivation

Mushroom cultivation also provides employment generation. There is ample scope to earn more from mushroom cultivation using some innovation like attractive packaging for longer shelf-life, processing units for canned items, value addition and new products such as mushroom nuggets (*burries*), biscuits, *papads*, pickles, soup powder, etc.

Food Security

Mushrooms are of excellent food value as they provide a full protein food containing all the twenty one amino acids besides containing useful amount of fats, vitamins and minerals. Mushroom protein being easily digestible (70-90%) is considered superior to vegetable proteins. Two essential amino acids lysine and tryptophan, present in mushrooms in large amounts, are not even found in cereals. Being low in caloric value (300–390 Kcal/100 g dry wt), low fat and high protein, they are considered as the 'delight of diabetic patients'. Folic acid and Vitamin B-12 which are normally absent in vegetarian foods are present in mushrooms (3g fresh mushroom can supply 1 micro gram vitamin B12; recommended for daily uptake).

At present we have the lowest rate of protein consumption and due to population explosion the problem of protein deficiency will become more acute. Under prevailing circumstances all possible sources of protein products will have to be exploited to save the country from hunger and malnutrition. Edible mushrooms can therefore be used as a weapon against starvation because of their high protein and vitamin content. Mushrooms can in a way contribute to food security by being easily available, affordable and usable.

Major Constraints

- Mushrooms are not popular in India.
- Being highly perishable, lack of immediate access to markets is a major bottleneck in mushroom farming.
- Lack of storage facilities like processing units, cold storage, refrigerated transport etc.

Horticulture: Post Harvest Management

Horticultural crops form a significant part of total agricultural produce in the country and have become key drivers for economic development in many of the states in the country, and they contribute 29.5 per cent to GDP of agriculture (Economic Survey 2007-08). These crops play a unique role in India's economy by improving the income of the rural people. Cultivation of these crops is labor intensive and as such they generate lot of employment opportunities for the rural population. Fruits and vegetables are fastest growing sectors within horticulture. India produces around 111.77 million MTs of vegetables and 57.73 million MTs of fruits (National Horticulture Board), which accounts for nearly 11.90% and 10.90% of world production of

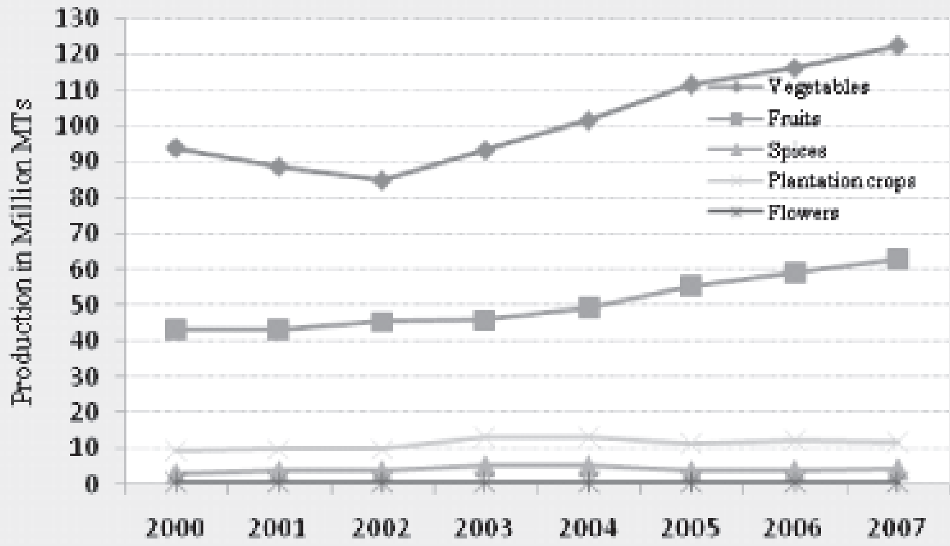


Fig 6-15.01: Trends of Domestic production in horticulture sector (2000-07)
***Source**: Indian Horticulture database 2006*

vegetables and fruits, respectively and the country ranks second in the world. Fruits and vegetables combined form the major contributor to total horticulture production and show a constant linear increase in production (Fig. 6-15.01).

In the world production of fruits India is the biggest producer of banana and mango and second largest producer of lime.

Post Harvest Research

Joint efforts of R&D institutions, farmers, government agencies with a strong post harvest infrastructure for post harvest management and trade has resulted in India emerging as a major producer of fruits and vegetables in the world.

Realizing the need for strong Post Harvest Management (PHM), several initiatives have been implemented:

- Establishment of packaging houses in different states which have facilities of international standards for grading and packing of fruits and vegetable.
- Appropriate pre-treatments; like curing, hot water treatment, fungicide application, waxing pre-cooling, packaging, storage (cold storages) have been standardized.
- Drafting of the National Food Processing Policy and Act.
- Reduction of Central Excise Exemption on Processed Products of Fruits and Vegetables.
- Establishment of Food Parks and Cooperative Food Parks.

- Establishment of Agri-Export Zones.
- Value addition.

For rural handling of farm inputs and outputs, Horticulture mission seeks to develop and make available farm and village level technologies. All India Coordinated Research Project (AICRP) centers for Post Harvest Technologies, Central Food Technological Research Institute (CFTRI) (CSIR) and several other organizations involved for PHM aim to develop location and crop specific post harvest technologies and equipment to minimize quantitative and qualitative post harvest losses and also to develop technologies for better economic growth. Several field level technologies like cleaners, graders, dryers, decorticators etc were successfully developed for farmers by various organizations and some are highlighted in Box.

Environment Control Technologies by Central Institute of Post Harvest Engineering & Technology

- Two Stage Evaporative Cooler
- Low cost Seed, Spices, Crop Dryer
- Mobile Cool Chamber
- Shrink Packaging of Fruits and Vegetables
- Evaporatively Cooled Room for Storage of Fruits &Vegetables
- Porous Bricks
- Evaporative Cooled Storage Structure
- Low Cost Polyhouse for Higher Benefit: Cost Ratio

Looking into the present agricultural production and post production scenario in India, the most appropriate action for employment generation in rural sector is primary processing and value addition in production catchments.

Fruits and Vegetable Processing

The Food Processing Industry sector in India is one of the largest in terms of production, consumption, export and growth prospects. The utilization of fruits and vegetables for processing is estimated to be around 2.20 percent of the total production. Over the last few years, there has been a positive growth in ready to serve beverages, fruit juices and pulps, dehydrated and frozen fruits and vegetable products, tomato products, pickles, convenience veg-spice pastes, processed mushrooms, and curried vegetables. Production of juices and value-added products including jams, jellies, pickles, canned products etc. has become a commercial success and all the R&D institutes & private sector are engaged in development of new innovative products for marketing and commercialization (Box). Several significant technologies developed by Central Institute of Post Harvest Engineering & Technology, Defence Food Research Laboratory, Indian Institute of Horticultural Research, Indian Agricultural Research Institute, G.B. Pant University of Agriculture & Technology, Himachal Pradesh Krishi Viswa Vidyalaya, Central Institute of Post Harvest Engineering & Technology (CIPHET) have commercialized several rural based value added technologies and popularized food processing technologies among the farmers and entrepreneurs (Box).

New products in the market

- Strawberry wine
- Apple wine
- Plum wine

By HPMC

- Cashew apple squash
- Cashew apple jam/jelly
- Stone apple beverages

By Orissa University of Agriculture & Technology and Indian Institute of Technology

Processing technologies for value addition at rural threshold by Central Institute of Post Harvest Engineering & Technology

- Weight based grader for fruits
- Vegetable washing machine for on-farm use
- Green chickpea shelling machine
- Chilli seed extractor for seed growers/processors
- Betel leaf curing chamber
- Tamarind de-fibring, and sheeting machine

Recent Policy Initiatives

- National Bank for Agriculture and Rural Development (NABARD) has set aside Rs. 1,000 crore, especially for agro-processing infrastructure and market development.
- Excise duty on processed fruit and vegetables has been brought down from 16 percent to zero percent in the budget, 2001-2002.
- Presently, food and food processing is regulated by 13 different laws and regulatory orders.
- All Fruit and Vegetable Products exempt from Central Excise Duty.
- New Exim Policy to set up exclusive Agro Export Processing Zones with fresh incentives.
- Ministry of Food Processing Industries is promoting Food Parks - an integrated processing concept with common facilities and marketing.
- Specific Concessions for EOUs
- Full duty exemption on all imports
- Tax holiday for any 5 consecutive years
- Permissions to have up to 100% foreign equity
- Use of foreign brands freely permitted

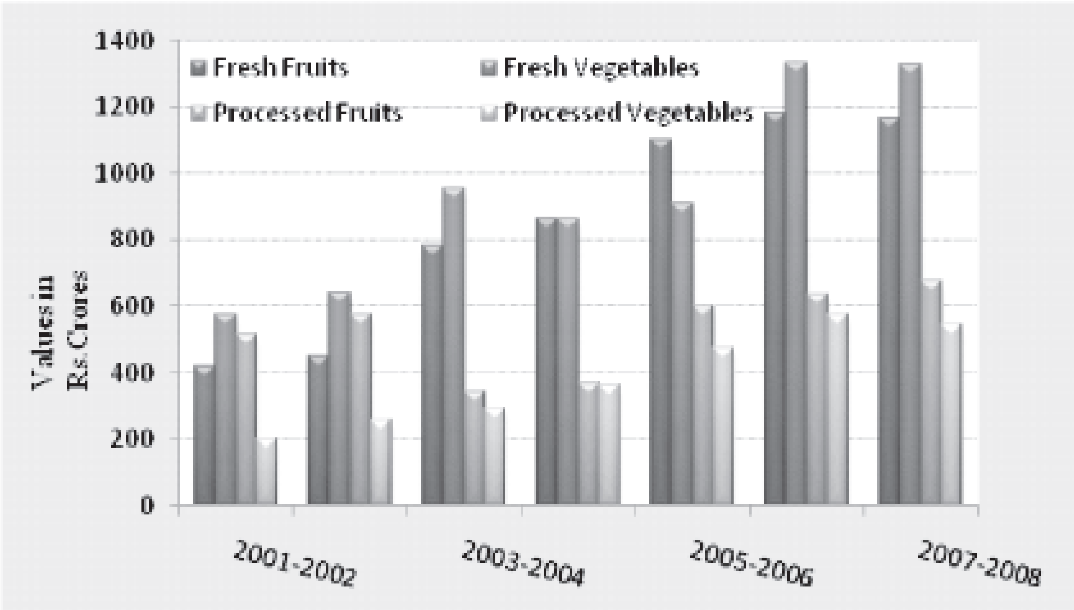


Fig 6-15.02: Export of Fruits & Vegetable produts during the Years 2000 to 2008

EXIM Scenario

Fresh fruits and vegetables comprise almost 35% of the world trade in horticulture, out of which, almost two-third is accounted for by four items, namely, citrus, banana, apple and grape. The other important items are mangoes, papaya. Among the vegetables, which account for about 22% in the world trade in horticulture, the major items are tomato, onion, potato, bean, pea, mushroom, asparagus and capsicum. Processed fruits and vegetables account for about 20% and 17% of the world horticultural trade, respectively.

