ACADEMIA–INDUSTRY INTERFACE IN TECHNOLOGY COMMERCIALISATION - A CASE OF INDIAN INSTITUTE OF TECHNOLOGY, DELHI

DISSERTATION SUBMITTED TO
THE JAWAHARLAL NEHRU UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF PHILOSOPHY

NIMESH CHANDRA

Centre for Studies in Science Policy
School of Social Sciences
Jawaharlal Nehru University
New Delhi -110067
India

JULY 2003

Centre for Studies in Science Policy
School of Social Sciences
Jawaharlal Nehru University
New Delhi - 110067

Date: July 19, 2003

Certificate

This is to certify that the dissertation entitled **"Academia-Industry Interface in Technology Commercialisation - A Case Study of Indian Institute of Technology, Delhi"** submitted by **Nimesh Chandra** in partial fulfilment of the requirements for the award of the degree of **Master of Philosophy** of this University is an original work according to the best of our knowledge and may be placed before the examiners for evaluation.

31.7.03

Prof. V.V. Krishna

(Chairperson)

CHAIRPERSON
Centre for Studies in Science Policy
School of Social Sciences-I
Jawaharlal Nehru University
New Delhi-110067

Dr. K.J. Joseph

(Supervisor)

Centre for Studies in Science Policy
School of Social Sciences-I
Jawaharlal Nehru University
New Delhi

DEDICATED TO MY PARENTS

ACKNOWLEDGEMENT

The work with this dissertation has been extensive and trying, but in the first place exciting, instructive, and enjoyable. Without the help, support, and encouragement from several persons, I would never have been able to finish this work.

First of all, I would like to thank my supervisor Dr. K J Joseph, for his inspiring and encouraging way to guide me to a deeper understanding of knowledge work, and his invaluable comments during the whole work with this dissertation. He has been more than co-operative especially during the final stages of this dissertation.

I wish to thank all the faculty members at CSSP including the Chairperson Dr. V V Krishna and Dr P N Desai, who have been helping me with important suggestions on the topic and otherwise. The unselfish effort of my faculty, Prof. Nasir Tyabji, in evaluating the contents of this dissertation is highly acknowledged. His constructive comments, invaluable suggestions and patience to listen to my observations have significantly improved the contents of this dissertation. The insights provided for the selection of topic by Professor Ashok Parthasarathi is also highly acknowledged. I would not have chosen to do a study on technology commercialisation mechanisms focusing on the Indian Institutes of Technology had he not suggested the same.

I would like to thank Dr A K Sengupta, Managing Director, FITT, IIT Delhi and his entire team especially Mr K K Roy, Mr Mohit Mahajan, Mr N K S Prasad, Mr. Partho, Mrs Nagachoudhary Mr Jagdev and Ms Seema Lamba for taking out their precious time for my never ending queries. This work would not have been possible without their help and support.

I would also like to acknowledge all the CEOs, Directors, management and other important personnel in different firms, where I got much encouragement and support for my work.

I wish to extent my gratitude to these very special people:

To my wonderful friends, Vinod, Chandan, Ravinder, Rakesh, Manish, Piyush, Mukesh, Abhishek, Manik, Rati and Tuhin for being there to tap my shoulders whenever I felt down towards my work; to my special friends Seetha, Sangeeta, Rini, Arpita, Biswanath, Ashutosh and Jean-Luc for sharing their opinion on the progress of my work; to my ex-boss Mr. Shashanka Bhattacharya who has been an ever inspiring individual for me; to my relations, Shashank, Ashish, Dr. Rajesh Bhatnagar, Archana, Jayati, Smita, Rajkumar, Pranay and Puneet who serve as an inspiration for me to move on against all odds on my way; to my friends at Lucknow, and Ranchi, especially Sameer, Prashant, Shivaji, Dr. Violet and Lovely, who unselfishly cared for my mother while I was away for my studies; to my mother, my Grandmother, my sisters Tulika, Anshu and Nilika, my brother Amit Prakash, Shashi Verma and the rest of my family for their unselfish commitment toward my desire to finish my M. Phil. degree. Thanks also to all my colleagues, seniors and juniors at the Centre for Studies in Science Policy for providing a good working atmosphere, especially to Mrs Shyamala Krishnamurthy at the documentation unit and to Meena Madam, Mr. Khanna, Tawarjee, and Murugesan in the CSSP Office.

My work progressed in a quiet yet happening place and I must thank the JNU ambience, the lively discussions with friends and faculty at Ganga Dhaba, the thought inducing Library reference hall, the invigorating SSS-I canteen's victuals and the long and calm connecting pathways in JNU.

At last, I wish not to thank Mahesh, Pritpal, Sanjay, and Amiya since thanking them would definitely blemish the wonderful relationship we share.

There are others whose names have not been mentioned above yet they have contributed to this work in their own way. I thank them all for supporting me with love and understanding and also for all interesting and endless discussions concerning the work.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AM	APPLIED MECHANICS
CARE	CENTRE FOR APPLIED RESEARCH IN ELECTRONICS
CAS	CENTRE FOR ATMOSPHERIC SCIENCE
CBME	CENTRE FOR BIOMEDICAL AND ENGINEERING
CCS	CENTRE FOR COMPUTER SERVICES
CE	CIVIL ENGINEERING
CEO	CHIEF EXECUTIVE OFFICER
CES	CENTRE FOR ENERGY STUDIES
CET	CENTRE FOR EDUCATION TRAINING SERVICES
CHE	CHEMICAL ENGINEERING
CHY	CHEMISTRY
CPSE	CENTRE FOR POLYMER SCIENCE AND ENGINEERING
CRO	CONTRACT RESEARCH ORGANIZATION
CSE	COMPUTER SCIENCE AND ENGINEERING
DBEB	DEPARTMENT OF BIOENGINEERING AND BIOTECHNOLOGY
DMS	DEPARTMENT OF MANAGEMENT STUDIES
DSIR	DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
DST	DEPARTMENT OF SCIENCE AND TECHNOLOGY
EE	ELECTRICAL ENGINEERING
FICCI	FEDERATION OF INDIAN CHAMBER OF COMMERCE AND INDUSTRY
FITT	FOUNDATION FOR INNOVATION AND TECHNOLOGY TRANSFER
GATE	GRADUATE APTITUDE TEST IN ENGINEERING
HSS	HUMANITIES AND SOCIAL SCIENCES
ICICI	INDUSTRIAL CREDIT AND INVESTMENT CORPORATION OF INDIA
IDDC	INSTRUMENT DESIGN AND DEVELOPMENT
IIPA	INDIAN INSTITUTE OF PUBLIC ADMINISTRATION
IPR	INTELLECTUAL PROPERTY RIGHTS
ITMMEC	INDUSTRIAL TRIBOLOGY MACHINE DYNAMICS AND MAINTENANCE ENGINEERING
JEE	JOINT ENTRANCE EXAMINATION
KDM	KEY DECISION MAKERS
LCD	LIQUID CRYSTAL DISPLAY
LED	LIGHT EMITTING DIODE
MA	MATHEMATICS
ME	MECHANICAL ENGINEERING
MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NIFM	NATIONAL INSTITUTE OF FINANCIAL MANAGEMENT
NISTADS	NATIONAL INSTITUTE OF SCIENCE TECHNOLOGY AND DEVELOPMENT STUDIES
OECD	ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
PHY	PHYSICS
RDAT	RURAL DEVELOPMENT AND TRAINING
SPRU	SCIENCE POLICY RESEARCH UNIT
TBIU	TECHNOLOGY BUSINESS INCUBATION UNIT
TT	TEXTILE TECHNOLOGY
TTO	TECHNOLOGY TRANSFER OFFICE
UNESCO	UNITED NATION EDUCATION AND SCIENTIFIC CULTURAL ORGANIZATION
UNISPA	UNIVERSITY INDUSTRY SCIENCE PARTNERSHIP

LIST OF TABLES AND CHARTS

List of Tables

List of Charts

1.0 Introduction

In today's world, power is measured in terms of economic and technological capabilities. In the era of globalisation, the concern for industry in India is to build technological capabilities such that it is able to sustain and compete by being efficient, dynamic and innovative, in a highly competitive world. In these changing times, the research and development (R&D) scenario shows that the world has reached a profound stage for discovering the seeds of novel and breakthrough technologies as also for possessing remarkable 'knowledge base'. It is indeed essential for the future development of Indian industry that we gain these novel and breakthrough technologies and 'knowledge base' that will not only bring industry to a sophisticated level but would help a developing country like India to be highly competitive in the global market. For our concern, the novel technologies are the technological innovations that play a crucial role in a nation's economy.

With the ongoing economic reforms especially in the era of globalisation, liberalisation and privatisation, there has been a major shift in the economic environment confronted by firms, academic institutes and public research laboratories. Import substitution is being replaced by export promotion and globalisation, protection is getting replaced with competition, and controls are giving way to liberalisation. The role of the government in providing support is increasingly being withdrawn in all areas, especially in the social sector activities including higher education and research. Thus in the coming years the academic system will have to increasingly depend on industry, for not only in financing its research projects and programmes but also in pursuing its academic activities. The firms too in different industries are increasingly realising the fact that given the limited resources and with the opening of economy, it will be extremely difficult for them to compete in the domestic market, let alone globally, making use of the technologies purchased mainly from transnational companies, when those very foreign companies befall as competitors in both the markets. Since the early 70's, there have been an increasing number of technological co-operative agreements because it has been so difficult for firms to develop all the technologies that they need (Fernandez, 1991). Thus, the firms also are being compelled to look towards academia for new sources of knowledge, including novel and breakthrough technologies. The present situation and the current policy environment appear to be most conducive for fostering a strong and mutually reinforcing interface between the two entities, academia and industry.

Researchers have indicated that the future competitiveness of industry and success in accelerating growth and increasing employment depends on the capacity of firms to innovate in response to changing external conditions, including the continuing rapid pace of technological development. A strong and vibrant science and technological base and the ability to exploit new technologies commercially are key components in generating economic growth, and a major input, which determines the strength of science and technological base, is the educational infrastructure (Evans, 1998).

With the growing importance of technology and its progress in the economic development of a nation, much emphasis has been placed on institutional and policy factors. The path-breaking works by Nelson & Winter (1982), Freeman (1982, 1987), Lundvall (1988) and Rosenberg (1982) has led to an altogether new chapter in the study of technology that focuses on the evolutionary nature of technological progress and the importance of institutional and policy factors in the process (see the essays in Dosi et al. (eds.), 1988). These developments have resulted in the evolution of the concept of 'National Systems of Innovation' (NSI), where the significance of institutional factors, and the inter-relationship between the constituent parts including universities, in the determination of technological progress have been emphasised (see the essays in Lundvall (ed.), 1992, and Nelson (ed.), 1993).

Looking at the broad theoretical framework and approach to address the issues of university-industry interaction, the most relevant and popular is the 'triple-helix' framework, in which the third actor, apart from academia and industry, is government. The 'triple-helix' framework contends that the university can play a central role in innovation and that this would increasingly be in the case of knowledge based societies and more specifically in those industries where innovation is more knowledge based (Etzkowitz & Leydesdroff, 2000). The growing literature on 'triple helix' framework places university as the knowledge producing and disseminating institution, that plays a central role in innovation, more so in technological innovation[1]. The underlying model that of 'triple helix' is analytically different from the NSI approach, which considers the firm as having the leading role in innovation, and from the 'Triangle' model of Sábato (1975), in which the state is privileged (cf. Sábato and Mackenzie 1982). The 'NSI' approach is especially suited to analysis of bounded phenomena, within nations or individual firms.

[1]The Triple Helix conferences are held once every other year at different places across the globe. The first conference was in 1996 at Amsterdam; second one at Purchase New York in 1998 followed by one in Rio-de-Janeiro in 2000 and the 4th in Copenhagen and Lund in 2002. The fifth conference is scheduled in fall 2004 at Milan/Torino.

Although other sources are taken into account, incremental innovation is viewed as primarily occurring within the firm, through various forms of learning (Lundvall, 1988), a different model of the sources of innovation is required to account for discontinuous as opposed to incremental approach. The further argument in support of the 'triple helix' model is that as innovation moves outside of a single organization, lateral relationships across boundaries, rather than hierarchical bureaucratic structures, become more important[2]. To analyse these developments and to guide their future growth, a new model of the relationship among the institutional spheres and their internal transformation is needed.