Major exports from India

Fruits:	Mango, Grapes, Orange, Apple, Banana, Other Citrus Fruits and Lemon.
Vegetables:	Onion, Potato, Tomato, Pumpkins

India's major export partners

Fresh Fruits & Vegetables:	UAE, Bangladesh, Malaysia, UK, Sri Lanka, Netherlands, Pakistan,
Processed Fruits &Vegetables:	USA, UAE, Bangladesh, Russia, Netherlands, Nepal, UK, France, Sri Lanka, Malaysia, Kuwait, Canada, Germany

Source: *DGCIS Annual Export*

For the last 10 years, Indian export statistics clearly reveal the progressive growth of exports (to World) in the fresh as well as processed fruits and vegetables (Fig 6-15.02) and the major export partners for India is highlighted in Box.

Future Post-Harvest Research Priorities

Several research programmes like Post harvest treatments (heat, UV, irradiation CO2, chemicals) for storage ability; Optimum storage conditions for storage of tropical fruits, ornamentals, planting material, fresh pack and lightly processed produce; Possibilities of modified atmosphere packaging (MAP), absorption layers, inserts sensors; PP films with micro-pores; Adaptive control of storage conditions with biological sensors; Environmental friendly packaging using nanotechnology; Fundamental research on senescence, ripening, respiration, ethylene effect, chilling, fermentation, superficial browning; Impact of pre-harvest and postharvest factors on shelf life and postharvest quality; Regulation of fruit colour and aroma and Controlled atmosphere (CA) storage of fruits are the main future research priorities for coming years.

Key issues in Post harvest Management of Fruits and Vegetables in India

Fruits and vegetables are important supplements to human diet. According to National Horticulture Board, 58.92 and 116.03 million tons of fruits and vegetables respectively were produced during 2006-07. Taking into account post-harvest losses and nutritional requirement for balanced diet for one million people, there is a shortage of 65 million tons of fruits and vegetables. For reducing post harvest losses and improving quality, the following key issues need proper consideration.

Inadequate Post-Harvest Infrastructures

Table 6-16.01: Commodity-wise distribution of Cold Storages in the country (as on 31 Dec 2003)

Commodity	Number	Capacity ('000 tonnes)	%
Potato	2,618	14,792.3	81.23
Multipurpose	1,045	3,108.3	17.06
Fruits and Vegetables	121	38.9	0.21
Meat and fish	464	174.7	0.96
Milk and its products	202	79.1	0.43
Others	91	15.7	0.08
Total	4,541	18,209.0	100.00

Source: *Report of the Working Group on Horticulture, Plantation Crops and Organic Farming for the XI Five Year Plan (2007-12), Planning Commission, Govt. of India.*

Inadequate post harvest infrastructures in the country result in losses of 30% each of fruits and vegetables, valued respectively at Rs 13,600 crores and 14,100 crores (GOI, 2004). Lack of sorting facilities, inappropriate packaging, slow transport systems and inadequate storage facilities add to the deterioration of these perishables. There are 11 grading and packing centers in Himachal Pradesh with an installed capacity of 37,500 tonnes. Jammu and Kashmir has also developed apple grading packing centers in six locations and walnut hulling and drying centers of 500 tonnes capacity each at three places. The Agricultural and Processed Food Products Export Development Authority has recognized 106 pack houses (Maharashtra – 97, Andhra Pradesh – 5, UP – 2, one each in Karnataka and Gujarat) that have facilities of international standards for grading and packing of fruits and vegetables particularly for exports. As on 31 December 2003 (See Inbox) the capacity of cold storage in the country is 18.21 million tonnes (about 10 % of total production).

Lack of Processing Facilities

In 1996, there were more than 4,000 processing units of various capacities in the country. Of these, 70% are in small scale and unorganized sector. Less than 2% of fruits and vegetables in India are being processed. A boost to 10% by 2010 would require an investment of Rs 1,40,000 crores, that would most likely generate direct and indirect employment for 7.7 and 30 million people, respectively. The constraints perceived in the growth of food processing are: cost of processed food is high, unavailability of quality raw material, inadequate infrastructure, high packaging costs, unavailability of timely credit, technological obsolescence, long and fragmented supply chain, taxation on processed foods and processed food quality monitoring & certification problems.

Pesticidal Contamination

Consumption of pesticides in India has increased from 2,353 MT in 1955-56 to 40,672 MT in 2004-05. The consumption of pesticides by vegetables in India is 9%. Major vegetables like tomato, okra, cabbage, brinjal, capsicum, potato and cauliflower showed pesticidal contamination with organochlorines, organophosphates, synthetic pyrethroids and carbamate insecticides during 1988-2000. Among these, 61% samples were found contaminated, with about 11 per cent samples having residues above MRL. During 1998-99, out of the 180 samples of mango, grapes, berries, guava, ber, orange, sapota, pomegranate analyzed for fungicides, gibberellic acid insecticides, 55% were found contaminated with pesticide residues and 6% exceeded their MRL values.

Plant Breeding for Quality

The current focus of plant breeding in India is on higher yield, disease resistance, herbicide resistance, drought and salinity tolerance and to some extent quality. The focus now should be on biochemical qualities such as proteins, vitamins, sugar, dry matter, flavor, alkaloids, flavonoids, etc.

Livestock in Mixed Farming: A Leveraging Asset for Inclusive Rural Development in India

During 1997 to 2003, the total livestock population has decreased by around 14.1%. Among cattle, the population of indigenous breed has decreased by around 7.6% while crossbreed cattle shows an increase of 12.6%. There are only 30 breeds of cattle and 6 breeds of buffalo registered along with the National Bureau of Animal Genetic Resources (NBAGR), Karnal. India's total milk production as on 2004 stands at 97.1 MT (Million Tonnes) which accounts for 14.9 % of the global milk production. Annual growth rate of milk production was 4.11% during 1990-91 to 2000-01. The per capita availability of milk in India is 241 gm/day which is much less than many developed countries like USA (661 gm/day), UK (656 gm/day). The value of consumption of milk and milk products for 30 day period has increased from Rs. 5.29 (1977-78) to Rs 47.60 (2003-04) for rural India. Likewise, the value of meat production from beef has also increased over the years indicating the importance of livestock for rural people.

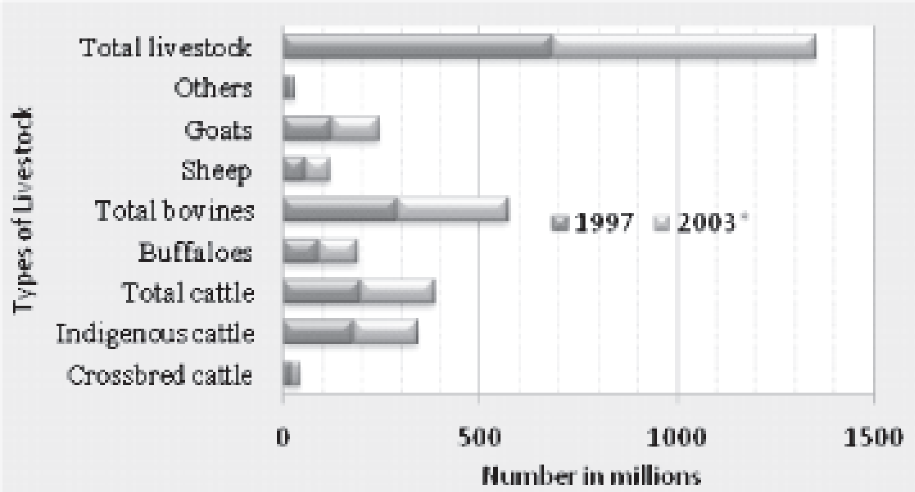


Fig 6-17.01: Change in number of different types of livestock during 1997-2003

Source: *Livestock Census, 2004 and FICCI presentation*

Production of Eggs, Milk and Meat Requirement:

From the graph below, we have an idea of projected meat consumption in 2020. For India the consumption reaches 8 million tons in 2020 (just double from 1993). This rate is almost the same as for the rest of the world. We observed a declining trend of employment in livestock sector from 4.88% in the year 1983 to 3.05% in the year 2000.

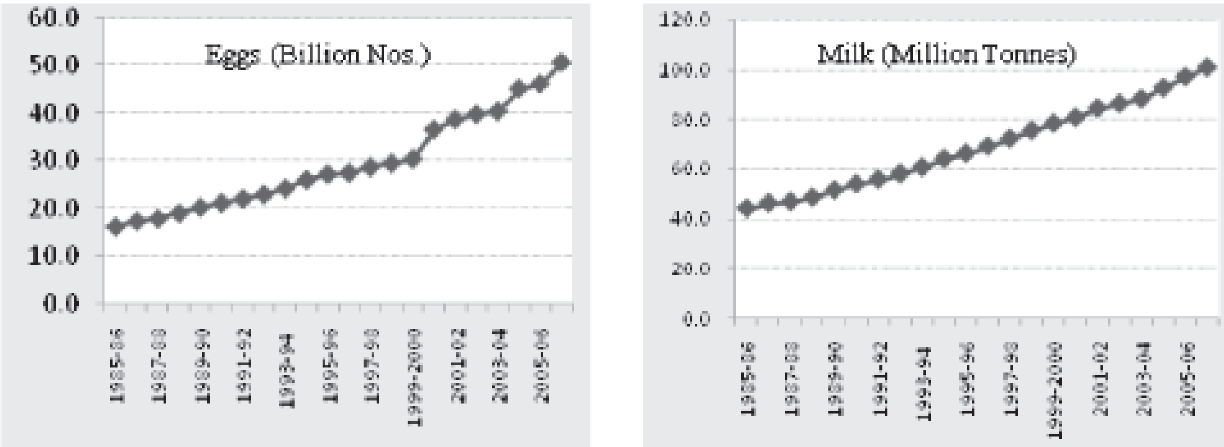


Fig 6-17.02: Milk and Egg production between 1985-86 and 2006-07 in India

Source: *Agricultural Statistics at a Glance 2008, Department of Animal Husbandry& Dairying New Delhi.*