As per Etzkowitz and Webster (1998), universities are undergoing a 'second revolution' which implies the translation of research findings into intellectual property, a marketable commodity, and economic development. Universities in particular have a crucial role in making up of the infrastructure, which becomes a necessary condition for the genesis of high technology industry. For instance, research on the patterns of industrial success in ten industrial nations and the company strategies and national policies that achieved that success has suggested that a common and central characteristic of an effective science and technology policy is the existence of a strong university R&D capability (Porter, 1990).

In the context of developed countries, studies have already underlined the importance of university research to enhance the innovative capacity of the industrial sector (Berman, 1990; Mansfield, 1991; Link and Rees, 1990). In fact, many believe that the current uncertainties and continuing structural problems in the world economy will only be resolved by a new cycle of innovations that ties together the universities and industries (Rothwell, 1993).

While the academic institutes operating in a national system of innovation carry out certain functions, an interface between industry and academia is very much required to spur growth and to enable firms in acquiring technological competence through innovations to be able to survive in a highly competitive environment. Whether one is talking about large or small funding, but the more extensive pre-competitive and contract research collaboration that university and industry share, academia-industrial relations and the growth in commercialisation of academic science have become major items on any

[2] The discussions at the 4th Triple Helix conference focused on the role of universities in shaping new innovation environments for both entrepreneurial initiatives and public participation. The thought behind is that formulation of public demand for technological innovations may help to stimulate the transition to an increasingly knowledge based economy.

science policy agenda (Etzkowitz and Webster, 1998). There are other proponents of the view that direct contributions to industry from the new universities and regional colleges, which have based their research programmes on its premises, are important. Science and technology have become important to regional developments (e.g., Braczyk *et al.* 1998). Both R&D and higher education can be analyzed also in terms of markets (Dasgupta and David, 1994).

Given the growth in the infrastructure and number of academic institutions in India and the build up of human capital stock in science and technology, there is no doubt that there lies immense potential for technological innovations to occur. The achievements in the area of industrial development, telecom and broadcast communication, railways, all forms of energy including atomic energy and renewable energy, space and defence production would not have been possible without the building up of this large stock of human capital in S&T of fairly high quality (Joseph and Parthasarthi, 2003). Thus, there is no reason not to believe as to why the premier academic institutes like the IITs, despite facing the pressure of generating revenues through internal resources, should not be able to make significant contributions to the system of innovation and to commercial interaction with industry.

The issue thus lies in creating trust in industry about indigenous R&D outputs, especially novel technologies that have potential to be commercially successful. The focus for technology generation and development should be given on all those institutes which have the necessary infrastructure and faculty scientists and researchers who are willing, dedicated and proficient. The institutes of national importance like the IITs emerge as one of the best institutions in this direction. However for building trust in industry for indigenous research and development results, much needs to be done at all fronts be it industry, academia or government.

It has also been argued that academic technology transfer mechanisms may create unnecessary transaction costs by encapsulating knowledge in patents that might otherwise flow freely to industry (for details see Rosenberg and Nelson, 1994). These arguments however pose important questions like would the knowledge be efficiently transferred to industry without the series of mechanisms for identifying and enhancing the applicability of research findings? How are development processes to be carried further, through special grants for this purpose or in new firms formed on campus and in university incubator facilities? These questions need to be addressed and as such the study attempts to do the same.

In some institutions, the industry liaison function is being done through the establishment of Technology Transfer Offices (TTO), which becomes the primary formal route by which links between the educational institution and external organisations are formed. The key function of such offices lies in facilitating technology transfer. The technology transfer office at IIT-Delhi is the first autonomous establishment in any of the IITs that has been comprehensively working on marketing the intellectual-ware of scientists and researchers at IIT-Delhi to industry. Thus the research question leading to specific objectives of the research can be stated as follows:

1.1 Research Questions and Objectives

Research Questions:

1. Whether the TTO has created new opportunities for technology commercialisation.
2. If the TTO has made academia-industry relationships more transparent and efficient.

Specific Objectives:

1. To understand the academic institutes' technology commercialisation process, the difficulties faced in the process and commercialisation mechanisms.
2. To examine the role of TTO and the role of Intellectual Property Rights in facilitating technology transfer
3. To examine the main opportunities and constraints in the development of links between academic institute and industry, the benefits to academic institute from Industrial links, and the perception of industry's assessment of the relationship with the academic institute.

In the light of the above discussion, this would be an attempt in bridging the gap between industry and academia as far as technology transfer from latter to the former is concerned.

1.2 Methodology

This work draws upon both qualitative and quantitative data. In view of the exploratory nature of research, we focus on a single institution rather than attempting a broad survey.

IIT Delhi was chosen as the focal institution because it is one of the premier academic research institutions in India and it is the only institute that has an autonomous organisation dedicated to innovation and technology transfer. Moreover it has historically been firmly orientated towards a goal of having an immediate impact on the academic environment in the country, serving as a role model for other institutes to ensue. The focus of present research is restricted to a set of 'inventions' developed in IIT Delhi and commercialised, and handled by the technology transfer office of the institute. Whilst examining the specific cases of Technology transfer, a detailed study has been done explicating the chain of events starting from conceptualisation of idea to its productionisation and commercialisation. The important aspects involving the initiation of the technology transfer process, entrepreneur's efforts, TTO's attempts, inventor's endeavour, interaction between them during the technology development phase, dynamics of problem solving, decision making for technology commercialisation etc. were minutely considered and investigated. The small number of cases that we examine, though revealing, have limitations in terms of drawing general conclusions.

As has been stated earlier, that the focus of this research is to understand the technology commercialisation mechanisms being adopted by the institute, the study also evaluates the role of TTO and the role of IPR in facilitating technology transfer from academia to industry. The study contemplates the general role and function of the TTO and examines how has its existence has affected change in the earlier mechanism of direct involvement of IIT with industry. The study also examines the main opportunities and constraints to the development of links between academic institute and industry, the benefits to IIT from Industrial links, and the perception of industry's assessment of the relationship with IIT Delhi. Individual case studies have been taken to facilitate the understanding of the above issues.

1.2.1 Data Collection

The research involved data collection primarily through primary sources in IIT and in industry. The secondary data included annual reports, newsletters, websites and public documents both of TTO and IIT Delhi, wherein much of the information was collected from the documents in the TTO office.
Information support through books, journals, and other literature was sought from the libraries in JNU, IIPA, IIT, Nehru Memorial, NIFM, and NISTADS and from organisations like NRDC, FICCI, and FITT.

The details of the firms involved in technology transfer were obtained from the TTO office and a database was created which included their telephone numbers and postal as well as e-mail addresses. The firms were initially contacted through telephone and then appointments were sought for face-to-face interviews. From a Universe of 31 technology transfer cases, a dossier was made that comprised of: the title of invention, the name of inventor and his/her department or centre, the name and address of the licensee, the terms of transfer, Intellectual Property Status, Technical Fees, and a list of deliverables. No information was available on 3 cases from TTO, thus the total number of cases came down to 28. Out of these, further information was available on 22 technology transfer cases from 16 firms that could be contacted[3]. The unavailability of information on the three cases from three firms was due to a possible change in address or telephone number. Moreover in two cases, where the firms were outside Delhi, one could not reach the concerned person through repeat long distance phone calls. Out of the16 licensee firms, only 11 showed their willingness in further talks. Out of these 11 firms, appointment was sought with the CEO and/or the concerned person who was involved in the technology transfer. At this stage, interviews were possible with only 9. Although information was made available by all the firms they were limited for reasons of confidentiality and interest of the personnel. Thus, six cases were chosen for the study and finally three case studies were selected for a detailed study and understanding.

The main method of gathering data during the fieldwork was face-to-face semi-structured interviews with individuals representing TTO as also with CEOs and/or concerned higher management personnel of the involved firms in industry.

In seeking answers to the above raised research questions and in order to address the issues the present study has undertaken a select number of cases of technological inventions of IIT Delhi reported in the TTO annual reports, and it is hoped that such an approach will enable us to better understand the processes and mechanisms involved for an academic institute in connecting with industry for technology transfer. There is a little understanding of exactly what roles technology transfer offices play in bridging the gap between academia and industry and how do they specifically facilitate in technology transfer from academic institute to industry. One of the main activities of the TTOs also is to protect the

[3] This is because more than one technology was sold to single firm on two occasions.

university inventions by filing patents and other forms of Intellectual Property Rights (IPR), which draws our attention to the role that intellectual property rights play in facilitating technology transfer.

1.3 Organisation of the Study

The dissertation is structured as follows. Following introduction, Chapter 2 begins with a brief overview of the state of academic institutions in the context of research and development expenditure in India and proceeds to briefly discuss the development of technical education in the country. In addition to exploring the evolution of Indian Institutes of Technology, their distinguishing characteristics, and their importance, the chapter also depicts the growth of IIT Delhi, its infrastructure and industry cooperation. A survey of literature on the interface between academia and industry as well as on the impact of academic research, mainly with regard to technology transfer forms the next chapter. In chapter 4, the focus is on the technology transfer office, its activities, and its achievements. This section also gives an account of all the cases of technology transfer from IIT Delhi to individual firms, with substantial details, given the limitation of available resources be it information or time. The activities and achievements with special emphasis on technology transfer are critically examined here. Chapter 5 briefly discusses the response of firms to innovation and technology choices and proceeds to give a detailed account of individual cases of technology transfer with inputs from IIT Delhi as well as from the involved individual firms. Drawing on these individual cases and on the inputs from chapter 4, the role of technology transfer office and the role of intellectual property rights in facilitating technology transfer is discussed and analysed, as also are the policy implications and issues. In the last chapter (6), the main findings are summarised, and conclusions are drawn with little discussion on implications for future research.

2.0 The Development of Technical Education in India: An Overview[4]

2.1 Introduction

Today, India has a vast Science and Technology (S&T) infrastructure with more than 400 National Laboratories, over 250 Universities with science and technology departments including the institutes of national importance like IITs, and over 1300 in-house research and development units in the industrial sector. Indigenous efforts have enabled the country to make considerable progress not only in developing local capabilities but also in adopting and adapting foreign technologies. These have also led to India being classified as a type-I[5] country with the requisite skills to design manufacture and sell a host of products (Mani, 2001).

This chapter begins with an examination of the state of academic institutions in the context of research and development expenditure in India and proceeds to discuss the development of technical education in India and the evolution of IITs and their distinguishing characteristics, and it focuses on the Indian Institute of Technology Delhi, the object of the current study, its infrastructure, and industry interaction.

2.2 Education and Science & Technology Scene in India

The new Science and Technology Policy 2003, announced early this year in the 90th session of the Indian Science Congress in Bangalore, has highlighted government's concern for improving research and development base in the future, as the S&T outlay would be enhanced to 2 percent of the country's Gross Domestic Product (GDP) by the year 2007 from the current 0.8 percent. In the same document it has been stated that the private sector would be encouraged to adopt and fund institutions and their courses and in return get marketable technologies. The other proposed significant outcome in the policy

---

[4] This section is by no means an exhaustive study, but it is important as it sets a stage for our focus discussion on academia technology transfer.

[5] Type I countries are those developing countries, which have the potential to create technologies on their own. This technological potential is measured in terms of number of patents granted to inventors from these countries in the US. There are 11 such countries [for further details and typology see Mani, (2000)]

document is that the autonomous technology transfer organisations would be set up within selected national laboratories and universities. The given directives indeed indicate government's interest in promoting academia-industry collaboration, yet the present situation gives a rather indigent picture of the research and development activities in the country.

In India, the majority of research and development funds are spent in large government owned research laboratories[6], with Defence Research Development Organisation, Department of Space and Department of Atomic Energy accounting for more than 64 percent. The Council of Scientific and Industrial Research (CSIR) laboratories in the year 1998-99 had a share of nearly 10 percent. The share of industry in the total national resources for research and development is only around 26.6 percent, with the private sector industries accounting for more than 81 percent of the industry total.[7] The Industrial sector spent 0.52 percent of their sales turnover on R&D in 1998-99, which came down from 0.7 percent in two years. This figure is nowhere comparable to the OECD countries, where the industrial sector spends close to 9-10 percent of their sales turnover, and even in the Newly Industrialised Countries (NICs) like South Korea and Taiwan, the spending is nearly 5 percent.