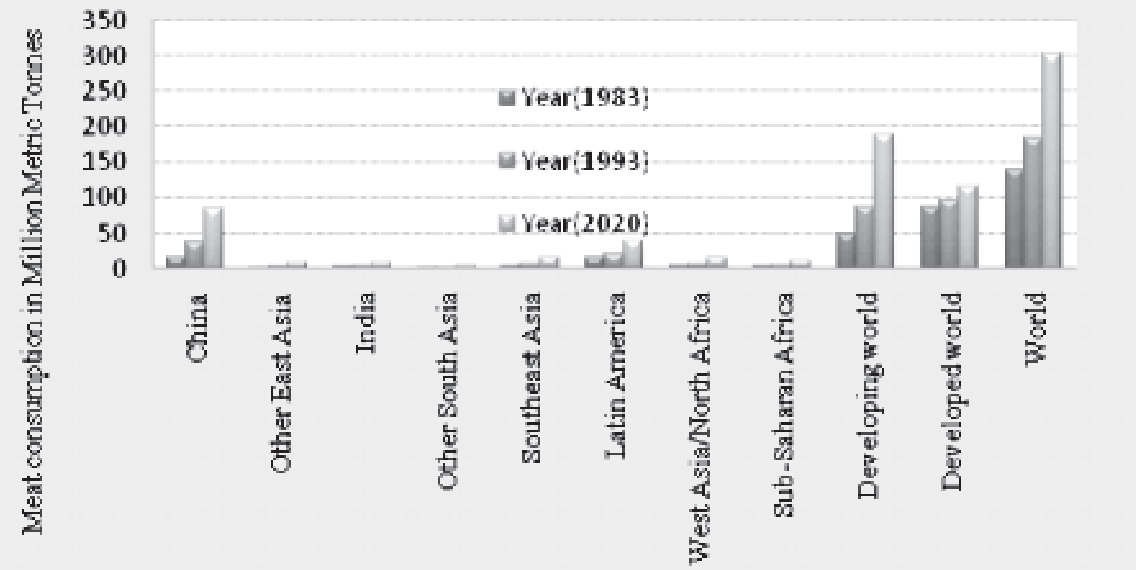


Fig 6-17.03: Total meat consumption and projected consumption in the year 2020

Source: *IFPRI Vision 2020 brief 61*

Status of Livestock Asset according to Land Holding Capacity

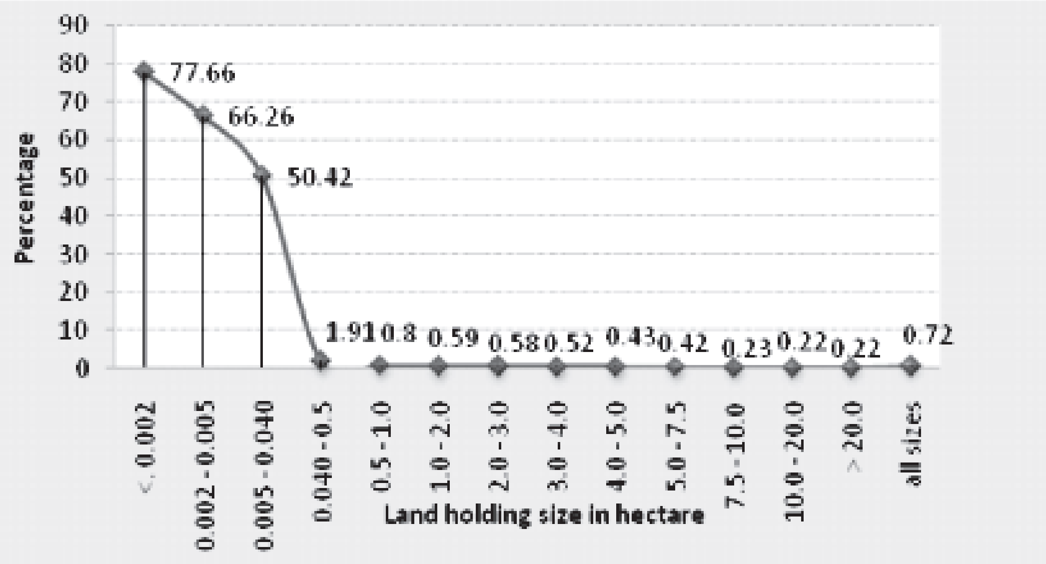


Fig 6-17.04: Percentage of area operated for farming of animal in rural India according to land

Source: *NSS Report No.493 Appendix A, Livestock Ownership, 2002- 03*

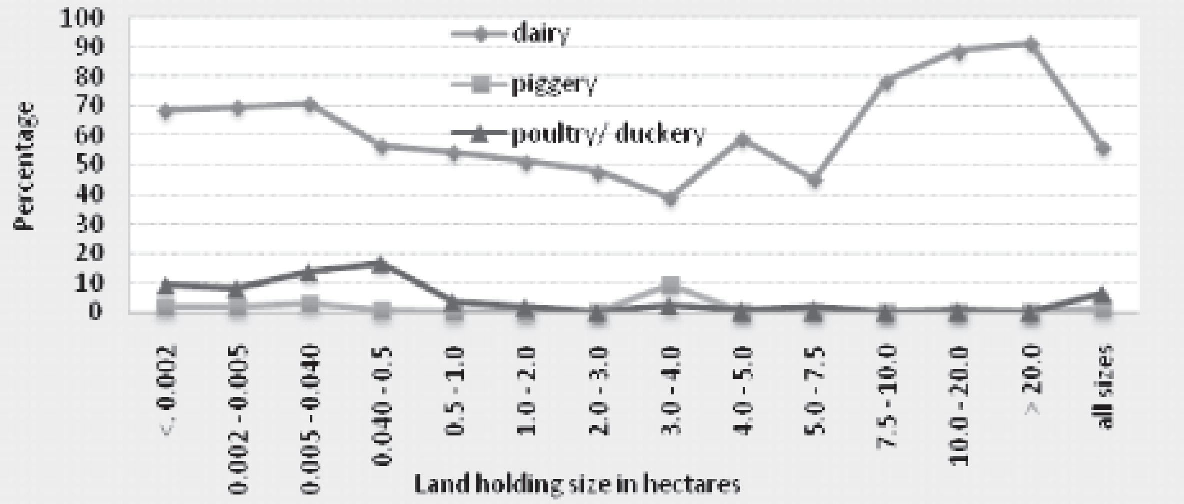


Fig 6-17.05: Percentage of area of animal farming for different livestock in rural India

Source: *NSS Report No.493 Appendix A, Livestock Ownership, 2002- 03*

The above figures show the percentage of area reserved for animal farming. It is clear that rural people still hold maximum land for dairy farming. Surely for the development of rural livestock, there is a great need for S&T based intervention targeted more on dairy related assets.

Livestock Diseases and Clinics

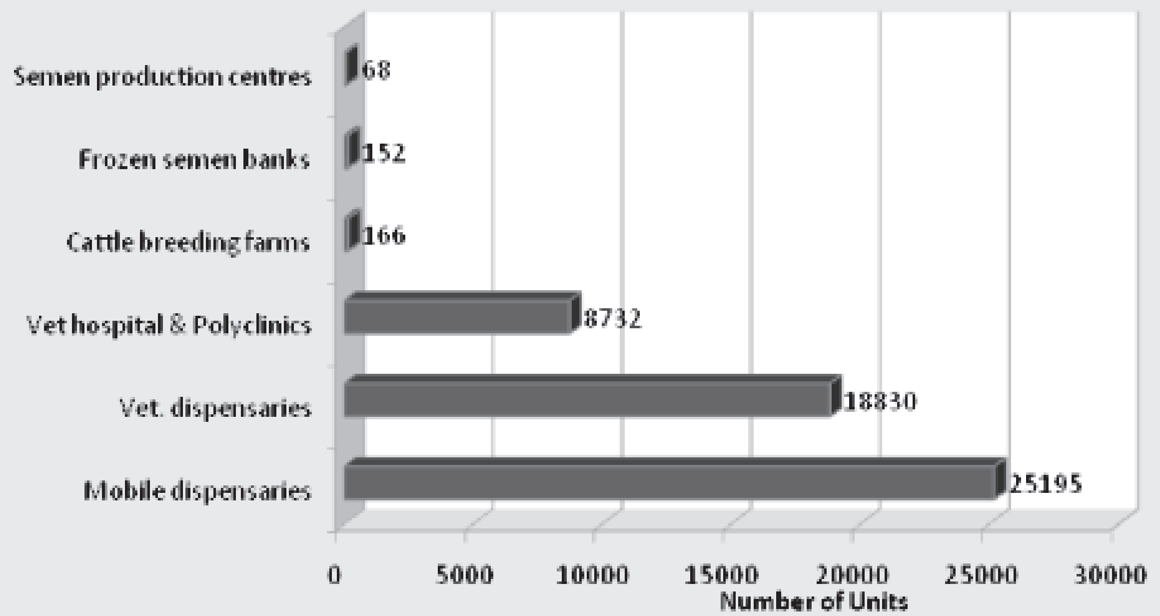


Fig 6-17.06: Types and numbers of livestock treatment facilities in India under the Department of Animal Husbandry and others

Source: *www.dahd.nic.in/stat_files/BAHS2006%20web%20web.pdf*

Total number of buffalo breeding farms under Animal Husbandry Department (AHD) is 26. And the numbers of Gaushalas under AHD is 870 and from other department is 2,215. Diseases are the main problems for the Livestock Health & Disease Control (LH & DC): macro-management scheme called "Livestock Health and Disease Control" is being implemented with an outlay of Rs. 525.00 crores.

Key Points to Focus on

- Livestock in general and cattle and buffalo in particular are important sources of livelihood for rural people. While the available land is unevenly distributed, the livestock resources are equitably distributed is a unique feature for rural India. These resources once managed properly with special emphasis on value addition and integrated market approach can bring change in rural economy. We must be careful about the entry of corporate sector, by ensuring the stake of the small dairy farmers. The AMUL as a model could prove instructive in future, without proper cooperative mode and inclusion of milk producers as Chairman and Board member the effort cannot achieve the success.

- Expansion of veterinary services must be in public sector mode because of low paying capacity of small dairy farmers.

- Downsizing of dairy technology is one of the most sought technological interventions. TIFAC has provided support to Gujrat farmers in downsizing Chilling Plant.

- Milk Marketing is still handled by unorganized sector. This should change with proper introduction of cooperatives to maintain safety standards/quality for milk consumption and also to help small dairy farmers.

- As per MSME Census 2001-02, only 0.15% of the total registered MSMEs are related to dairy products (like manufacturing of ghee, khoa, ice-cream, sweet meats) in rural India. To increase rural employment, we need to emphasize setting up small dairy related processing units.

- More VSAT and Telemedicine centers for quick remedy of livestock diseases in remote villages.

- Multi-skilled veterinary training centers are a unique method to take care of the veterinary problems in rural India' including marketing of veterinary by-products.

- Livestock can also be used as an asset generator as well as the pledgeable in case of emergency.

- Multi skilled veterinary training centers is a unique method to take care of the veterinary problems in rural India including marketing of veterinary by-products.

- Making a national database on dairy byproducts like khoa, ghee, paneer etc produced by unorganized sector of dairy product producer can help to standardize and analyze the products mainly consumed by huge number of middle class people in India.

Sericulture Industry in India – A Review

Sericulture is both an art and a science of raising silkworms for silk production. It is a farm-based, labor intensive and commercially attractive economic activity. At present it exists as cottage and small-scale industry. A brief overview of the present status of the sericulture industry in India, its trends, position in global sericulture as well as science and technological achievements and some critical issues like potentiality of the sector in national economy, rural development, women empowerment and employment generation have been identified to underline the importance of the sector as an instrument of poverty alleviation in India and finally some possible approaches have been suggested for sericulture development in India.

Present Status

India is the second largest producer of raw silk after China and the biggest consumer of raw silk and silk fabrics. Currently, the domestic demand for silk, considering all varieties, is nearly 25,000 MTs, of which only around 18,475 MTs (2006-07) gets produced, the rest being imported mainly from China.

Types of Silk

India is a home to a vast variety of silk secreting fauna which also includes an amazing diversity of silk moths. This includes all the five commercially traded varieties of natural silks namely, Mulberry, Tropical Tasar, Oak Tasar, Eri and Muga. Indian domestic silk market is mainly multivoltine mulberry silk oriented. Variety-wise share of raw silk production during the year 2007-08 has been depicted in Fig 6-18.01.

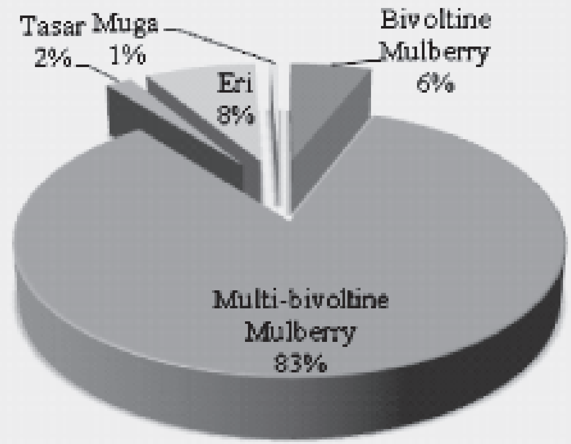


Fig 6-18.01: Variety-wise raw silk production (2007-08)
Source: Indian Silk 47(5), 2008

Science, Technology and Trends

Over the last few decades, Indian silk industry has registered an impressive growth, both horizontally and vertically. The age old multivoltine hybrids have been replaced by multivoltine × bivoltine and bivoltine hybrids with a quantum jump in the raw silk productivity. Average yield of 25 kgs of cocoons / 100 dfls in the recent past, have increased to current range of 60 – 65 kgs / 100 dfls. The new technology, besides doubling yields has also led to qualitative improvements in cocoon production with considerably reduced renditta. Silk statistics of India is presented in Table 6-18.01.

Table 6-18.01: Silk Statistics of India				
Particulars	Unit	Year		
		2004-5	2005-6	2006-7
Production of silk (Total)	MT	16500	17305	18475
Production of silk fabrics	Rs.(Crore)	14620	9812	9240
Silk Imports	Rs.(Crore)	322	780	673
Mulberry acreage	Ha.	1448	179065	191183

Source: DGCIS, Ministry of Commerce, GoI

India has a large domestic market for silk goods and about 85% of silk goods produced are sold in the domestic market. However, India exports approximately 15% of its output of all types of silk goods (including value-added items). The export of silk products has been showing a steady growth and the export earnings showed a rapid increase during the last decade (Fig 6-18.02).

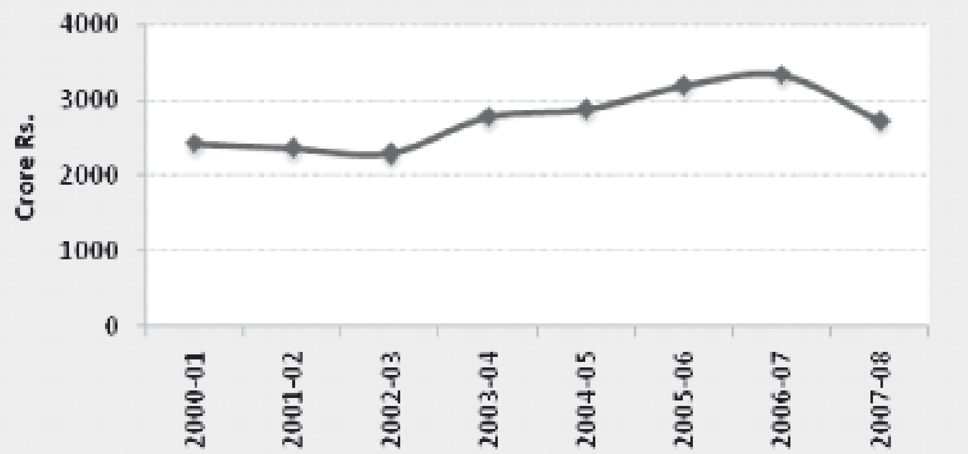


Fig 6-18.02: Year-wise silk export earnings
Source: DGCIS, Ministry of Commerce, GoI

Position in Global Sericulture

Global raw silk production was around 1,25,605 MTs in the year 2005-06, with China as the major player with 81.65% share followed by India with around 14% (Table 6-18.02).

Table 6-18.02: World Raw Silk Production (Unit in MTs)				
Year	Major silk producing countries			Total
	China	India	Brazil	
2000	61,648	15,857	1,389	84,403
2001	64,567	17,351	1,485	90,488
2002	68,600	16,319	1,607	95,858
2003	94,600	15,742	1,563	1,17,042
2004	1,02,560	16,500	1,512	1,25,605

Source: Sericulture and silk statistics, 2008, Silk industry at a glance (2005-06), Central Silk Board, Bangalore and Sericologia, Vol. 44 (3), 2004.

Potentiality of the Sericulture Industry

Seri biodiversity: Among 34 mega biodiversity countries in the world, India is home to many species of insects with a diverse silk moth fauna.

Sericulture and national economy: In India, sericulture related activities ensure the livelihood security of over six million families spread over in some 59,000 villages across the country. The silk sector is also a valuable foreign exchange earner for the country (Rs. 3,338 crores during 2006-07).

Sericulture and women empowerment: Sericulture provides ample opportunities for income for women in the rural areas particularly in silkworm rearing and reeling activities. Involvement of women in different activities of sericulture is about 53% (Table 6-18.03).

Sericulture and rural development: Sericulture being a farm-based enterprise is highly suited both for large and small land holdings, with low capital investment. Largely, the silk goods are purchased by the urban rich and middle-class consumers and it is estimated that around 57 % of the final value of silk fabrics flows back to the primary producers in the rural areas.

Sericulture and employment generation: Raw silk production is the most appropriate tool to provide gainful employment to the poorer sections of the society, as the net income ranges from Rs. 12,000 to 70,000 per annum depending upon the variety of the silk to be produced and the unit area (under host plants). It is estimated that sericulture can generate employment @11 man-days per kg of mulberry raw silk production (in on-farm and off-farm activities) throughout the year (Table 6-18.04).

Table 6-18.03: Involvement of Women

Sl. No.	Activity	No. of districts	No. of villages	Sericulture families	Involvement of women (%)
1.	Silkworm seed production	10	14	082	20.46
2.	Mulberry cultivation	07	14	422	49.55
3.	Silkworm rearing	07	14	422	49.67
4.	Silk reeling	06	13	392	48.81
5.	Silk spinning	02	20	200	80.00
6.	Silk throwing (twisting)	04	06	096	56.34
7.	Silk weaving	06	12	267	49.02
8.	Dyeing – Printing of silk yarn and fabrics	04	06	071	41.00
9.	Silk by-products	01	08	050	65.00
10.	Silk and Milk production	04	15	300	75.00
	Overall	**47**	**107**	**2,002**	**53.45**

Source: *Central Sericultural Research and Training Institute, CSB, Mysore.*

Sericulture and new emerging area (value addition and product diversification): It is imperative that adequate thrust on non-traditional uses of silk could create a positive pressure in the sector to concentrate on high quality raw material for high value addition leading to a quantum leap forward.

The non-traditional areas are:

- Medical application
  - Artificial skin
  - Artificial blood vessels
  - Artificial bone
  - Suture threads
- Cosmetics such as facial masks, dermal lotions, powders etc.
- Liquid silk
- Interior home decor and handicrafts
  - Wall papers
  - Lampshades

Sericulture and higher profit: Several socio-economic studies have affirmed that the benefit-cost ratio in sericulture is highest among comparable agricultural crops (Fig 6-18.03).

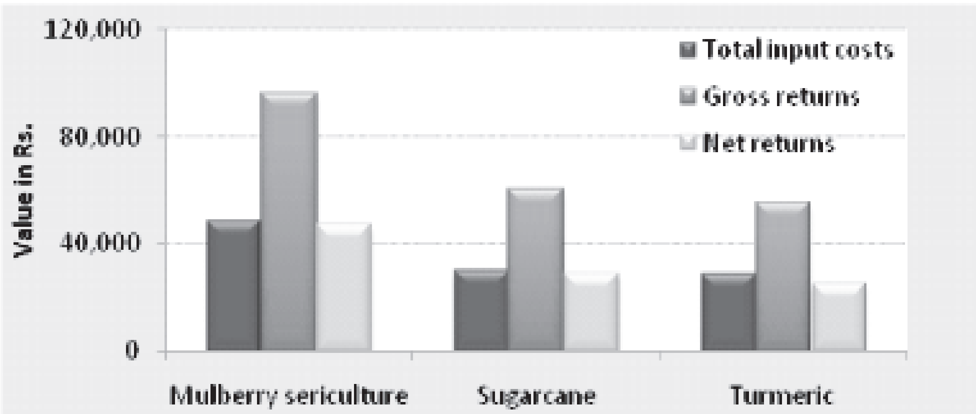


Fig 6-18.03: Sericulture with higher remuneration
***Source**: Dandin et al. (2005)*

Table 6-18.04: Employability in mulberry sericulture/ha

Activity	Employment generation	
	Man-days	Man-years
A. Mulberry cultivation and silkworm rearing	1255	5.020
B. Reeling of silk cocoons		
@ 300 mandays per 1000 kgs of reeling cocoons (@ 8.0 renditta; 760 kgs cocon / ha.; 95 kgs raw silk / ha.)	2250	9.120
Total (A + B)	3535	14.140
C. Twisting		
@ 220 g of silk per mandays	432	1.727
D. Weaving		
Handloom@ 0.13 kg per manday	438	1.752
Powerloom@ 0.3125 kg per manday	122	0.486
Sub-total (Weaving)	560	2.238
E. Printing and Dyeing		
@ 40 mandays for 40 kg of raw silk	95	0.380
F. Finishing		
@ 751 mandays for 40 kf of raw silk	1784	7.135
G. Silk waste processing		
@18.775 mandays per kg of raw silk	26	0.104
Total (C to G)	2896	11.580
Grand Total	**6431**	**26**

Source: *Central Silk Board, Bangalore.*

Summing up

Indian silkworm breeds are multivoltine and though good progress has been achieved in multivoltine × bivoltine silk production, the quality still remains inferior to that of Chinese breeds which are bivoltine. Recently, Central Silk Board has started a testing laboratory for Silk and Zari at Kancheepuram to facilitate customers, producers and other stakeholders for spot non-destructive testing of silk and zari material. More importantly, 'Silk Mark' Scheme has been introduced by Silk Mark Organization of India (SMOI), a registered society, sponsored by Central Silk Board, Ministry of Textiles, Government of India. The Silk Mark is a quality assurance label for the assurance of pure silk and in addition serves as a brand for generic promotion of Pure Silk. The Silk Mark is under the process of registration as a Trade Mark.

Indian sericulture is not only vast, widely dispersed but also multidisciplinary in nature involving silkworm seed sector, cocoon sector (cultivation of food plants and silkworm rearing) and post cocoon sector (silk reeling, spinning, twisting, processing and weaving). Although collaborative research activities promoted and implemented by the Central Silk Board in association with National level R&D Institutions, State Sericulture

Research and Development Institutes, Universities, Department of Science and Technology, Department of Biotechnology, CSIR / ICAR / IARI / IITs / IIMs and other Private and International Research and Development, have resulted in the development of appropriate technologies towards attaining higher quality and productivity levels of Indian silk, there is however a big gap between the domestic demand and supply. In spite of abundant natural resources, socio-economic benefits of the sector like generation of employment for large sections of tribals and marginalized rural men and women, growing export market as well as large domestic demand, a variety of problems have kept Indian sericulture from achieving its true potential. In this context, some possible approaches have been suggested:

- Evolution of appropriate cost-effective technologies through focused research projects addressing constraints and maximizing the production of quality eggs.
- Teaming up of sericulture scientists with molecular biologists, bio-engineers, immunologists, textile technologists, clinicians, experts from industry and a host of other stakeholders in charting out a new road map.
- Adoption of region and season specific approaches in the development of superior breeds / hybrids and feed package of practices.
- Establishment of close linkage between forward and backward sub-systems for greater efficiency and synergy as sericulture and silk industry is highly scattered and unorganized.
- Identification and promotion of potential clusters for Bivoltine and Vanya silk production in potential traditional and non-traditional areas.
- Skill up-gradation through structured and specially designed training programmes.
- Establishment of linkages among the four identified production sub-systems *viz.,* seed, cocoon, yarn and fabric.
- Capacity building for production and supply of adequate quality planting material, silkworm seed, reeling cocoons and silk yarn through promotion of large-scale production units with required techno-financial support.
- Development and promotion of participatory extension system for effective adoption of technologies by similar stakeholders.
- Protection to some extent of Indian silk market from Chinese cheap raw silk and fabrics by implementation of anti-dumping duty.
- Effective utilization of by-products for value addition.