Given the above statistics, the state of academic sector does not appear to be in the priority list in terms of government spending on research and development. This becomes clear by looking at the current available data. As per the latest statistics published by DSIR (2000-01), the share of Research and Development (R&D) spending in academic institutes in 1998-99 is only 2.9 percent of the total, which in absolute terms is Rs. 3741.6 million, showing an increase of 2 percent in two years. The role of universities in societal formulation, nation building and scientific development is enormous and all pervasive and therefore such an important human development agency needs to be managed without any financial stress or strain. While the requirement for funds has increased over the years, the traditional source of finance has been drying up. The allocation to higher education was 20.89 per cent of the total allocation to education sector in the Sixth Plan (1980-85), 17.6 in the Seventh Plan (1985-

---

[6] As per the Union Budget 2003-04 there has been an increase in fund allocation to the Department of Science and Technology (DST) by 1750 million, which is now close to 8000 million. The different constituents of DST namely the Department of Scientific and Industrial Research (DSIR) and Department of Biotechnology (DBT) have been allocated Rs. 5200 million and Rs 2600 million respectively.

[7]The public sector industry share of national expenditure on R&D is just 5 percent of a total of Rupees 12901.54 crores. These are the 1998-99 R&D expenditure figures given in the R&D Statistics 2000-01 published in May 2002.

90), and came down to 11.2 per cent in the Eight Plan (1992-97). As a result, the universities are hard pressed to manage their meagre finances efficiently (http://ficci-sedf.org/fsedf/university4.htm).

In the Indian context, the major institutions for converting the R&D outputs innovations include (1) public research laboratories (2) private R&D institutions (3) premier teaching and research institutes like IITs and (4) universities. Technological education juxtaposed with advance research is being pursued in premier academic institutes like IITs from their very inception for more than four decades now. As these institutes rely on fund support from the government, yet with the insufficient amount that they receive, they depend mostly on generating revenues internally. Given the constraints of funds and other factors[8] a good number of R&D output of such institutes have been taken up by industry in the past and continue to do so, some without any modifications while some after joint up-scaling efforts.

With the growth in number of sponsored research projects, consultancy assignments, educational sources, and use of infrastructure facilities like university laboratories by industry, as also for sources of innovation, there has been an overall improvement in the collaboration environment between industry and academia. However the technology transfers from academic institutes to industry have not increased. Most of the Indian firms look towards acquiring foreign technology, when the need arises and this has been the trend for several years, a fact noted by various researchers. The building up of industrial capacity of the country has proceeded almost totally on the basis of imported technology (Parthasarathi, 1987; Desai, 1980). Indian Industry has so far preferred to go for international collaborations rather than to academic or domestic R&D organisations in search of new technologies, or even when technological solutions are called for to address issues like up-gradation or modernisation of the existing process (Sengupta, 1999).

The issue thus lies in creating trust in industry about indigenous R&D outputs, especially novel technologies that have potential to be commercially successful. The focus for technology generation and development should be given on all those institutes, which have the necessary infrastructure and faculty scientists and researchers who are willing, dedicated and proficient.

[8] These factors are dealt separately under the heading "Indian Institutes of Technology in chapter 3

2.3 Origin of Technical Education in India

India, just after attaining independence in 1947, was faced with the great challenge of rapidly industrialising a predominantly agrarian economy. In 1958 with the announcement of Scientific Policy Resolution (SPR) that served as a basis for the government policy on domestic R&D, efforts were made on a vast scale to create a broad-based infrastructure of higher and technical education institutions, research laboratories and industries, covering a wide spectrum of disciplines and capabilities.

> *'aims of scientific policy will be to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognize their work as an important component of the strength of the nation'*
>
> *Scientific Policy Resolution' 1958*

The resolution considered the creation of scientific bases as a prerequisite for developing domestic R&D capacity, on the assumption that technology grows out of the study of science and its application. The policy aimed at ensuring an adequate supply of research scientists and fostering scientific research for expanding the scientific base within the country. Thus the university and professional education institutions and their supporting mechanisms were expanded to generate scientific engineering and technical manpower as also the administrative support personnel to monitor and govern. The development and expansion of higher and technical education institutions has been notable as the number of universities and academic institutions of national importance have grown from 27[9] in 1950-51 to 254 in 2000-01. In addition there is a vast network of colleges and other institutions for technical education offering courses in medical sciences, engineering, pharmacy, management and so on. The extensive network and the human resources graduating from these institutions have put India on to the third largest producers of scientific and technical manpower[10] (Economic Times, April 27, 2003).

---

[9] This given figure indicates only the number of universities in India, while the numbers of professional colleges were 208 and colleges for general education were 370 in number. In 2000-01, the reported numbers are 2223 and 7929 respectively (www.education.nic.in/htmlweb/edusta.htm).

[10] But for every 1000 Indians there are only 3.5 persons who are scientists or technician, and of these only 0.3 are involved in research and development (Economic Times, April 27, 2003)

The foundation of present day Technical Education System in India was, perhaps, laid during 1840's with the establishment of technical institutions at Roorkee, Madras, Calcutta and Pune[11]. The All India Council for Technical Education was established in 1945 as an advisory body in all matters of Technical Education. Technical Education in India gained momentum after independence in 1947 when Government of India laid emphasis on the same and the States made provisions for technical education in their policies and plans.

Technical education is imparted at three different levels in India:

- Industrial Training Institutes (ITI), which conduct trade courses for skilled workers
- Polytechnic Institutes, which conducts diplomas to produce middle level technicians and
- Engineering Colleges, which conducts undergraduate and postgraduate degree courses in engineering and technology.

There are engineering institutes and colleges that are supported by the state and central governments, and also a large number of private engineering colleges and institutes that provide technical education in India. The number of private institutions is increasing rapidly. Government expenditure on technical education has increased by almost 400 times from the first five-year plan to the eighth.

2.3.1 Policy Documents and Institutions

There are two sources of policy documents on technical education namely the National Policy on Education of 1986, as revised in 1992, and the Eighth Plan document (1992-97) of the Planning Commission, which are considered as landmarks in Indian technical education. The National Policy on Education focuses on the need for reorganising the technical and management education system to effectively deal with the changes in the economy, social environment, production and management processes, and the expansion of knowledge and advances in science and technology.

The Eighth Plan document emphasises on the following four vital spheres:

- Modernisation and up-gradation of infrastructure facilities;
- Quality improvement in technical and management education;

[11] For more details see www.dynalogindia.com/Dynavoice/Vol3/dvoice1.htm; Dynavoice: Technology Leaps in Education, May-June, 2002 and www.education.nic.in/htmlweb/edusta.htm

- Response to new industrial policies and institution-industry-R&D laboratories interaction; and
- Resource mobilisation

The salient features of these are as follows:

Modernisation relates to both technical equipment and teaching methods. The need is to adopt futuristic approaches for achieving modernisation and self-reliance in a sustained manner. Coordinated and concerted efforts are required to upgrade and consolidate infrastructural facilities in the existing institutions. Steps should be taken to strengthen and create facilities in crucial areas of technology where weaknesses exist, in areas of emerging technologies and in the new specialised fields.

A holistic and needs-based approach needs to be adopted to reorient the technical and management education. New technology-oriented entrepreneurship and management courses have to be introduced in selected institutions having adequate infrastructural facilities. There has to be a greater emphasis on production engineering and towards design and product development.

Manpower planning assumes greater significance in the context of the resource crunch and to void unemployment and under-employment. In this context, it is desirable to couple technology forecasting with the system of manpower forecasting and planning. Universities and IITs need to play an important role in technology forecasting and assessment, with the fruitful involvement of Technology Information Forecasting and Assessment Council (TIFAC), Institute of Manpower Research (IAMR), and Indian Trade and Industries Associations (ITIA). This enables the development of indigenous technologies, assess related manpower requirements and produce related trained manpower.

As per the Tenth Five year plan (2002-07) of the planning commission, technology transfer to industry would be another thrust area. Research and Development/academic institutions should give appropriate importance to design and product engineering aspects, the application and constant upgrading of the technology to be transferred. Interaction with industry should not end with technology transfer but the agency providing the technology must be in constant touch with the user industry for problem solving. The draft also lists out that management centres manned by qualified personnel, would also be considered besides the establishment of S&T entrepreneurship parks, Technology Business Incubators, upgrading R&D infrastructure of industry through consortiums of industry associations. The reference of this may be interpreted towards the establishment of technology transfer offices within the university.

The draft also states that incentive/support measures would also be need for promoting the purchase of products developed through indigenous technologies.

There are varied views on the development of technical education in the country. While there is much criticism with regard to the funding support available and research and development spending on technical education, evident from the above discussion and statistics stated, there are further insights on the same. Technical education is one of the most critical infrastructures required for creation of knowledge capital (Chauhan et al., 2001). Since technical education determines the development and socio-economic condition of a nation, there is a greater need for high quality technical education to produce technically skilled manpower in India (Vidyasagar et al., 1996).

However the present situation in which there is an unprecedented growth in number of engineering colleges and polytechnics, there is very little coordination with external entities like industry and R&D organisations in the country. Technical education institutions are functioning in isolation. Linkages and interaction between technical educational institutions and user agencies such as industry, R&D and design organisations and development sectors are not sufficiently strong. (Swaminadhan, 1995)

Institution: All India Council for Technical Education (AICTE)

The All India Council for Technical Education (AICTE) is an apex organisation responsible for planning and coordinating development of technical education in India. The AICTE is also responsible for the accreditation of both state and private engineering colleges. AICTE monitors the qualitative growth of technical education in relation to planned quantitative growth and proper maintenance of norms and standards. The National Board of Accreditation (NBA) was constituted by the AICTE as an autonomous body, under section 10(u) of the AICTE Act, 1987 in order to periodically conduct evaluation of technical institutions or programmes on the basis of guidelines. According to the information available on the official website (www.aicte.ernet.ac.in), the accreditation exercise is very rigorous and has several inputs, such as quality of teaching, level of research, faculty expertise, evaluation of teachers, and standard of infrastructure and resources available at the institution. There are seven Statutory Regional Committees across the country for assisting the Council in planning and development of technical education, monitoring and periodic evaluation of the approved institutions in the region. The numbers of engineering colleges and polytechnics have been increasing rapidly to cope with the growing demand for technically skilled people due to rapid industrialisation and infrastructure development in the country.

2.4 The Indian Institutes of Technology

At present there are seven Indian Institutes of Technology (IITs), located at Kharagpur, Mumbai, Chennai, Kanpur, Delhi, Guwahati and Roorkee that have long had a reputation of being among the very best engineering institutions, not only in India but in the world[12]. These first five higher institutes of technology were set up during 1951-1963, with IIT Kharagpur being the first in the series, at the site of Hijli Detention Camp in West Bengal in May 1950 followed by IIT Bombay (1958), IIT Madras (1959), IIT Kanpur (1959) and IIT Delhi (1961). The sixth IIT was established in Guwahati in 1994 as per the Assam Accord. The first technical institute, set up in 1847 known as the Thomson College of Engineering and, subsequently, the University of Roorkee was ordained through an act of parliament, as the seventh IIT in September 2001.

In their initial phase of development, the IITs received technical assistance and collaboration from some of the foremost technologically advanced nations, IIT Bombay from USSR, IIT Madras from Germany, IIT Kanpur from USA and IIT Delhi from UK representing distinct systems of technical education. The six IITs, apart from IIT Delhi, are administered centrally by the IIT council, an apex body established by Government of India to co-ordinate activities of these institutes [13]. The Minister for Human Resource Development of the Government of India is the chairman of the council.

2.4.1 Origin of IITs

An interim report on the "Development of Technical Education in India" was prepared and submitted under the chairmanship of N K Sarkar in the month of March 1946, which further led to the

[12] All the IITs figure in the top ten engineering institutes in India, based on survey results that appeared in *India Today*, June 2003. In ranking of Asia's best Science and Technology institutions by Asiaweek in 2000, five IITs (Bombay, Delhi, Kanpur, Kharagpur and Madras) were ranked in top eight.

[13] IIT Delhi is an autonomous statutory organization functioning within the "Institutes of Technology Act" amended by The Institutes of Technology (Amendment) Act, 1963.

establishment of the Indian Institutes of Technology. The main recommendations of the report, more popularly known as the Sarkar Committee report, were as under:

I. Not less than four[14] institutions, one in the North, one in the South, one in the East, and one in the West will be necessary to meet post-war requirements.
II. The one in the East should be set up in or near Calcutta at an early date.
III. Establishment of the Western Institution, which should be in or near Bombay, should be taken in hand concurrently with the Eastern Institution or failing that as soon as possible.
IV. To satisfy the immediate needs for engineers generally and for those with specialised training in Hydraulics in particular, the engineering nucleus of the Northern Institution should be set up without delay.
V. To ensure the planning of buildings, equipment and courses of study, the Principal and Heads of the Main Departments of these institutions should be appointed and the services of an architect with experience in the planning of technical institution secured at a sufficiently early stage."

According to Indiresan and Nigam (www.talkelab.ucsd.edu/vijay/iit.html), these interim recommendations were never finalised. These institutes of higher technical education were established on the model of the Massachusetts Institute of Technology (MIT) in America. At the time of submission of the interim report in 1946, India had 11 affiliated Colleges/Departments, and four independent institutions offering undergraduate programmes in Engineering and Technology[15].

A central statute for the Indian Institute of Technology (Kharagpur) Act, 1956, declared the IIT to be "an institute of national importance". The Institutes of Technology Act, 1961, which created a unique framework for the funding, administration and academic development of the IITs as privileged institution, confers a high degree of autonomy on the system and protects it from academic pressures. A 1963 amendment Act has provided for further expansion of the IIT family. (Murali, 2003)

---

[14] IIT Delhi which was initially (1961) set up as College of Engineering and Technology, was included in the IIT system in1963 through an amendment of the IIT Act (1961).

[15] The first college was set up in 1794 at Guindy, four colleges during the 19th century, and the remaining during early 20th century.

2.4.2 IITs and their Distinguishing Characteristics

IIT experience represents a major innovative and novel reform in higher technical education in India, encompassing curricular, institutional and public policy issues. The IITs have had an enviable reputation for providing the best undergraduate and postgraduate engineering education in India (Palit, 1998). The IITs are intended to be a kind of model institution designed to play a leading role in promoting engineering and technological education (Rajagopalan and Singh, 1968).

The key features that give IITs a distinct advantage include an undergraduate curriculum which places a strong emphasis on understanding of fundamental principles rather than specialised knowledge; a postgraduate programme, larger in size to undergraduate programme, and distinguished by its interdisciplinary approach and emphasis on research (Indiresan and Nigam, www.talkelab.ucsd.edu/vijay/iit.html). Further IITs attract highly qualified faculty resource with educational, teaching and research experience in some of the leading academic and research institutions in the world; and enjoying the freedom to plan and implement teaching and research programmes according to their own perceptions. According to Indiresan and Nigam, IITs also have an open decentralised system of administration, which is seen as a very different setting from traditional university type hierarchy common in India. In addition, it has adequate financial support to establish and maintain a state-of-the-art basic infrastructure consisting of teaching and research laboratories, library, computing environment, workshops and so on and other institutional and residential facilities on a modern campus. IITs bank upon having a composite student body selected on an all-India basis through an exercise of free-choice by the students based on their merit in Joint Entrance Examination (JEE) and Graduate Aptitude Test Examination (GATE) for postgraduate courses. The IITs formulate their own curriculum with faculty committees and through formal consultation with professional organisations. The IITs have a semester system, with each semester lasting for sixteen weeks, and an academic year comprising of two semesters.

2.4.3 Funding of IITs

The Sarkar committee that prepared the report for the establishment of IITs, suggested that the cost of education in IITs should be shared one-third each between the students, the central government and through the income earned by the IITs. A debate is going on about the best way of financing the IITs which costs nearly Rs 10 billion to establish and about Rs 800 million a year to run. In 2002-03, the Central Government's budgetary allocation to the IITs was Rs 5640 million compared with a total elementary education outlay of Rs 35770 million (Murali, 2003). This is nearly 16 percent of the total elementary education outlay.

Indian Institutes of Technology draw upon a wide variety of funding sources. Revenue comes from student fees and from Central, State government grants and budgetary allocations. It is further supplemented by endowments and investment income, grants and donations from private industry, foundations and individual benefactors as well as from its alumni[16]. IITs enjoy a special status in the country and the pursuit of multiple objectives and the concomitant reliance on the different sources of funding, these institutes of national importance have research units that are unique in their capabilities and have distinct relative advantages over research universities. The prime factor that differentiates the character of IITs from being a provider just of educational services and public knowledge to being a key element in the industrial innovation infrastructure, is the economic power produced by the infrequent but repeated emergence of commercially valuable new technologies from their research laboratories.

At present all IITs receive almost equal grants – about Rs. 900 million to 1000 million every year as part of the plan and non-plan allocation from the central government. As has been stated earlier that a consensus is yet to be reached on the best way of financing the IITs, proposals are being formulated. As per newspapers in one of the proposals, the proposed funding pattern is based on performance where the weightage would be given to the number of students (*Economic Times*, 08 October 2002). The performance would also depend on productivity and one factor that would determine productivity would be the quality and quantum of post-graduate research. While generic research would also be given a weightage (proposed is 5 percent), it would be far less than that given to cutting edge-work. The other criterion for determining funding would be the ability of the IIT to generate funds on its own through industry involvement, which would help promote cutting edge R&D (*Economic Times*, 09 July 2002). Also according to newspaper reports, it is known that the IITs would now get funds from the government only if 50 percent of the money is spent on research projects. (*Indian Express*, 05

---

[16] The IIT Delhi alumni association in monetary terms contributes approximately Rs 40 million. Direct contribution through donation of equipments and through other sponsorships amounts to approximately Rs 80 million. (Official documents, IRD, IIT-Delhi, 2002)

December 2002). This decision was based on the recommendations by the review committee accepted by the IIT council.

2.4.4 The Innovative Outputs of IITs and Industry Cooperation

The output of research labs at IITs are classically embodied in scientific papers, books, and students trained with new knowledge and skills. Yet, the research outputs also lead to intellectual property-including patents, copyrights and designs. Many of these outputs are of value to industry; few of them, including the patented inventions, are used for real commercial application.

The need for building bridges between academia and industry has been widely discussed and unanimously claimed. In the Indian context, IITs are one of the earliest to promote and have institutional mechanisms for working with industry (Raju, 1995). The interaction between industry and IITs in particular has grown substantially during the last decade and it is expected to increase exponentially in the near future[17]. The prevalent interaction mechanisms are consultancy, external registration of staff from Industry (usually for higher degrees), association with industry, visiting faculty from the industry, joint development and operation of facilities, industry lectures to IIT students, joint student projects and Technology Development Missions

2.4.5 IITs and the Technology Development Missions

On the initiative of the Planning Commission, the Technology Development scheme was started, which was the outcome of an approach paper that emphasised on four thrust areas, namely technology development in a mission mode, international consultancy, establishment of industrial foundations and corpus fund. Towards technology development, for the first time, all the five IITs and Indian Institute of

[17] In December 1999, there was a proposal to privatize the Indian Institutes of Technology. As stated in the newspapers, a group of industrialists from India and the US (the latter of Indian origin, mainly from Silicon Valley) proposed to take over the five IITs with its five campuses. A one billion dollar fund was planned for the purpose of privatizing "the premier technology institutions of India". It was claimed that the group would work "towards raising the level of IITs to make them comparable with world class institutes like MIT, Harvard and Stanford." The Government had agreed in principle, and the Prime Minister had asked the group, most of whose members were IIT alumni, to submit a detailed report on the proposed takeover. (*Times of India*, Dec. 13 1999) There was much resistance to the proposal, which followed the views in line with the idea of developing IIT into a research university, either through a transformation into a private institution with strong industrial backing or as a development within the existing status of a State institution (*The Times of India*, Dec. 19, 1999).

Science, Bangalore came together and identified eight generic areas for technology development in mission mode (see Table 2.1). Subsequently, one area–National Hazards Mitigation–was not approved thereby leaving the following seven areas

Table 2.1: Technology Development Missions (TDM)

No.	Generic Area	Coordinating Institute
1.	Food Process Engineering	IIT Kharagpur, IIT Bombay
2.	Integrated Design and Competitive Manufacturing (Engineering and Industrial Design, FMS)	IIT Kanpur, IIT Bombay
3.	Photonic Devices and Technology	IIT Kharagpur, IIT Delhi
4.	Energy Efficient Technology and Devices (Fuel Efficient Engines and Coal)	IIT Delhi, IIT Madras
5.	Communication, Networking and Intelligent Automation	IIT Kharagpur, IIT Kanpur
6.	New Materials (Composites and Electronic Materials)	IIT Madras, IIT Delhi, IIT Kanpur, IISc
7.	Biotechnology and Genetic Engineering	IIT Kharagpur, IIT Delhi, IISc
8.	Natural Hazards Mitigation (Use of Remote Sensing Applications) – [Not Approved]	IIT Madras, IIT Bombay

TDM not only involved research as the foremost constituent but it also had a commitment to the development of technology though innovation and subsequent transfer to Indian industry. The generic areas thus selected were of strategic importance and did have export potential. A national level steering committee has been constituted under the chairmanship of D. Swaminadhan to oversee the implementation of the TDMs. A small cell has been constituted in the Department of Science and Technology to compile necessary information and to do the documentation for giving technical support to the Steering Committee.

TH-10768

The total outlay for the seven TDMs including industrial contribution is approximately Rs 800 million spread over five years. The industrial contribution equals 25% of the government contribution. The objective of these missions is to give a major breakthrough in interaction between IIT system and industry.

According to Indiresan and Nigam (www.talkelab.ucsd.edu/vijay/iit.html), while the achievements of the IIT system are considerable, it has faced criticism on issues, such as, high cost of technical education, brain drain, urban and elitistic orientation, and inadequate interaction with industry. To quote the IIT Review Committee Report, 1986, (MHRD, 1986)

"One cannot, however, overlook the fact that output from the IITs may not have been commensurate with the inputs and expectations...... of late, there are indications that the undergraduate programmes themselves tend to be less flexible than originally envisaged. Experimental research and design and fabrication of sophisticated instruments are on the decline. IITs do not seem to be able to motivate the students and teachers sufficiently in regard to their commitment to the nation to give their best and to achieve excellence."

2.5. Indian Institute of Technology Delhi

IIT Delhi was established in the year 1963 with a vision *"to contribute to India and the World through excellence in scientific and technical education and research; to serve as a valuable resource for industry and society; and to remain a source of pride for all Indians."*[18] It is spread over 320 acres providing a residential accommodation to about 800 academic staff and 600 other staff members of the institute. Over 3000 students live in the campus in 9 hostels. There are 13 departments which are Applied Mechanics (AM), Biochemical Engineering and Biotechnology (DBEB), Chemical Engineering (CHE), Chemistry (CHY), Civil Engineering (CE), Computer Science and Engineering (CSE), Electrical Engineering (EE), Humanities and Social Science (HSS), Management Studies (DMS), Mathematics (MA), Mechanical Engineering (ME), Physics (PHY) and Textile Technology (TT). IIT Delhi also has 10 specialised centres namely Applied Research in Electronics (CARE), Atmospheric Sciences (CAS), Biomedical Engineering (CBME), Computer Services (CCS), Educational Training Services (CET), Energy Studies (CES), Industrial Tribology Machine Dynamics and Maintenance Engineering (ITMMEC), Instrument Design and Development (IDDC), Polymer Science and Engineering (CPSE), Rural Development and Training (RDAT) and the National Resource Centre for Value Education in Engineering. These departments run four year B.Tech and five year integrated M.Tech programmes. In addition to the above programmes, the Institute has interdisciplinary M.Tech programmes. The institute also has a department of Industrial Research and Development (IRD) and an autonomous organisation, the Foundation for Innovation and Technology Transfer (FITT) for promoting industry-academia interaction.