Potential of Bio-pesticides in Indian Agriculture vis-a-vis Rural Development

Pest induced crop loss is on the rise despite increasing usage of pesticides. Fortunately, realization of the negative effects of chemicals (including on humans) shifted the focus to more reliable, sustainable and environment friendly agents of pest control - the Bio-pesticides. In spite of the claimed efficacy, their use, however, has remained very low due to a number of socio-economic, technological and institutional constraints. Nonetheless, rise in income levels coupled with increasing awareness of health related effects of chemicals increased the demand for organic foods. In view of this demand and the government's efforts to mitigate climate change, bio-pesticides are going to play an important role in future pest management programmes. The status of bio-pesticides as well as their future prospects for increasing agricultural production in general and for sustainable rural development in particular is discussed here.

Scope of Bio-pesticides

A pesticide that is of biological origin is known as bio-pesticide. They are highly specific, affecting only the targeted pest or closely related pests and do not harm humans or beneficial organisms, while chemical pesticides are broad spectrum and known to affect non-target beneficial organisms including humans.

The striking feature of bio-pesticides is environment friendliness and easy biodegradability. In terms of production and commercialization also, bio-pesticides have an edge over chemical pesticides because they involve low research expenditure and have faster rates of product development.

Usage of Bio-pesticides

The global weighted average consumption level of bio-pesticides is about 1 kg/ha. With the global organic farming area comprising about 24 million hectares, global bio-pesticide consumption is thus estimated at about 24 million Kg.

Industry Overview

In 2005, bio-pesticides accounted about 2.5% of the total pesticide market, up from merely 0.2% during 2000. This share is expected to grow to about 4.2% by 2010 while the market value is estimated to reach more than US $1 billion (*BCC research*). Orchards claim the largest share (55%) of the total bio-pesticides used. Region wise, North America consumes the largest share (40%) followed by Europe and Oceanic countries accounting for 20% each.

Factors affecting Growth of Bio-pesticides

Some factors which have restricted the growth of bio-pesticides are:

- Low reliability because of low stability

- Target specificity means more work for the farmers
- Slow action compared to synthetics
- Erratic availability of bio-pesticide in the market
- Regulatory system favorable to chemical pesticides
- Declining multiple/mixed cropping.

R & D Status of Bio-pesticides

In terms of research publications, India occupies 2nd position with 443 papers, which accounts for 13.23% of the 3,348 global papers on bio-pesticides. The share of India in bio-pesticide related patents is only 3.55% of the global holdings.

The average annual growth rate of global publication during the specified period is 51.1% while that of India is 37.4%. In terms of patenting, Indian condition appears to be very poor. India has so far secured only 19 patents in bio-pesticides.

Bio-pesticides in India

Bio-pesticides represent only 2.89% (as on 2005) of the overall pesticides market in India and are expected to exhibit an annual growth rate of about 2.3% in the coming years. In India, so far only 12 types of bio-pesticides have been registered under the Insecticide Act, 1968. Neem based pesticides, Bacillus thuringensis, NPV and Trichoderma are the major bio-pesticides produced and used in India.

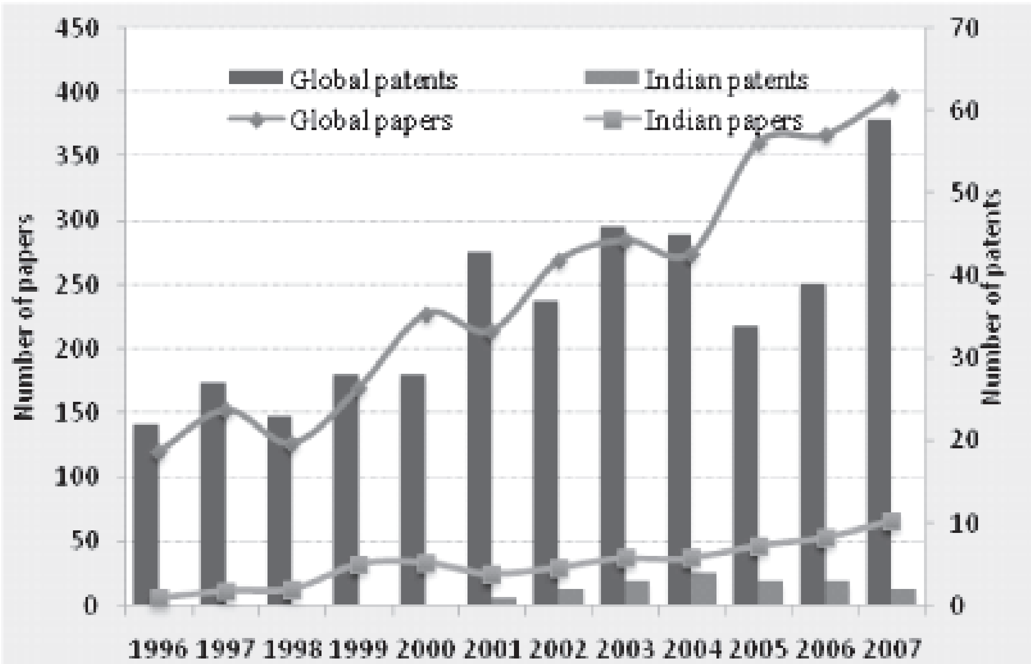


Fig 6-19.01: Trend of bio-pesticide research outputs
Source: Scopus; keyword-biopesticide

Consumption of bio-pesticides has increased from 219 MT in 1996-97 to 683 MT in 2000-01; about 85% of the bio-pesticides used are Neem based products. Consumption of chemical pesticides has significantly fallen from 56,114 MT to 43,584 MT during the same period.

Public Support System

The Indian government is promoting bio-pesticide usage through various rules, regulations, policies and schemes. The Department of Biotechnology (DBT) spearheads the promotion of bio-pesticides, especially research funding and production. The National Centre of Integrated Pest Management (NCIPM) looks after plant protection needs in various agro-climatic zones of the country. Besides, it oversees the setting up and running of State Bio-control Labs (SBCLs). There are around 38 such SBCLs across the country.

The Insecticide Act of 1968 has been amended to simplify the process of registration to allow speedier development and production of bio-pesticide. The National Farmers Policy 2007 has recommended the promotion of bio-pesticides for increasing agricultural production. It also says bio-pesticides would be treated at par with the chemical pesticides in terms of support and promotion.

Bio-pesticides for Rural Development

Desired agricultural growth can be achieved in part through recognition and capitalization of the rich traditional knowledge base of India, especially in bio-pesticides. Successful use of traditional knowledge includes development of commercial pesticides from *Azadirachta*, *Cymbopogon* etc. Hundreds of plants like Mahua, Tagetes, and *Chenopodium* etc await serious attention. The suggestion of National Commission on Farmers to provide incentive/support for promoting the purchase of products developed using indigenous technologies in areas including bio-pesticide appears to be a concrete approach to boost rural livelihood. But, the National Farmers Policy 2007 does not reflect any such interventions. Working out a mechanism to certify traditional bio-pesticides in the line of Public Guarantee System (PGS) of organic products is desirable. This certification system should be integrated with the Panchayat System for administrative control. The research organizations should contribute to the certification process by providing empirical evidences of the traditional practices. Bio-pesticide has the potential to be developed into a rural industry like many other sectors. For instance 'Natural dye' has successfully emerged as a rural household industry in the villages adopted by Gandhigram in Tamil Nadu. Likewise, the production of bio-pesticides can be a decentralized activity under the Ministry of Rural development.

Opportunities

If we consider the global usage of 1 kg of bio-pesticide per hectare of organic farming area, India should be consuming at least 1,00,000 MT of bio-pesticide instead of the present 2,890 MT. This indicates the huge scope for growth of the bio-pesticide sector in India. Due to rising cost of developing new molecules and the incapability of most Indian companies to invest such amounts, there should be greater growth in the bio-pesticide sector. Rich biodiversity of India offers plenty of scope for natural biological control organisms as well as natural plant based pesticides. Rich traditional knowledge base of the diverse indigenous communities may provide valuable clues for developing effective bio-pesticides.

Indigenous Agricultural Systems of Northeast India

Certain indigenous agricultural systems found in Northeast India with their inbuilt sustainability offer tremendous scope for addressing the ecological crisis and quest for sustainability today. They are presented here very briefly.

Rice based farming system of the Apatanis

The economy base of the Apatanis community in the Lower Subansiri district of Arunachal Pradesh comprises of sustainable integration of land, forests, water and farming systems. The farmers grow wet rice, integrated with fish culture in terraces and finger millets on terrace bunds. Common carp (*Cyprinus carpio*), on reaching 200 gm weight in four months time are harvested. The fish feed on phytoplankton and other naturally available microorganisms. Every stream arising from the surrounding hills is tapped and diverted to the terrace fields by a network of water channels. Agricultural wastes such as straw, pig and poultry droppings, rice husks, kitchen waste, ash, weeds are decomposed in the fields. No modern agricultural implements and inputs such as HYVs, fertilizers, pesticides, etc are used. Despite this they have been able to sustain paddy yields of about 5.2 t/ha over the years. Domestic sewage directed to the fields adds organic matter to the soil and also provides feed to the fishes. The hills surrounding the terraces are covered with natural and plantation forests and these are conserved through taboos and strict penalties.

Zabo farming system of the Chakhesangs

The Zabo farming system is an integrated agricultural and forestry land use system found in Kikruma, a Chakhesang tribe inhabited village in Phek district of Nagaland. The word 'Zabo' means impounding of water. It is a viable practice of resource management and maintenance of ecological balance. The system consists of a protected forestland towards the top of the hill, water-harvesting tanks in the middle and cattle yard and wet rice terraces at the lower side. Fish fingerlings are raised in a small pit, dug in the middle of the wet rice terraces of 0.2-0.8 ha in size. From one-hectare field, 3-4 tons of paddy and 50-60 kg of fish are harvested.

Bamboo drip irrigation system of Meghalaya

Bamboo drip irrigation system, practiced mainly in the Jaintia and Khasi Hills of Meghalaya for the last 200 years is a useful irrigation system in a place where there is water scarcity and soils are poor in water holding capacity, the topography is rocky and undulating and irrigation is required for crops that need relatively less water. Water distribution is done with the use of bamboo channels, bamboo supports, water diversion pipes and strips. Betel vines, arecanuts, black pepper are irrigated with this system in which water trickles or drips drop by drop at the base of the crop. This is achieved by having holes at appropriate points on the water distribution channels. Water from the natural stream located at a higher elevation is conveyed to the plantation sites through gravitational flow with the use of bamboo channels. It takes about 15 days for 2 laborers to install the system in a hectare of land. The maintenance cost is minimal.