2.5.1 Academic Statistics

As per the official publications of IIT (2002), the academic statistics of the institute was as under (see Table 2.2):

[18] From IIT Delhi at a Glance, IRD, IIT Delhi (2002)

Table 2.2: Faculty and Student Strength at IIT Delhi

Staff Strength	
Academic	432
Administration and Supportive	1572
Total	2004
Student Strength	
Under Graduate	1917
Post Graduate	1595
Management	168
PhD	632
Total	4312

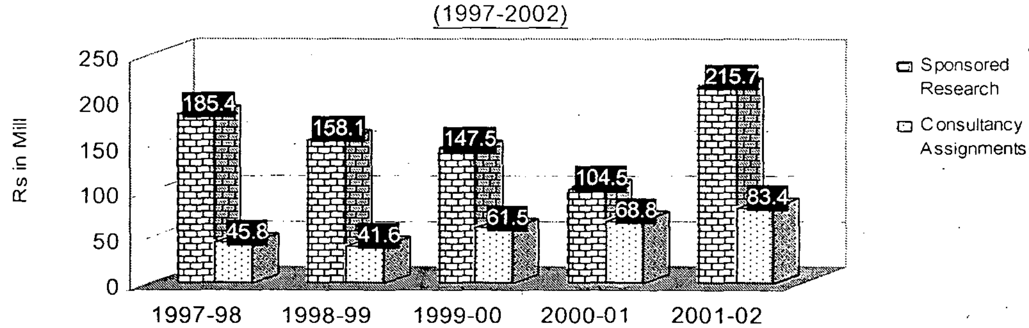
2.5.2 The Industrial Research and Development Department

The IRD unit provides administrative support and project management for different types of projects basically taken up by the IIT faculty. The Board for IRD (BIRD) is responsible for liaison with industry and regulating sponsored R&D projects, consultancy assignments, sponsored and industry based short term courses, patents and technical know-how transfer to industry, and inter-institutional collaborative links abroad. The representatives of the BIRD comprise of people from all the departments or centres of the institute as well as from outside government agencies/industry and sponsoring agencies.

The given chart (Chart: 2.1) gives the achievements of IRD unit in terms of sponsored research projects and consultancy

Chart 2.1

Sponsored Research Projects and Consultancy Assignments undertaken (1997-2002)



2.5.3 Industry-Institute interaction

IIT Delhi has a memorandum of understanding to facilitate and co-ordinate institution-industry collaboration. The thought behind is that industries provide certain physical and training facilities to the institution, and in return the institute offers continuing education to their working professionals. Industry expert and technical staff work as a team with the Institute's staff and participate in workshops, conferences and short courses. Industry managers, supervisors and executives, who are able to share practical experiences with the students, are invited as guest lecturers. Students' vacations are effectively utilised by working in the industries with a small incentive in the form of scholarships or stipend. Almost every department of the institution has an R&D section partly funded by industry, with one staff member being its co-ordinator. The involvement of students under the guidance of a supervisor for undertaking industry-oriented projects is not only useful to the students and the academic staff, but also promotes interactive networking between the institution and the involved industries.

2.6 Concluding Observations

Thus the development of technical education has been rather impressive as far as growth of institutional structures is concerned. However, the academic sector does not appear to be in the priority list in terms of government support on research and development expenditure. Despite the fact that academic institutes have the potential to be a source of technological innovations, along with knowledge transfer for the benefit of industry, most of the Indian firms still look towards acquiring foreign technology. The focus for generation and development must be given on all those academic institutes which have the necessary infrastructure and faculty scientists and researchers who are willing, dedicated and proficient. The discussion on origin and distinguishing characteristics of IITs, their funding, outputs and industry cooperation all attempt to build an awareness among industry of their capability to foster better industry-academia relations by offering their R&D outputs. The next chapter (3) looks at how the university-industry relations can be a mutually beneficial game to academia and industry; it also discusses the impact of academic research and the literature on industry-academia interaction both in India and in the world.

3.0 An Overview of Literature

3.1 Introduction

For Knowledge to be useful, it must be shared, hence the development of an alliance between academia and industry becomes extremely important, more so, in the current competitive world wherein innovation is the only means of survival[19]. Looking at the present development across the globe, in the coming years, neither partner will be able to continue to contribute to the society without this alliance firmly in place. Over the years, the research universities have evolved to satisfy multiple objectives that include not only educating the students, but also to pursue academics for intellectual and/or economic advantage.

In order to understand the technology transfer mechanisms in an academic institute, we need to understand the environment under which these institutes operate. In the same environment, industries exist and they function in close co-operation with external entities comprising of universities, research and development institutes, and with facilitating body which is the government. There is a vast body of literature dealing with each of these entities. The literature overview given in this chapter is important because it gives an understanding of the enormous work that has been done in the broad area of university-industry interface and identifies issues for further research.

This chapter proceeds as follows: Initiating the discussion on the interaction between academia and industry and its consequent benefits, the first section addresses the issue of shift of faculty members from basic to applied research and also briefly discusses the debate on whether academic research should be carried out for commercial gains in universities which are traditionally meant to undertake teaching activities. The university-industry interaction especially with respect to India is discussed in the second section. This is followed by the discussions on literature about technology transfer which

[19] It has been suggested according to Afuah (1998) that innovation will be to 2000s what Total Quality Management was to 1970s, what Time Base Management was to 1980s and what efficiency was to the 1990s as a precondition for gaining and/or maintaining a competitive advantage.

includes licensing, equity participation, start-up firms and studies done on cases of success and failures in technology transfer and finally the focus shifts in the last section to giving an overview of the literature on the impact of academic research which highlights the studies undertaken on the mechanisms and impact of knowledge transfer from university to industry. This section also includes a brief review of literature on technology transfer office and role of intellectual property rights in facilitating technology transfers.

3.2 Academia-Industry Interface – A Mutually Beneficial Game

The biggest advantage, as perceived by the university, of interacting with industry is that an increase in collaboration activities results in greater funding for research from industry. This in turn leads to better teaching and research facilities, as well as access to new ideas, techniques and the development of specific research initiatives within industrial firms. Further it is believed that as the scope of academic activities widen, the universities are able to make a greater and better contribution to the economic needs of the region. Closer association with industry gives researchers the opportunity to have practical exposure to the real world problems and to be much more focused thereby broadening their experience. In addition, close partnership with firms, may also add to the quality of research, especially through feedback on the applicability of research results. This becomes possible since firms as clients play the role of "efficient testing grounds" and they can be used to assess the relevant research areas that are of interest to industry. In the new science-based industries, mainly the biotechnology and information technology industry, however research has proven to be a steady source of entrepreneurship and fresh economic competitiveness, often leading to the creation of new firms and contributing to the obsolescence of others.

Looking at University-Industry interaction from an industry perspective, Rooesner and Wise (1994), show that, business particip 'tion in research consortia, university-industry alliances and other forms of R&D partnering is steadily on the rise, and large US firms, particularly research intensive firms, regard research-intensive universities among the best sources for technical information. It is in this context that the universities have got much attention in being a proactive constituent in creating technological innovations contributing to the economic development of a country.

3.3 Academic Research: Shift from Basic to Applied?

In the United States, in the 1980s, there was an apprehension about the declining trend of American economic and technological competitiveness, which resulted in the call for what was later termed as 'neotransferism' which means return to the "land-grant philosophy" with a renewed emphasis on the transfer of knowledge, technology, know-how and trained people to industry, in the economic interest of the country (Lee, 1996)[20]. Neotransferism implied a thrust on the university-industry collaboration, which meant enhanced transfer of new knowledge and advanced technology, an exclusivity in the transfer of intellectual property rights from public domain to industry, start-up assistance to new technology based firms, university-industry consortia, large collaborative projects, increased consultancy assignments from industry for the faculty, and an exchange of scientific personnel between university and industry.

In the United States, according to Lee (1996) the more promising reason for neotransferism not happening is that there are more number of people in the school of thought who feel that the basic function and responsibility of a faculty is to teach and share knowledge, and not to do research for commercial gains. This opinion is held by many people in India too (Bhargava, 1980) who feel that close industry-academia collaboration is likely to interfere with the traditional academic values and is unlikely to support know-how or technology transfer from the academic institute. Conversely, those without such fears offer support for technology or know-how transfer. The above discussion inspires the debate on why the academics are shifting their research that is more industry oriented or in other words why there is a shift from basic to applied research. Lee (1996) explains the development using two theories: the Social Responsibility Theory (Bok, 1982, 1990; Geiger, 1993) and the Utility Maximization Theory (Bell, 1993; Fairweather, 1989; Feller, 1990; Geiger, 1993). The Social Responsibility Theory holds that the academics are engaged in the production of 'public goods' and they have a social responsibility for national imperatives. The Utility Maximization Theory, on the other hand, links institutional behaviour to the need for research money. It views the present academic reorientation essentially as a strategy to maximize on institution's revenue streams. The shift in university system to the model university, which is inclined towards the utility maximization view and has a role in economic development, has several consequences. Not only it is a new academic function but it also transforms the professorial role even at

[20]The basic mission of the land grant system is to enable people to improve their lives and communities through learning partnerships that put knowledge to work, unlike universities established in Europe centuries before the Land grant system was created by Federal Law; the Morrill Acts of 1862 and 1890. (www.ces.purdue.edu/anr/field/gob/board.htm)

the level of the universe of discourse that faculty make. Faculty who have been seriously involved in technology transfer, now describe their technologies at a certain level of generality and do not get specific for the fear of potential intellectual property rights that could be given away (Etzkowitz, 1996). Earlier faculty would have been willing to be more open or perhaps to disclose their knowledge to a company as a consultant for a small fee, but now their interaction with industry is carefully calculated based upon the expectation that their university wishes to market that knowledge and/or that the faculty member might themselves wish to form a company based on that commercialisable knowledge (Etzkowitz and Webster, 1998).

In the Indian context, Neotransferism would imply little possibilities in a difficult situation. With the government research funds getting scarce year by year, the universities grappling with shrinking student enrolment especially in the science stream[21] and increased competition for external research grants, neotransferism phenomena is likely to thrive only in the distant future in India.

3.4 Present State of Academia-Industry Interaction in India

The importance of university–industry linkages in India was also recognized in a major way in 1961, when Thacker Committee stressed the need for the establishment of various forms and mechanisms of cooperative relationship between industry and academic institutes (Kharbanda, 2000). As referred by Kharbanda (2000), Kothari commission in 1964-66 and Bhide in 1969 did suggest useful methods of promoting linkages between universities, R&D laboratories and industry[22]. The other committees at the national level advocating the need for a stronger and closer university-industry collaboration include discipline-oriented expert committee of University Grants Commission (UGC) and National Council of Science and Education (NCSE); research committees of Council of Industrial Research (CSIR), Indian Council of Medical Research (ICMR), Indian Council for Agricultural Research (ICAR); Review committee on Post-Graduate Education and Research in Engineering and Technology (1971); Satish Chandra Committee on UGC (1980) and so on. The principal agencies making efforts in this direction of enhancing cooperation and interaction between academic institutes and industry are All India Council

[21] This was quoted in the Prime Minister's speech at the Indian National Science Congress held in Lucknow in January 2002. In his speech, he said that enrolment of students in science stream has been declining, since the number of students enrolled in science has come down to 16 percent in 2001 from 32 percent in 1947.

According to the latest available data from the organisation, the annual turnover of NRDC in 2001-02 was Rs. 40.758 million and the profit in the same year was Rs. 3.351 million. The premia and royalty earned for the year 2002-03 is Rs. 24.5 million, which showed a decline from Rs. 27.36 million in the previous year[23].

NRDC is the oldest Government of India enterprise Contract Research Organisation (CRO). The use of CROs as agencies for enhancing technology transfer between academia to industry is a well-accepted norm especially in the OECD countries. As per Webster (1994a), there are Public Sector contract research organisations like German Fraunhofer Gesellschaft, IAGB; Dutch Toegepast Natuur-Wetenschappelijk Onderzoet (TNO) as well as private CROs such as AEA Technology in UK and the California based SRI International that are engaged in technology transfer activities[24].

3.4.1.2 Science and Technology Entrepreneurs Parks (STEPs)

The scheme initiated by the National Science and Technology Entrepreneurship Development Board (NSTEDB) under DST in 1984 aims at promoting entrepreneurship among science and technology persons, forging close linkage between academic and R&D institutions on the one hand and industry on the other and providing R&D support to small scale industry. Initially there were twelve (12) STEPs[25] across the country in different stages of development which have been successful in promoting nearly 400 enterprises in different areas like electronics, mechanical engineering, biotechnology, material sciences, computers, machine tools etc. However, at present only 9 STEPs are functional and just two have performed exceptionally well. STEPs have been instrumental in development and commercialisation of more than 350 products/processes (DST Annual Report, 2000).

---

[23] Source: NRDC promotional literature and website: www.nrdcindia.org

[24] There are other notable larger CROs such as MIRA, SIRA (specialists in optical, electronic and mechanical engineering) and Smith Associates (with strong defence links) in UK; Bertin in France; Centro Informazione Studi Esperienza CISE) in Italy; Batelle in USA. ATT Bell Labs, GTE Labs and Alcoa Laboratories are private corporations in USA, operating on behalf of both their parent company and industrial clients.

[25] The NSTEDB, jointly with the financial institutions like IDBI, IFCI, and ICICI have so far established 15 STEPs in different parts of the country having developed close to 340 technologies till 1999.

3.4.1.3 TIFAC and Home Grown Technologies

Technology Information, Forecasting and Assessment Council (TIFAC) is an autonomous society under the DST which was established in the year 1988, following the technology policy statement of 1983 and the recommendations of the Technology Policy Implementation Committee. The objectives of TIFAC are to promote key technologies, undertake technology assessment and forecasting studies in selected areas of national importance, and to look for global technology trends so as to formulate preferred options for India (TIFAC, 2001). The important programmes and activities relating to promotion of new technologies and entrepreneurs include the Home Grown Technology Programme, Technopreneur Promotion Programme, Technology Project in Mission Mode, Technology Vision 2020, and Patent Facilitating centre.

There are several other programmes on promoting industry-academia interaction. UNESCO has also initiated a programme in the country called the University Industry Science Partnership (UNISPA), which aims *"to match university engineering education with industry needs, transfer research findings from university to industry, retrain practicing engineers, and re-orient university curriculum to cater to every developmental sector"* [26].

3.4.2 Academia-Industry Relations in India

In India, university, industry and government have been trying various methods to create an environment for interchange of knowledge and thereby increase productivity and economic growth. The government has emphasised that education and research must be geared to relevance, competence, excellence, entrepreneurship and development. It is increasingly being advocated that higher educational and research institutions should be involved not only in generating but also in transferring such knowledge to industry and to the society at large. They should act as seedbeds for technological innovation and new industrial ideas. As per Menon (2002), part of the university function can be seen as generators, storehouses and transmitters of new scientific knowledge to science based industries. They are the vital participants in the technology transfer process. The potential growth in new technologies

[26] UNISPO has been initiated drawing upon a similar development in Australia that of Commonwealth Industrial and Scientific Research Organisation (CISRO) that has established useful links with industry. Of the A$ 700 million that is spent by CISRO, one-third of the funds come from industry. The research findings contribute towards industrial development in the country.

has been phenomenal in recent times and it is vitally important for universities and R&D institutions to make their technology and information transfer mechanisms as effective as possible, in terms of both content and communications. Industry-academia interaction is a rarity in India but, with the corporatisation of the economy and the increasing need for trained manpower, corporate organisations are willing to play a proactive role in the development of university and professional education in India (Raghunath, 1997).

3.5 Technology Commercialisation Mechanisms

> *Whenever systematic rational knowledge developed by one group of institutions is embodied in a way of doing things by other groups or institutions, we have technology transfer.*
>
> *Brooks, 1968*

There are two methods through which university technologies are transferred to industry first is the Internal Mechanism, where the transfers take place on the basis of one to one direct interaction between the two entities. The most common of all mechanisms in this category is licensing. The other not so popular are equity participation and start up companies, of which the latter might be an offshoot of the former mechanism. The second method of technology transfer is through institutional intermediaries, which are basically external entities like the government funded technology transfer companies or other private contract research organisations, yet other common commercialization strategies include Informal transfers and Influencing Key Decision Makers.

3.5.1 Licensing

The licensing contracts reflect the overall objectives of the academic institute and the early stage of development of technologies apart from the terms, conditions, and payments as agreed upon in the negotiations between the licensee and the institute's TTO. The licenses could be negotiated to be either exclusive or non-exclusive. Many researchers state that first a technology needs to be protected, and then the choice between exclusive licensing should be made and appropriate licensee (s) found. Exclusive licensing is often necessary to interest private industry. Non-exclusive licensing is more appropriate when the potential market for a technology is large enough to accommodate many firms or when there are many potential direct or spin-off applications of a technology. The term of the licensing agreement depends upon the assessment of the technology in a product market that is often uncertain and thus difficult to evaluate (Feldman, 2002)

Licensing agreements involve selling a firm the rights to use a university's inventions in return for a revenue in the form of a fee usually paid in advance at the time of signing the agreement and/or annual running royalty payments that are contingent upon the commercial success of the technology in the market. The firms are usually required to provide ongoing evidence of their efforts to develop the invention and ability to commercialise it, as well as to report on specific performance 'landmarks.' These firms are also required to provide project proposal, business plan, company specific details like year of incorporation, financial strength, number of employees etc.

The license payments have two general components, initial payments and running payments. Initial payments or generally the lump sum payment are paid at the time of signing the agreement in advance and may include legal expenses, service charges and patent application fees etc. Running payments usually consists of annual royalty as well as 'landmark' payments associated with the agreed-upon dates for technical or regulatory achievements and maintenance. As mentioned earlier the payment amounts for a particular license depend upon the outcome of negotiations between a willing buyer and an equally willing seller. According to Bongirwar (1999), royalty may be defined or understood as one of the specific forms of compensation for industrial property rights or technology developed which is a calculated recurring post payment. It is a function of economic use of the know-how and essentially compensation paid to the licenser by the licensee, calculated on the basis of fixed percentage share of the production or sale of products or services delivered by the licensee on the basis of acquired rights. Arithmetically royalty is:

$$R = (Y * Z) / 100$$

where R=Royalty; Y=Licensee's profit on sales (%); and Z=Licensor's share of licensee's profit[27] (%). The resulting amount should represent an appropriate sharing of additional profits realized as a result of technology transfer collaboration between the two parties. According to Graff et al. (2002), the '25 percent rule' often serves as a simple starting point for negotiations, to justify the contribution of each

[27] This formula is given in the UNIDO Publication, No. UNIDO/ICICS-51, dated November 18, 1977

party to the net profit generated by the invention. In this model, net profits are assumed to result from four distinct activities vital for bringing the technology from laboratory to market: invention, R&D, production, and marketing/distribution/sales. When each activity is assumed to contribute equally, each activity, thus 'earns' 25 percent of the additional profits generated. Thus, if the academic institute is understood to have contributed only the inventive activity, its earned royalty would be 25 percent of the net profit usually before tax. The royalties as specified in the license agreement are normally based on the more reliable measures of gross sales. Therefore if profit is calculated to be 10 percent of sales, the academic institutes' royalty rate will be designated as 2.5 percent of sales.

3.5.2 Equity Participation

The other mechanism, apart from licensing, for technology transfer that many universities are experimenting with is equity participation.[28] In an equity based license agreement the focus shifts from negotiating on price and performance of a technology to agreeing on ownership shares, which means how much stock does the academic institute receive for the right to use the developed technology. The three advantages of opting for equity position as against licensing fees according to a study done by Feldman et al. (2002) are that firstly, equity provides a university with options or financial claims on a company's future income streams, secondly, since the equity alternative offers part ownership of the company, the interests of the university and the firm are aligned towards the common goal of commercialisation of technology and finally the advantage lies in the fact that equity may serve a certification function that provides a signal to relevant third parties that the university is entrepreneurial.
That equity participation has emerged as a technology transfer mechanism holds true because there has been a considerable increase in the number of patents filed by the universities and also in the number of universities filing them (see Henderson et al., 1998; Mowery and Ziedonis, 1999). This corresponds to an increase in the number and size of technology transfer offices (for details see Seigel et al., 1999; Thursby et al., 2001). The other benefits of equity deal are that they invite less matters of dispute as both partners share in all value created; that it provides legitimacy and prestige to both the firm and the university, that they are easier to write[29], that with a high number of equity deals,

---

[28] The studies by Feldman et al. (2002), Thursby et al. (2001) and Jensen and Thursby (2001) among others give an account of universities in America which consider equity participation as a technology transfer mechanism for promoting the commercialization of academic research and generating revenue from university intellectual property.
[29] The argument for this according to Feldman is that equity agreements center on the delineation of property rights and do not involve the specification of the large number of contingency terms that a traditional license does.

universities generally gain an affirmative reputation for being progressive and entrepreneurial. (Feldman et al., 2002)

In the Indian context however the academic institutes should look before they leap. Equity could be riskier because of its sheer novelty, where very few institutes, if any have had any experience with this technology transfer mechanism. Further, while the traditional and at present the most common mechanism, licensing are narrowly bound between lump-sum payments and running royalties, returns from lump-sum payments are certain.

3.5.3 Start-Up Companies and Technology Business Incubation

The incubation program provides an opportunity for faculty, students and alumni to start companies within the academic campus. Companies in the incubator program provide employment opportunities for graduates of the university and when they grow and graduate from the incubator program it is believed that they will stay in the region and create additional job opportunities. The Technology Business Incubator is another mechanism to provide advisory, training and information services, management and marketing support, linkages to research faculty and facilities, access to capital, thereby greatly enhancing the chances of success of the early stage Technopreneur (Lalkaka, 1996).

Often entrepreneurs set up their business with the help of university support be it technology, faculty or infrastructure. These are the start up companies, usually more in the new developing fields of information technology and biotechnology. While many start ups may fail within a few years as the technology itself fails to prove viable and financiers pull out, on occasion university based start ups may grow into major industrial contenders[30] (Graff et al, 2002).

One of the challenges of any incubator program is to provide incentives for companies to stay where they were started. The most significant difference between traditional incubators and university

[30] Several major employers in the San Francisco Bay that spawned with university TTO involvement include Sun Microsystems, Cisco Systems, Chiron and Genentec. Often the successful start-ups, based on university technologies are acquired and absorbed by larger corporations who seek out the technology or expertise developed by a start-up to complement their own R&D initiatives. Cetus eventually purchased by Chiron, Calgene a start–up at UC Davis.taken up by Monsanto.

incubators is the importance of a theme or clear focus of the university-based incubator (Zucker et al., 2002). For faculty and students to interact with the companies in the incubator there must be a match between the academic or research strengths of the university and the type of companies recruited to the incubator program. For instance, if the university strength is in the life sciences, then the companies may be biotechnology, bioengineering or pharmaceutical related. University-owned patent rights facilitate this process in part by providing a source of exclusive rights to assure private firms that successful products would be profitable.

3.5.4 Other Commercialisation Strategies

3.5.4.1 Informal Transfers

Many universities discoveries are transferred to firms informally. According to Kneller (1999), the informal transfers occur in many ways. Professors consult with companies, corporate researchers working in university laboratories communicate research results back to their companies. Graduates find employment in companies. The informal system of technology transfer can be very efficient if there is a proper understanding and 'rapport' between the inventor and the firm that is if the firm is willing and able to develop the inventor's discoveries. Transaction costs are low; no funds need to be paid to support the operations of TTO, as marketing and licensing has already been done by the inventor and the firm.

However, the informal system has many disadvantages. It does not have a mechanism to select the most appropriate industrial partner among the potentially interested firms, relying instead on pre-existing relationships between individual researchers and firms. It also does not have a mechanism to ensure if the firm will actually develop and market the technology. The informal system has no means to educate university researchers about the commercial value of their research and the importance of protecting intellectual property rights. Further the disadvantage lies in the fact that unlike the formal system like TTO, there is no mechanism to collect data on technology transfers as they occur, to understand the weak and strong points through failure and success cases of transfers as the outcomes of such transfers are not known. Finally, because the official procedures and formalities are bypassed, firms may be concerned whether the university invention that they obtained gives them the legally enforceable rights.

3.5.4.2 Influencing Key Decision Makers

The application and adoption of R&D results is sometimes best accomplished by carefully identifying and 'influencing key decision makers' targeting information and incentives for key decision makers has the potential advantage of a higher response rate relative to an untargeted outreach approach (Brown et al., 1991). This strategy involves (1) identifying the key decision makers(KDMs) who are inhibiting the use of a particular technology, (2) conducting market research to determine why there is resistance and how to reduce it, and (3) implementing a technology transfer programme aimed at influencing these KDMs. However in some industries and in firms there may be so many intermediaries that this strategy may not be workable. Here one should also be on a look out for KDMs who would support the technology transfer be it a highly acclaimed academician, an industry professional or a government official. In some of the cases it is also seen that people in politics come to rescue, yet it is believed by most of the respondents that they hinder more than aid in this strategic move.