Alder-based *jhum* system of the Angamis

The alder-based *jhum* system was developed in Khonoma village in Nagaland. It provides about 57 food crops to supplement the staple crop rice. The root nodules of the Alder (*Alnus nepalensis*) plants improve soil fertility by fixing atmospheric nitrogen into the soil. The fallen leaves act as mulches and add humus to soil. The wood is used as fuel-wood, for charcoal burning and in construction. The mature wood is used for making luxury furniture. Alder saplings collected from nursery or wild forest are planted in a *jhum* field located in hills above 1000 m. In the first year in a *jhum* plot, alder trees are pollarded at a height of 2 m from the ground before or after the slash and burn operation. Mixed cropping is repeated in the second year. The field is then left fallow for 2-4 years to allow the alder trees to grow for pollarding and cropping in the subsequent cycle. Initial pollarding is done when young trees with bole circumference of about 50-80 cm are pollarded for the first time, usually at the age of 7-10 years. Cyclical/subsequent pollarding is performed after 4-6 years. During this operation, the pollarded stumps that coppice profusely are allowed to grow till the harvest of the first year's crop. On the second year, 4-5 selected shoots are retained and the rest removed. These shoots are allowed to grow till the next *jhum* cycle and the same process is repeated. Thus with the incorporation of alder trees in their *jhum* lands, the farmers are able to obtain higher productivity while at the same time avoid loss of soil fertility.

Foodgrains: Seed Development & Production

Facts

- Since 1950,increase in land under cultivation 26%
- Foodgrains production has increased four folds from 50.82 million tons to 208 million tons in 2005-06
- Area under certified seeds increased from 500 Ha in 1962 -63 to over 5 lakh Ha in 1999-2000
- The quantum of production of quality seeds has crossed 150 lakh quintals
- Yield/Ha has increased from 522 kg/Ha in 1950 to 1750 Kg/Ha in 2004-05

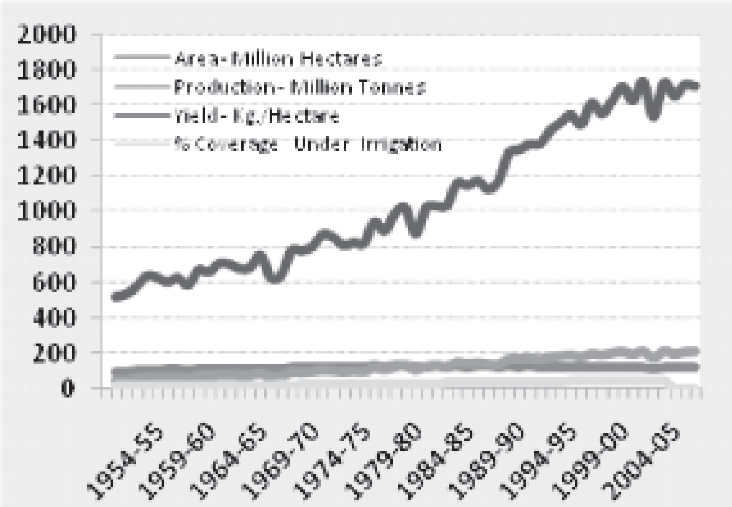
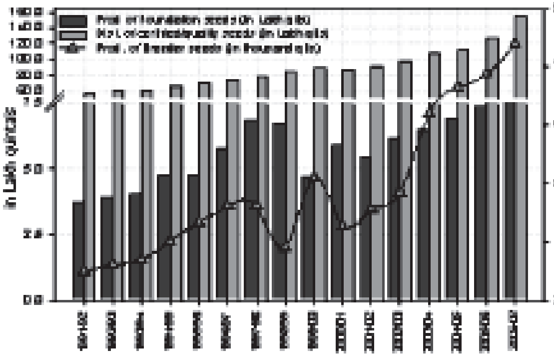


Fig 6-21.01: All India area, production & yield of foodgrains from 1950-51 to 2006-07 alongwith percentage coverage under irrigation
Source: Ministry of Agriculture

India is a labor-abundant and land-scarce country. Agricultural growth therefore largely depends upon raising productivity of the land. The generation and diffusion of new yield improving technologies is therefore critical in sustaining agricultural growth. As varietal development is embedded in seeds, they are therefore primarily responsible for triggering progress in agricultural sector.



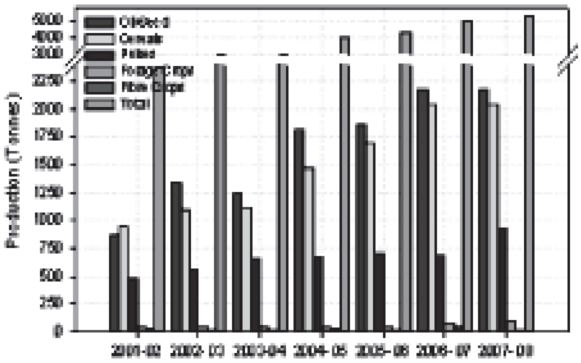


Fig 6-21.02: Total quality seed production by National Agricultural Research System

Source: *Ministry of Agriculture Annual Reports of relevant years*

Fig 6-21.03: Total breeder seed production by ICAR

Source: *ICAR Annual Reports of relevant years*

Variety development is predominantly carried out in the public sector, although in recent years there is some growing private sector involvement. Indian seed program includes the participation of Central and State governments, Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAU) system, public sector, co-operative sector and private sector institutions. Seed sector in India consists of two national level corporations i.e. National Seeds Corporation (NSC) and State Farms Corporation of India (SFCI), 13 State Seed Corporations (SSCs) and about 100 major seed companies. For quality control and certification, there are 22 State Seed Certification Agencies (SSCAs) and 101 State Seed Testing Laboratories (SSTLs). Indian Seeds program largely adheres to the limited generation system for seed multiplication. The system recognizes three generations, namely: breeder, foundation and certified seed, and provides adequate safeguards for quality assurance in the seed multiplication chain to maintain the purity of variety as it flows from the breeders to the farmers.

Table 6-21.01: Number of Notified Seeds of Cereals Produced

Species	1971-1980	1981-1990	1991-2000	2001-07
PADDY	118	203	192	193
WHEAT	64	76	68	73
BARLEY	16	15	18	20

Source: *http://seednet.gov.in/*

The Indian Council of Agricultural Research (ICAR), operating through 30 All India Coordinated Crop Improvement Projects (AICCIPs), five Crop Directorates, and seven National Research Centers; coordinates public sector plant breeding.

Government Initiatives

- The government regulates the seed industry and the seed trade in various respects. The Seed Act of 1966, the Seeds Control Order of 1983, and the Seeds Policy of 1988, PVPFR Act 2001 & Seed policy 2002 are the major components of policy specific to the industry.

Table 6-21.02: Average annual growth rates

Time period	Foodgrains production
Between 1950-51 and 2006-07	average annual growth rate of 2.5 %
Between 1990-2007	decelerated to 1.2 %

- All India Coordinated Research Project (AICRP) on seed called "National Seed Project" initiated in 1979, has 35 breeder seed production centers and 23 seed technology research centers.

- Mega seed project captioned "Seed production in Agricultural Crops and Fisheries" with total outlay of Rs.198.89 crores is the country's biggest seed project under DSR coordination.

- Recent Programmes launched: National Food Security Mission (total outlay of Rs. 4,882.5 crore for XI five year plan) and Rashtriya Krishi Vikas Yojana (Rs.25,000 crore for XI five year plan).

But recently a sharp decline in the rate of growth of foodgrains production (Table 6-21.02) is observed which can be attributed to the slackening in the pace of rapid improvement in the yield levels pointing to the need for some technological interventions. Some suggestions therefore are

R&D Focus

- Developing HYV for abiotic stress areas. The lack of suitable varieties for rain-fed upland and lowland areas, flood prone or cold tolerant varieties is one of the major reasons why some areas are still uncovered by modern varieties.

- Currently crucial aspect is biodiversity conservation, its enhancement and utilization such that indigenous pure-lines are conserved without genetic mixing. Emphasis should therefore be on varietal improvement of traditional wild varieties such that loss of biogenetic wealth is curbed.

Seed Strategy/Long Term Policy Framework

- Focus on improving inter and intra-sectoral linkages. Put together all resources for an outcome oriented research program, especially in the area of using high-yielding varieties of seeds, extension support for facilitating adoption of improved practices, and market access.

- Focus on areas which can be brought under HYV program, such that a paradigm shift can be made from emphasis on technologically saturated areas to the areas untouched.

GM Crops: Potential for Second Green Revolution?

Genetically modified or "GM" crops are being considered as having the potential to bring about second green revolution. India is currently working on 111 transgenic crop varieties of various vegetables, fruits, spices, cereals, bamboo etc. Transgenic crops: brinjal, cabbage, castor, cauliflower, corn, groundnut, okra, potato, rice and tomato are under field trials stage. But it is cotton which was the first GM crop to be extensively worked upon and commercially released in India.

BT cotton in India

- First Bt cotton hybrid "Bollgard" released in 2002
- Total cultivated area-6.2 million Ha
- India's position 5th in Bt cultivation
- Private companies-16
- First indigenous cotton variety- Developed by Central Institute of Cotton Research "Bikaneri Narma"

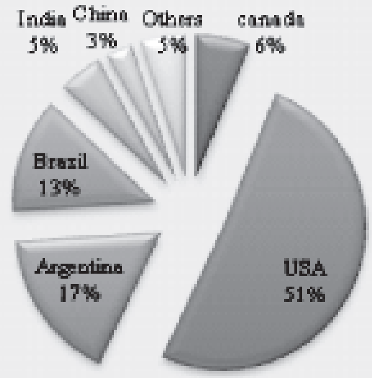


Fig 6-22.01: Global position of countries according to Biotech crop area (year 2007)
Source: http://igmoris.nic.in

Legal Institution

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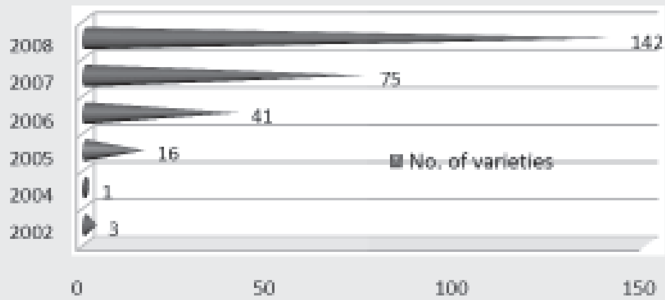

Fig 6-22.02: Number of commercially released varieties of Bt cotton hybrids (for year 2008, data upto July 30)
Source: ISAAA report, 2008

For approval of GMO, Genetic Engineering Approval Committee (GEAC) is the regulatory authority under Ministry of Environment and Forests. DBT brings out manuals of guidelines specifying procedures for regulatory process, activities involving GMOs in research, use and application from environmental safety angle. And the mechanism of implementation of these guidelines is through the Recombinant DNA Advisory Committee (RDAC) and Institutional Bio-Safety Committee (IBSC).

For importing GMO, the permits are issued by the director NBPGR with prior approval from Review Committee on Genetic Manipulation (RCGM). Plant Quarantine (Regulation of Import into India) Order, 2003 regulates the import of GMO.

For a GM seed to be commercially released it has to go under various examinations conducted by IBSC, RCGM, GEAC.

Time clearance to release a crop in India is minimum three years. This includes one year of multi-location trials for generating bio-safety data monitored by RCGM, followed by two years of large-scale field trials under the aegis of GEAC. Along with this, seeds are also provided to ICAR for assessing its agronomic performance for a period of two years. If the reports are satisfactory then GEAC allows the company to proceed with seed multiplication for commercial release.

GM Foods

Processed GM foods are monitored and regulated by the Food Safety and Standards Authority of India, which was established under the new Food Safety and Standards Act, 2006. It is an autonomous body under health ministry.

Implications

It can be seen that area under genetically modified crops has increased substantially resulting in surge in productivity. There is also an established regulatory mechanism regarding GM crops. But with all the systems in place, still there are apprehensions about it.