3.6 Studies on Success and Failure of Technology Transfer

Significant previous studies on technology transfer have identified key factors that either stimulate or stifle the technology commercialisation process. Even though most of these studies have been carried out clearly looking at the technology transfer process from National or Public/Private Research and Development laboratories to industry, they stimulate many issues and give much insight, when technology commercialisation takes place from academic institute to industry. The Science Policy Research Unit at the University of Sussex carried out Project SAPPHO (SPRU, 1972) which brought forth the key factors that distinguish innovations, which have achieved commercial success from those which have not. The study presumes that innovation is a complex sequence of events, involving scientific research and technological development, management, production and marketing. Therefore single factor interpretations are less than satisfactory and allowance must be made for multi-factor explanations. The study comprised of examining 29 pairs of successful and failure cases, 17 in chemical and 12 in instruments industries. The results indicate a consistent pattern of differences between success and failure in innovation, which can be summarized in the following five statements:

User Needs: Successful Innovators have a much better understanding of the user needs conversely, the neglect of user needs or failure to address and interpret such needs in the R&D work leads to the failure in innovation.

Marketing: Successful innovators pay much attention to marketing, whereas failures are characterized by neglect of market research, publicity and user education and failure to anticipate customer problems.

R&D Strength: Successful innovators perform the development work more efficiently, but not necessarily more quickly. They eliminate technical defects from the product or process before they launch it.

Communication: More effective use of outside technology and scientific advice by successful innovators is done, even though most of their development work is done in-house.

Management Strength: The responsible individuals in the successful innovations are usually more senior and have greater authority than their counterparts who fail. The greater power is reflected in satisfactorily controlling the project, establishing effective internal and external communication networks and integrating the project into overall company strategy.

In the study by Doctors (1969), barriers in the process of technology transfer are highlighted, which in a way suggest that removing these barriers would result in a successful innovation. According to him the possible barriers are insufficient mission orientation of the technical personnel in most of the agencies, conflicting policies concerning legal rights to patentable innovation and other proprietary data, Institutional barriers to information flow, vertical nature of institutions for transfer, low value being placed on the transfer function by scientific and technological personnel engaged in federally sponsored R&D, poor and antiquated methods of information & retrieval and poor understanding of the process among several others. The study by Schwartz concludes that innovation, whether based on internal ideas or transferred technologies is a manageable process. It is bad decisions rather than technical or informational deficiencies that influence the success of innovative efforts.

Based on a survey, Rothwell (1977) summarizes the key factors for an innovation to succeed, which include having good communication and effective collaboration both at the inter and intra-firm level between institute and industry, the use of careful planning and management techniques, having an organic and open management style with both commitment and enthusiasm for each project, understanding the influence of government assistance, being responsive to recognition of user needs, ensuring the presence of important individuals, and paying attention to after-sales-service.

The mechanisms that trigger an innovation have been examined by several researchers. From a review of several studies on technology transfer, it was noted (Utterback, 1974) that 60-80 percent of important innovations in different fields have been in response to market demands (need-pull factor), and the remaining 20-40 percent have their origin from scientific and technological advances or opportunities.

Table 3.1: Need-pull Vs Technology-push Factor in Technology Transfer

Authors	Proportion of innovation from needs of market production or government (%)	Proportion of innovation from new technical opportunities (%)	Sample Size
Baker et al.	77	23	303
Carter and Williams	73	27	137
Goldhar	69	31	108
Shervin and Isenson	66	34	710
Langrish et al.	66	34	84
Myers and Marquis	78	22	439
Tannebaum et al.	90	10	10
Utterback	75	25	32

Baker and Rubenstein (1967) postulated that two events are necessary precursors for the generation of an idea for innovation. (I) need event, i.e. recognition of the need, problem or opportunity which is perceived to be relevant to organizational objectives; and (ii) means event i.e. recognition of a means or technique by which to satisfy the need, solve the problem or capitalize on the opportunity. From a survey of innovations, they found that the 'need event' usually occur prior to the 'means event'.

Studies[31] have shown that only a small subset of invention disclosures generate any commercial interest which further aid in technology transfer from university to industry. The rule of the thumb in university technology transfer is that for every 100 invention disclosures, 10 patents and 1 commercially successful product result. (Blake, 1993)

[31] The studies include work done by Jensen and Thursby (2001), Mowery et al. (1999), Feller et al. (2000). In a survey done by Jensen and Thursby it was evident that only about 12% of the licensed technology is ready for commercialization. The majority of licensed technology requires significant development work and ongoing cooperation by faculty to realize commercial success.

Although studies have been done in India examining the cases of technology transfer (Nath, 1988; Qureshi et al., 1984; Subrahmanian, 1985; Desai, 1980) they are limited in number and are done on public funded research laboratories. Morehouse (1977) has noted that scientists in the laboratories are not sure about the economic feasiibiity of the inventions before the research is performed and actual bench scale results are obtained. Further most of the studies indicate that scientists are mostly concerned with publication of their research results rather than pursuing the planning of R&D activitiesbeyond bench scale resultsfor opening up opportunities for commercialisation. The importance of pilot plants in successful technology transfer has been highlighted in the above studies. The studies say that even if the technology is passed to a genuine entrepreneur, the work at the pilot plant level goes a long way to check premature or exaggerated claim of the scientist and thus avoids later failures of technology.

The notable factor in most of the studies is that they focus either on the supply side (university or R&D institutions) or on the demand side (firms or industries) and there are not many studies done considering the two entities simultaneously, by getting feedback from both sides on select individual cases of technology transfer. This study is an attempt to do so.

3.7 Barriers to Collaboration

One of the main barriers to develop increased collaborative links with industry is lack of internal resources at both individual and institutional level. The faculty at the individual level have increasingly less time to both establish and undertake collaborative projects with industry in addition to their teaching and administrative responsibilities at the university. Moreover the continued emphasis traditional outputs for academic work such as publications means that collaborative industrial research and development is not valued, except as a source of income. Therefore there is a distinct lack of motivation to undertake applied research or technology development activities related to firms (Evans, 1998). The other problem in university-industry interaction is that there is a widening of gap of knowledge between research and industry personnel. The organizational culture is different which is affected by the fact that there is a lack of communication between the two, about the merits and demerits of collaborative research and activities.

The problems also lie in the priorities of each entity relative to the research results produced from collaborative projects. Whilst the firms require research results either to be patented or, in some cases, to be kept confidential, the career structure of academia, based on published works, requires that the collaborative R&D be placed in a scientific journal. Thus the links with industry can, in some cases, restrict free flow of information. As a result, the impression exists that the lack of academic recognition for commercialisation and rewards for publications as opposed to patents, is a major barrier. The universities also have a bureaucratic structure and as a result, many small firms can have problems in dealing with the labyrinthine procedures of the academic institution. (Evans, 1998)

3.8 **Focus Literature on the Impact of Academic Research**

University transfers knowledge to Industry through various channels. The channels under consideration in previous studies include some subsets of publications, patents, consulting, licensing, research contracts, informal meetings, recruiting, joint ventures and personal exchanges.

Most of the literature on industrial impact of academic research and knowledge transfer from university has focused either on the role of patents and publications in the transfer process[32] (Adams1990, Henderson et al. 1998, Jaffe et al. 1993) or on consulting, sponsored research on institutional ties (Cohen et al. 1998; Mansfield 1995; Zucker et al. 1994, 1998). Several recent papers provide evidence on the nature of university licensing (Jensen and Thursby 2001, Mowery et al. 2001 a,b, Mowery et al., 2001; Siegel et al., 1999; Thursby et al., 2001; Thursby and Kemp, 2001). More recently there is an attempt to comment on the growing policy debates on Bayh-Dole Act of 1980 in USA, which gave the right to license inventions from State funded research (Mowery et al., 1999; Thursby and Thursby, 2002)[33]. The study by Thursby and Thursby shows that changes in the direction of faculty research appear relatively less important than other factors, such as the dramatic increase in the propensity of administrators to patent and license faculty inventions. The authors find that licensing growth has resulted largely from an increased willingness of faculty and administrators to engage in licensing.

[32] There has been heavy focus and emphasis on patents and licenses due to the accessibility of patent data that lends itself well to quantitative analysis.

[33] Here one may also mention that the similar 1998 Technology Transfer Law in Japan does not alter the basic principle that inventors retain the right to patent their inventions; yet it gives them the option of assigning their inventions to technology transfer offices but does not require them to do so.

Cohen et al. (1998, 2000) examine the relative importance of the set of transfer channels from the perspective of the knowledge recipient firms. Shane (2000) investigates the question of when it is best for a university to license an invention back to the inventor by considering the effectiveness of different transfer channels subject to the nature of the technology and its appropriateness. Within the context of licensed patented inventions, Colyvas et al. (2000) examine the importance of transfer channels that complement patent licensing across different types of technologies. They explore in significant detail how particular university inventions moved into practice, by studying a unique data set comprising of eleven case studies of inventions from Columbia and Stanford University derived from invention report records and interviews with licensing officers and licensee firms. The study is motivated by the belief that the dramatic increase in patenting, which is commonly attributed to the passage of Bayh-Dole Act of 1980, was actually passed by other factors including the maturing of important new areas (read information technology and biotechnology) and techniques of university research such as molecular biology, electronics and software. The act merely amplified an increase in university technology transfer that was already happening. Their work also explores the role of Intellectual Property Rights and role of Technology Transfer Office (TTO) in facilitating technology transfer from university to industry.

Feldman et al. (2002) emphasize on the increased use by university licensors of equity investment as a tool for technology transfer and commercialisation. The authors explain the inter-institutional differences by developing a behaviour model in which the use of equity is conditional on licensing experience, past performance, TTO operations and the organizational structure of the university.

Further, a lot of work has been done on university research affecting innovation, the study done by Cohen, Nelson and Walsh (2000) examine the effects of university research on industrial R&D and the mechanisms through which these effects exercise their influence. The work by Owen-Smith et al. (2002) address the relationship between university research and innovative activity in biotechnology firms and examines how they vary between United States and Europe. This work thus explicates the different paths of evolution in the biotechnology industries of each region, by comparing the ties that link public and private research institutions, and research universities in USA and Europe.

There have been a limited number of literatures focusing on the role of new firms as vehicles for commercialising university inventions. The university faculty, staff, and students were more likely to find firms to commercialise their inventions when these technologies did not enjoy strong patent protection. Non-inventors were more likely to commercialise those inventions, however when patent protection was strong (Shane, 2000). Zucker et al.(2002) focus on the role of scientific talent in the creation of university start-ups when they argue that scientific ability is central to the founding and performance of new biotechnology companies. They also examine the effect of the scientific ability of biotechnology firm's founders on performance of new biotechnology firms. They find that firms founded by "star scientists" outperform other firms even after accounting for the location of these firms and the amount of venture capital they receive. Shane and Stuart (2002) examine the related question of why some university start-ups are more successful than the others. They observe that the magnitude of venture funding is an important determinant of the likelihood of a successful Initial Public Offer (IPO).

According to Webster and Etzkowitz (1991) a wide range of collaborative links as well as intermediary agencies through which academic research can be commercialised have developed. Apart from the traditional short-term contract-research relationship, joint programmes between academia and industry or government research centres (Gluck, 1992; Blumenthal, 1992), regional technology transfer networks (Sheen, 1992) and incubator facilities (Seigel et al., 1999; Thursby et al., 2001; Venancio, 2000) have grown in the area of technology transfer from academia. However the extent to which these changes herald an evolutionary shift in the form of linkages between academia and industry needs to be debated (Peters, 1987). Moreover the costs that these interactions involve need to be discussed (Slaughter and Rhoades, 1990).

It is well known that the time lag between a discovery in the laboratory and its application in industry has been decreasing rapidly during recent years. Studies have shown that with closer university-industry cooperation this can be shortened even further and the benefits of the latest advances in scientific knowledge and innovation can be made more readily available for the welfare of the society, thus enhancing the image of science (Mehrotra, 1982). Berman (1990) has shown that, despite an estimated lag in converting research into hard products or processes in the market place, "collaboration not only increases future industrial research, but also speeds up the transfer and utilisation of academic research in industry".

3.9 Role of Technology Transfer Office (TTOs) in Facilitating Technology Transfer

Thus, there has been a growing amount of research, attempting to examine the relationship between academia and industry in the last few years. However these studies have failed to discuss, in any real depth, the important role that the industrial liaison office (or its equivalent function within the university system) can play in the technology transfer process (Evans, 1998). The views from limited pool of experts in this area nevertheless provide much insight into the role of technology transfer office in academic institutes, which is a rather new phenomenon in India. Limited studies have been done on the role of technology transfer offices (Graff et al., 2002; Etzkowitz, 2002; Teece et al., 1997) but they are mostly based on studies done in large universities in USA and Europe. Organisational innovations like technology transfer offices provide a window on academic discoveries with commercial potential and a point of contact to reach the academics who originated them (Etzkowitz, 2002). The creation of technology transfer offices have introduced organisational changes that have created many new opportunities for technology commercialisation and have made academia-industry relationships more transparent and efficient (Graff et al., 2002). Academic Scientists differ greatly in their interest in realising financial gains from their discoveries and in their ability to pursue the practical implications of their research. Even if they do not have a pecuniary motivation themselves, TTOs can make arrangements to protect and license discoveries on their behalf and that of institute (Etzkowitz, 2002).