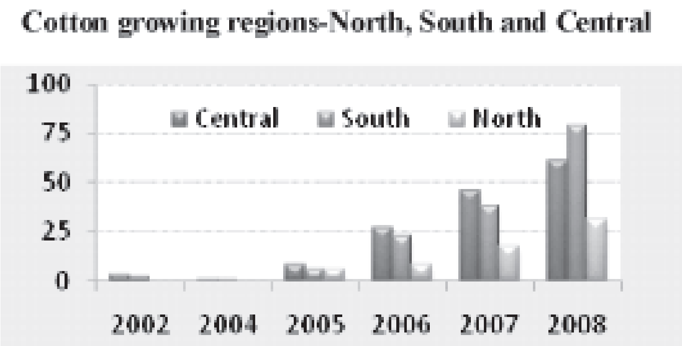

Fig 6-22.03 : Region wise breakup of number of crop varieties released
Source: Cotton statistic and news 2008

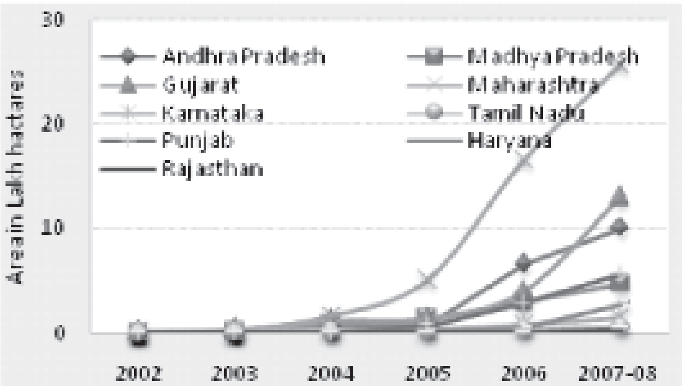

Fig 6-22.04: Area under Bt cotton in Indian states
Source: Cotton statistic and news 2008

It is generally major international and public organizations which are advocating the use of GM seeds. The Non-governmental organizations like Center for Sustainable Agriculture (CSA), Gene Campaign, Navdanya and Bharat Krishak Samaj etc. are voicing their concerns on the dubious reports of these organizations. Even one of the eminent scientists Dr. Pushpa Bhargava who founded Center of Cellular and Molecular Biology and was involved in setting up of DBT is against control of agriculture by multinational companies. According to their grass root and scientific studies/ surveys they found that other than bio-safety and environmental controversies surrounding Bt cotton, the major implication is the economic viability of its cultivation. The cost of Bt cotton seeds being exorbitant for poor Indian farmers (nearly three times more than non-Bt seeds) has resulted in large debts. In parlance to it NGOs point to a worrying rate of suicide among cotton farmers, though no direct correlation has been established as yet. This has gained ire from the public in recent times. Although it is too soon to be sure of overall impacts of Bt cotton but with polarization of opinions between pro–GM government and industry and anti-GM NGO activists, it's a bit difficult to come to any conclusions on the overall efficacy of the technology.

ICT in Agriculture Marketing

"No country will reap the benefits of the network age by waiting for them to fall out of the sky. Today's technological transformations hinge on each country's ability to unleash the creativity of its people, enabling them to understand and master technology, to innovate and to adapt technology to their own needs and opportunities."

The Human Development Report, 2001

The Indian Agricultural Scenario

India with 127 different agro climatic zones, immense biodiversity and natural resources is one of the biggest food grain and oilseed producers in the world. Small farms produce 41 % of India's total grain (49% of rice, 40% of wheat, 29% of coarse cereals and 27% of pulses, and half of its fruits and vegetables) India's economic growth significantly depends on the health of the agriculture sector which provides employment to 62.5 % of the work force and contributes 18 % to GDP, earning 14.7 % export revenue. Like agriculture, the subject of agricultural marketing is in the concurrent list of the Indian Constitution and is gaining importance. Agricultural Marketing in India with the help of ICTs is undergoing a significant metamorphosis and considerable opportunities have opened up. The Vision 2020 document of the Department of Agriculture and Co-operation acts as catalyst towards the development of "Agriculture Online". The various digital initiatives undertaken by the Government are Agrisnet, Agris, Agmarknet, Dacnet, Vistarnet, Aphnet, Fishnet, Hortnet, Seednet, Ppin, Coopnet, Fertnet, Arisnet, Afpinet, Arinet, Ndmnet etc. with their independent websites.

Regional Initiatives/Projects: AgriWatch; Krishi Vigyan Kendra's; MSSRF's "Mission 2007" (Village Knowledge Centers); e-choupals; Hariyali Kisan Bazaar N. Delhi; Tata Kisan Kendra U. P., Haryana and Punjab; Krishi Vipanan M.P.; Grasso PCO Project and Krishi Marata Vahini Karnataka; Kissan Kerala and e-Krishi Kerala; NCDEX, MCX, Akashganga Gujarat; aAQUA Pune, Mahindra Kisan and Krishiworld Maharashtra; Safal National Exchange of India Limited (SNX), Asha, Assam etc.

Major Recommendations

- As we know the future lies in rural computing, our rural ICT policies must be tailored according to our requirements, integrated websites should be set up for all agencies of both State and Central governments like APEDA, APMC, CWC, SWCs, CACP, CCI, DMI, FCI, JCI, KVKs, MPEDA, NAFED, TRIFED, NCDC, NDDB, NHB, SAMBs.

A Few Important Models, Initiatives, Projects of the Agricultural Marketing Information Network

Area/state	Agency/ Project	Activity Description	Reference Information
India	AGMARK NET	Launched, in March 2000, linking important agricultural produce markets, the State Agriculture Marketing Boards and Directorates. It provides information on agriculture products, their prices, arrivals, availability, trends, analysis, laws, etc. Currently, AGMARKNET covers 2,900 markets all over the country and displays information of 400 commodities on a daily basis in ten languages, linking all important APMCs in India. Marketing Channel --- PPP initiative Public-Partner- Participation concept	*http://agmarknet.nic.in*
Directorate of Marketing & Inspection	DMI	It maintains a close liaison between the Central and State governments in the implementation of agricultural marketing policies in the country to safeguard the interests of producer-sellers as well as the consumers.	*http://agmarknet.nic.in /dmiwelcome.htm*
State Agricultural Marketing Boards	SAMB	Aid sustainable development of agriculture that improves the quality of life of the rural population. Identify location of markets for connectivity under the Directorates of Marketing Scheme based on importance of the market in commodity flow patterns.	*http://agricoop.nic.in/s tateagri.htm*
Agricultural Produce Market Committees	APMC	Ensure reasonable gain to the farmers by creating environment in markets for fair play of supply and demand forces. Provide site for installation of Agmarknet node comprising of Market Committees) spread all over the country.	*www.dgmarketindia.com*
India	Kisan Call Centre	The Department of Agriculture & Cooperation (DAC), Ministry of Agriculture, Govt. of India launched Kisan Call Centers in 2004 in every state to deliver extension services and marketing information	*http://agricoop.nic.in/ policy Incentives/ kisan Callfirst.htm*

- Academic and research data in agriculture marketing needs to be digitalized in local languages.
- India needs to develop a structured nationwide common spot exchange.

- Introduce electronic scientific grading of agricultural commodities in the markets.
- Tele-density in rural areas continues to be low. Increase in tele-density, as component of infrastructure development should be taken up.
- Greater synergy between extension services and market is required.
- Strengthening of Agriculture Business Processes through e-Form, e-Document, Workflow Computing should also be given importance.
- The involvement of a local partner in the delivery of the services will be significant for a disciplined market.

Mechanism of Developing and Fixing Food Standards

The food industry in India is undergoing a radical change. The advent of technology in the food sector in the form of processing techniques has infused a new vigor; it has led to an increase in shelf life of products, new fortified products and storage solutions etc. Due to these technological interventions, processed food is now available from the place of production to far reaches, that too not only within the country but also across international boundaries. To ensure that products that are produced for consumers are safe and of high quality, food safety has become a growing concern across the world. Food standards are expected to acquire greater importance, given growing consumer demand for products which are healthy and due to increasing concerns about the quality of food.

Developing food standards:

The central government has constituted a committee called the Central Committee for Food Standards (CCFS) to advise it on matters related to standards. The standards setting body "BIS" is the main formulating body of Indian standards in line with national domestic requirements. It sets voluntary standards to indicate the quality of the product by the use of ISI mark. While DMI formulates grade standards known as "AGMARK" with relevant quality definitions and grade designation marks. Internationally, the "Codex Alimentarius Commission (Codex)" is the international food standards setting body under FAO and WHO, jointly. The Codex follows the food standards programme recognized by the World Trade Agreements on Sanitary

In India

- Central Committee for food Standards (CCFS)
- Bureau of Indian Standards (BIS)
- Directorate of Marketing and Inspection (D.M.I.)

International body

Codex Alimentarius

and Phytosanitary (SPS) and Technical Barriers to Trade (TBT), which is basically the reference point for food standards applied in international trade.

Regulatory Bodies

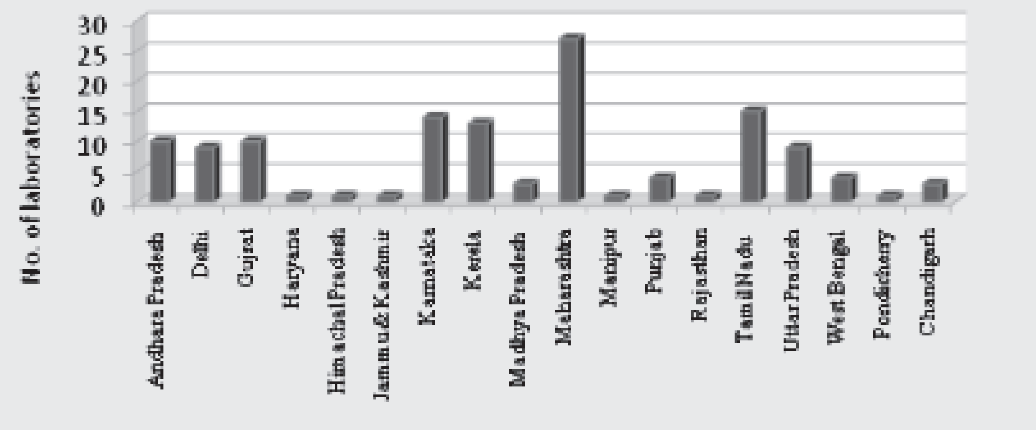

Fig 6-24.01 : State-wise distribution of food testing lab oratories (127labs)
Source: *Ministry of Food processing industry*

- Codex India
- Quality Council of India (QCI)
- Export Inspection Council of India (EIC)

Codex India: The Directorate General of Health Services, Ministry of Health and Family Welfare has been designated as the nodal ministry (National Codex Contact Point, NCCP) for liaison with the Codex Alimentarius Commission and to coordinate with the other concerned government departments at central and state levels, food industry, consumers, traders, R&D institutions and its shadow committees.

QCI: a non-profit autonomous body, coordinates, guides and implements a national quality initiative through its five bodies namely National Accreditation Board for Certification Bodies (NABCB), National Accreditation Board for Education and Training (NABET), National Accreditation Board for Testing and Calibration Laboratories (NABL), National Accreditation Board for Hospitals & Healthcare Providers (NABH) & National Board for Quality Promotion (NBQP)
EIC: An apex body under Ministry of Commerce to provide for sound development of export trade through quality control and pre-shipment inspection.

Food Safety Certification

The various food certification schemes running in India are:

- BIS Quality Management Systems Certification Scheme (QMSCS)
- HACCP (Hazard Analysis Critical Control Points)
- ISO 22000
- International Food Standard (IFS)

QMSCS: as per IS/ISO 9001 was launched in September 1991 under the provisions of the Bureau of Indian Standards Act, 1986. The Scheme is being operated in accordance with ISO/ IEC Guide 62.

HACCP : a process control system that identifies and prevents microbial, chemical and other hazards in food. BIS offers two Certification schemes to the food industry.

- HACCP Stand-alone Certification against IS 15000:1998
- HACCP based Quality System Certification provides for two Certifications: one, Audit Certification of Quality System against IS/ISO 9000 and the other Certification of HACCP against IS 15000:1998

Food Testing Infrastructure

According to a pilot study conducted by Ministry of Food Processing Industries, based on test capabilities, equipments and infrastructure 312 laboratories from all over India were identified. Of the 312 laboratories identified for the study only 127 labs replied to their questionnaire. The 127 labs were then categorized into 4 tiers namely National level (5 labs), Regional level (6 labs), State level (34 labs) and Local level (71 labs).

Suggestions

Lab accreditation through: NABL, APEDA, EIC, BIS

Human Skill development: CFTRI, IFTTC, IGNOU, ICAR, Industrial Associations (CII, FICCI)

- The protocols to be developed for standardization of food articles should keep in mind the actual users of these standards, the environment, the culture and the present infrastructure of the country where they are to be implemented.
- Knowledge of the changing scenario of food standards and their rigid requirements, typically, does not reach rural India timely. Public knowledge of food standards is therefore quite limited and only few farmers are aware of the procedures. So focus should be on assisting farmers to meet these standards.
- Ensure implementation of good hygiene and good management practices from farm to product level.
- Take a leading role in developing food standards and support other countries in developing standards similar to ours.

Towards Agricultural Innovation Policy

Continuing focus on household food and nutrition security, decelerating growth in total and partial factor productivity, unsustainable land and water use practices, economic and ecological access to food, especially for the poor: are some of the agricultural development challenges. In order to address these challenges with an emphasis on inclusiveness of the rural poor in the development process, the role of agricultural science and technology assumes greater significance. This is primarily because of limited scope for cultivation area expansion to produce more and also our reaching a stage where further exploitation of natural resources would compromise sustainability of agricultural production systems. Therefore, Indian agriculture will have to shift from resource or input-based growth to knowledge or science-based growth and development. In this context, efficiency of agricultural science and technology systems should be enhanced to promote technological innovations.

Agricultural Research System

In India, concept of agricultural research is moving from supply driven to demand driven kind of interventions. This paradigm shift entails a move from a process concept to some kind of output and outcomes. In this context, the actors, creation and application of new knowledge, institutional innovations and policy issues have become equally important. In India, there is an organised agricultural research system i.e., basically a three-tier system. At the centre there is a network of organizations under the Indian Council of Agricultural Research (ICAR). At state level there are the state agricultural universities (SAUs), and at the zonal level (covering a couple of districts) there are zonal research stations controlled by SAUs (Fig 6-25.01). So this is a very strong mechanism, establishing linkages between ICAR institutes, SAUs and private sector, for profit as well as non-profit activities. These strong inter-institutional linkages of the Indian Agricultural Research System link all the research institutions with farmers and development agencies.

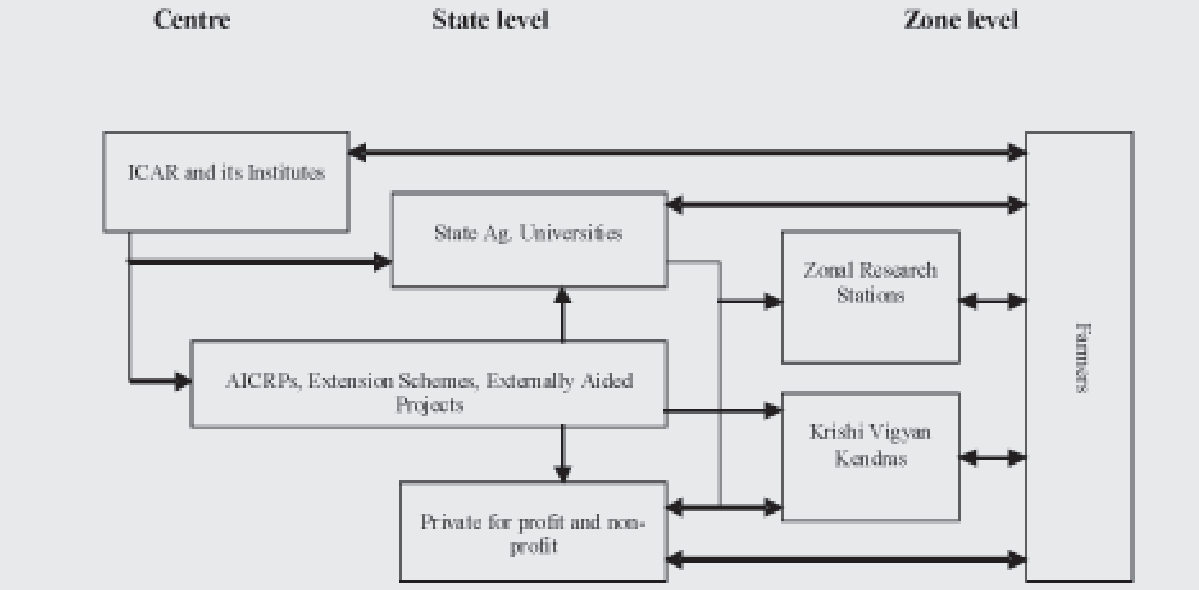

Fig 6-25.01: Organization and linkages of Indian agricultural research system

Source: *Pal & Byerlee (2006)*

Public funding is one of the major policy instruments for promoting technological innovations and human resource development. There has been a consistent upward trend in public funding for agricultural research and education. This is shown in Fig 6-25.02. However, composition of the public funding from the centre and state governments has changed over the years. Agricultural funding and expenditure by centre and states systems are given in Table 6-25.01. This is significant in terms of increasing overall effectiveness of the system through

Table 6-25.01: Centre and States in Agricultural Funding, 2000

	Funding Sources (%)	R & E performers (%)
Centre	46.6	36.8
State	42.6	51.9
Corporate	10.8	11.3

Source: *Ministry of Finance, GoI* commercialization and transfer of improved technologies and thereby making research demand-driven, which is a necessary condition for improving the capacity for agricultural innovations.

Committed fund for inter-institutional programmes is one instrument of developing the linkages and partnership within the system. Now when we focus on the knowledge creation, which is one component of the innovation system, what are the implications for agriculture R&D? First comes the question of resources. If we compare how much India is investing in agriculture R&D, we see that it is 0.5% of agricultural GDP, which is much below that spent by other developing and developed countries (Pal and Byerlee, 2006). So we need to increase it, gradually, to at least one percent of Ag GDP and then rationalize the allocation by regions and commodities. Eastern India still suffers from under-investment; additional resources should be invested there.

Capacity for Innovation: Role of Policy and Institutions

Another important issue is the increasing interaction between public policy, institutions and technology/knowledge. There is a need to align policies and institutions to facilitate the flow of knowledge and technology to the end users. Governance and management reforms now focus on participatory governance of technology systems so that we are able to bring the system close to the end-users, and research planning orientation has now shifted to outcomes rather than outlays. The new IPR policy of ICAR has emphasized on this, through commercialization of technology and incentives provided to the scientists. Mechanisms for partnerships like funding and intellectual property management provide incentive to work together and share the credit among the partners.

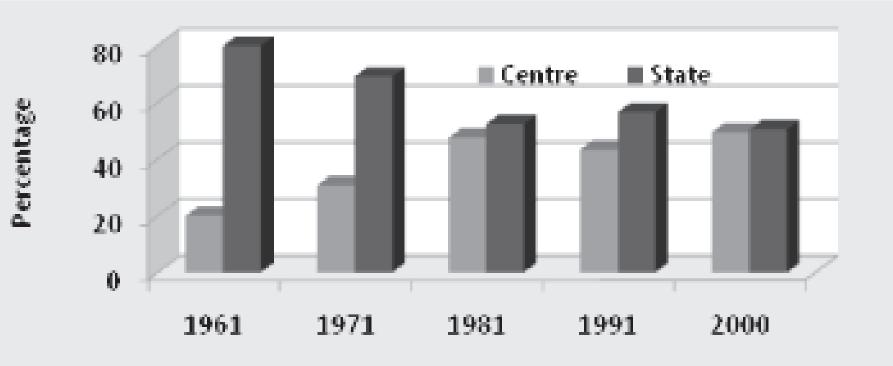

Fig 6-25.02: Share (%) of the central and state governments in funding for agricultural research & education

There is a need to empower the farmers through provision of information and skills, so that they are able to articulate their demand and respond to emerging opportunities through innovations. This can be achieved only when we bring the extension system close to farmers and understand their behavior in sharing and application of knowledge and technologies. Once this is done, farmers will be able to see where the opportunities are and where they can use their resources, knowledge and skills to tap these opportunities. Therefore there should be systematic efforts by public agencies, governments, and other agencies to develop this capacity among the farmers. There have to be some kind of local knowledge centers or interest groups so that they are able to integrate the knowledge available, pass it on to the farmers to make them understand and apply it. So this is very important as seen in case of Bt cotton.

Inference

Agricultural innovations system necessitates adequate investment in R&D for accelerating flow of technologies and knowledge to end-users. This should be supported with facilitating policies and enabling institutions. One should understand this policy-institution and technology interface and take appropriate corrective measures to promote innovations. Finally, efforts should be made to understand behavior of farmers in terms of access, application, and sharing of information, so that appropriate steps are taken to develop their capacity through provision of information and skill development, which are necessary for enhancing rate of innovations in Indian agriculture.

The country is entering the age of knowledge when increasing returns would be ubiquitous. The democratic governance structures of this country have evolved, over the course of six decades, sets of complex institutions systems and practices that bind or otherwise relate S&T to the other spheres. With about four thousand research and development organizations, large organized systems of knowledge production, millions of knowledge-workers and an even larger number of citizens trying to engage in knowledge-based activities ranging from agriculture through semi-skilled workers to industrial workers, coupled with the fact of the country being especially gifted with immense diversity in natural resources -- the opportunity set of potential outcomes are immense and invigorating.

The long twentieth century in Indian S&T based developmental experiments, in particular at grass roots, has thrown up immense volumes of data, facts and artifacts. A crucial issue emerges. The country very badly needs a strong mechanism to capture data related to S&T and innovation right from the regulatory or executive levels to source-points where S&T output or innovations get generated.

This Report presents several facets of Indian S&T. In lieu of attempting the development of a set of traditionally known indicators of S&T, the attempt here has been to capture multiple facets of Indian economy and society where S&T makes contributions. With unstated theoretical bases, contributors presented research conclusions in the form of several portrayals. Given the fact that S&T interfacing the economy and society has very large dimensions this Report could take up only a handful. Such a collage offers albeit a picture of where Indian S&T is located.

This printed version is about one fourth of the full Report, available at *http://www.nistads.res*.in The report is the first of its kind from this country. It is targeted at a wide readership ranging from policy makers and advisors to academic readers as well as the common person. Following six themes, with regard to S&T have been taken up in the report:

- Human Resources
- Financing
- Structure, Infrastructure and Public Space
- Industry
- Output and Patents
- Rural India and Inclusive Growth