The importance of having a separate unit, yet being a part of the institute has been emphasised by researchers. The skills necessary for successful technology commercialisation are largely tacit and are developed through a process of learning–by-doing (Teece, 1981). As a result these skills are not sold effectively in markets (Teece et al., 1997). The best solution for university technology commercialisation requires that economic actors who have a comparative advantage in that activity should commercialise that technology. On the average, the inventors of university technology do not have a comparative advantage in technology commercialisation. Technology commercialisation involves a set of skills– including identifying customer needs, developing product concepts, designing products and processes, prototyping, and manufacturing–that university inventors rarely possess (Shane, 2002). In the absence of problems in market for knowledge, the licensing of inventions to those advantaged in technology commercialisation provides a mechanism for allocating inventions to those actors who are best able to commercialise them (Teece, 1980).

In many institutions, the industry liaison function is not seen as an important part of the overall administration of the academic institute. This is despite the belief that technology transfer office is the primary formal route by which links between the educational institution and external organisations are created. In some academic institutions, the linkages with industrial firms are driven at the departmental level, like in other IITs today, often the reason being the absence of any substantial administrative support. This in many cases is due to a lack of resources being made available to support the operations of technology transfer office.

3.10 The Role of Intellectual Property Rights in Facilitating Technology Transfer

Even though research collaboration between university and industry has a long history, recent changes in the character of this relationship, especially the growth in university patenting and licensing of technologies to firms in different industries, have attracted considerable attention. As the academic institutes are not in a position to develop new discoveries into commercial products, they do need to attract commercial licensees to invest in further development, it is believed that university-owned patent rights facilitate the commercialisation process in part by providing a source of exclusive rights (as also non-exclusive) to assure firms in the industrial sector that successful products would be profitable.

Various researchers and experts have noted the importance of protecting intellectual property. In order to license a technology and preserve its commercial value, it must be protected as a patented invention, copyrighted material, or technical data (Brown et al, 1991). The award of a patent confers a temporary monopoly on an invention, in exchange for the publication of its details; it is an attempt to reconcile the interests of inventors to protect and profit from their investments in invention, with those of society to diffuse information about inventions as widely as possible (Venancio, 2000). According to Kneller (1999), exclusive IPRs are particularly important for small companies, which depend on exclusive control over technology to attract the capital necessary for product development and commercialisation. These become even more significant in certain industries, such as biotechnology and pharmaceuticals, where the costs of developing and proving the safety of new products are high whereas the costs of imitating final products are low moreover small businesses are frequently the test beds for embryonic university technologies. As the titles of patent remain with academic institutes, it is generally believed that a state sponsored research carried out in them, would not only facilitate technology transfer, but would also encourage industry to share the costs of academic research. It becomes easier for institutes to attract industrial funding for related research in the institute, because the industrial sponsors are not necessarily concerned that they will lose the rights to develop any commercially interesting discoveries that come out of the research because of government patent policy.

If title to a patent is held by a non-commercial institution, the discovery will have to be transferred to the private sector for commercial development, whether the patent holder is the government or a university. If technology transfer will be necessary in either case, there is no reason to believe that commercial development will be more likely if patent rights are owned by the university or other non-profit institution at which the invention was born than if they were owned by the government. (Colyvas et al., 2002)
Patents granted to academic institutes still reflect only a very small part of the practical value of academic research. These institutes account for a disproportionately small share of total patenting. The primary reason for this is that the main practical benefits of basic research are not codified and legally protected inventions, but trained researchers, instrumentation, techniques and membership of international networks (Venancio, 2000).

To sum up

We see that the state of academia-industry interface and its consequent benefits, the impact of academic research on industry, and the voluminous literature reflect the importance of industry-academia relations. The present state of academia-industry interaction in India also shows the growing concern of policy makers towards building up of infrastructure and other such mechanism that promotes better relations between the two collaborative partners. The discussions through literature survey highlight the knowledge transfer through various channels be it publications and patents, consultancies and research contracts, licensing and equity participation, informal meetings and personal exchanges or through recruiting and joint ventures. The literature review also discuses the role of the technology transfer office and role of intellectual property rights in facilitating technology transfers. Since the TTOs have an important role in the commercialisation of technologies developed in the academic institutes, the next chapter deals in great detail the role of TTO, its activities and achievements so as to better understand the positive and negative factors that eventually would lead to bridge the divide between academia and industry.

4.0 The Technology Transfer Office of IIT Delhi: Brief Outline and Achievements

Organisational innovations like technology transfer offices provide a window on academic discoveries with commercial potential and a point of contact to reach the academics who originated them.

Henry Etzkowitz, 2002

This chapter focuses on the technology transfer office, its origin, activities, and achievements over the last five years starting from 1997, and attempts to assess its role as an industry liaison agency. Technology transfers done through TTO have been discussed in detail in the last section which precedes the section on the emerging issues and problems.

4.1 The Foundation and Objectives

Technology Transfer office was registered as an autonomous society: Scientific and Industrial Research Organisation (SIRO) on the 9th of July 1992 with a view to achieve quantum jump in the level of collaboration and interaction with industry and other user organizations on programmes and projects of mutual interest. The foundation was established by a resolution of the Board of Governors of IIT Delhi and supported by a Corpus Fund provided by the Ministry of Human Resource Development of the Government of India (Sengupta, 1999). It has continued to pursue its mission "*to be an effective interface with the industry to foster, promote, and sustain commercialisation of Science and Technology in the Institute for mutual benefits.*"

The objective of TTO as per its annual report (2001-02) is to promote interaction between the Academia and Industry in a proactive manner to create greater measure of trust and collaborative work, which benefits both. Ever since its inception, TTO has been directing its efforts as an effective interface between Academia and Industry by marketing the 'intellectual-ware' of IIT Delhi to industry on competitive terms and injecting industrial relevance to the institute's teaching and research activities.

The 'intellectual-ware' of IIT Delhi comprises of a little over 440 faculty scientists and researchers who are the primary source of innovation, which in effect is the outcome of several years of research and development and technology development efforts as also of their present scientific endeavour. However given the fact that teaching and research supervision is the primary activity of academic institute, typically 15-20 percent of the faculty is involved in work with industry.

Linkages between TTO and Industrial Research and Development Department (IRD)

Prior to the formation of TTO, the industrial liaison function was undertaken by the IRD alone. At present the IRD department and TTO play a complementary role and have a standing committee as the formal link between the two. The recommendations of the standing committee with regard to having a closer association with TTO explicitly states that IRD unit will be the primary coordinating point in IIT Delhi for locating potential technologies while TTO will process their transfer to the market place[34]. In addition TTO will on its own try to locate transferable technologies. The long term projects falling under the generic and sponsored research and funded by government department or agencies will be processed through IRD unit and those projects that have been taken up by IRD unit but leading to new technology or product may be transferred to TTO to complete the technology transfer in consultation with the sponsor. Innovative consultancy and retainership proposals can be processed through IRD unit or TTO at the discretion of faculty. However any proposal brought up at the initiative of TTO or IRD unit will be processed through the initiator. An individual faculty member may, however also directly approach TTO for commercialising a developed technology or software. In such cases, TTO may, if necessary, approach IIT Delhi/IRD for necessary registration and assignment prior to finalising any agreement with a potential industry client.

4.2 Activities of TTO

TTO actively interacts with potential industry enterprises in order to bring research partnerships and technology transfer projects and industrial consultancy assignments.[35]The important activities of TTO

---

[34] From the standing committee minutes dated 10/12/1993; official documents – IIT Delhi.

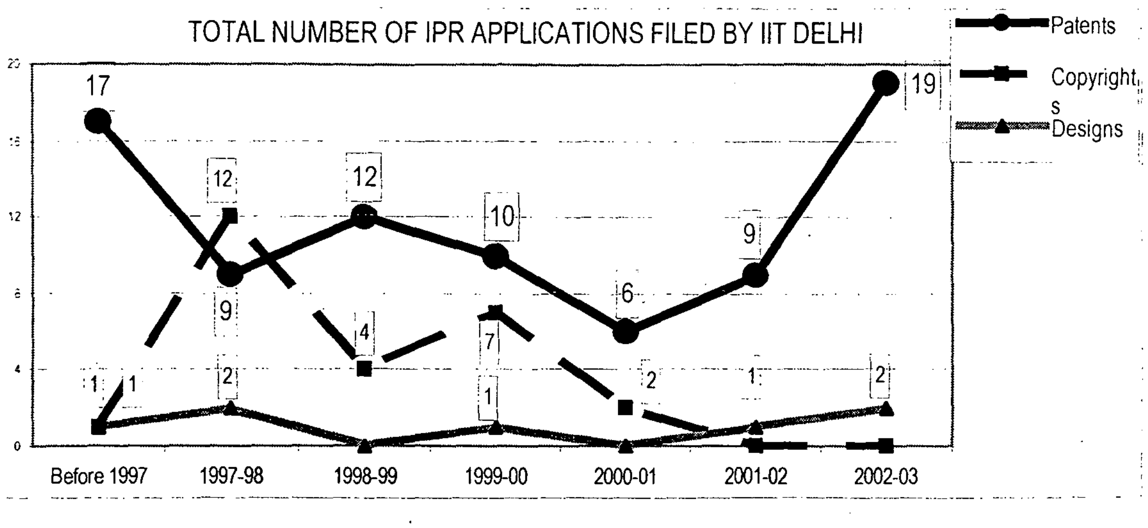
[35] Subsequent to the decision made by Board of Governors in a sub-committee, with regard to functioning of TTO, it was decided that TTO would not engage itself in sponsored research and routine consultancy assignments involving testing, evaluation, vetting of designs etc. and rather focus on its core objective of technology transfer and liaison with industry.

include Technology Transfer, Intellectual Property Rights (IPR) activities, Technology Development and Industrial Consultancy, Human Resource Development activities, building trust through offering corporate membership of TTO, Marketing of Educational and Video Programmes, and Information Support Services. The above-mentioned activities are achievable by reaching out to industry through visits, newsletter, seminars and lecture demonstration, participating in technology/trade and business exhibition and Internet among other networking means.

4.2.1 Intellectual Property Rights (IPR) Activities

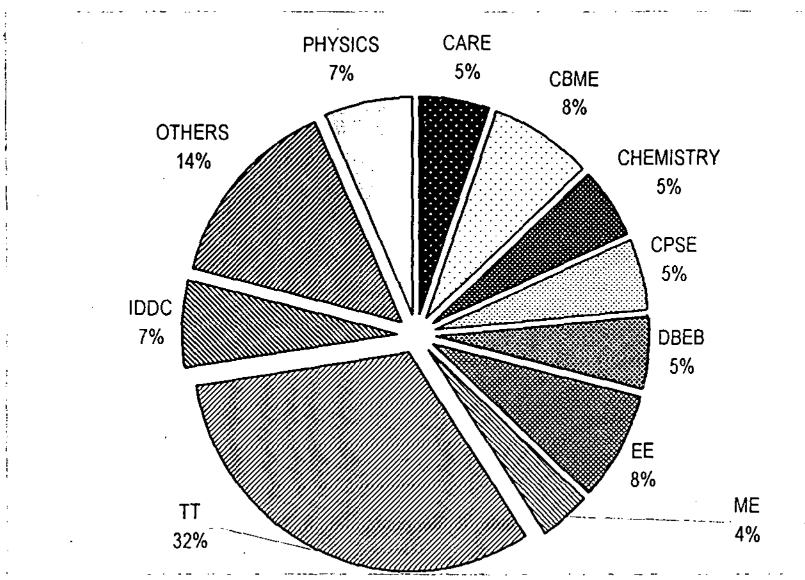
The intellectual property essentially includes patents, copyrights, designs and trademarks. One of the important functions of TTO is to file and register intellectual property rights on behalf of the inventors and scientists responsible for creating intellectual property when they make scientific and technological advancement and develop new technologies and/or its applications. The role of faculty members as IPR holders is becoming increasingly important especially in the context of growing industry-academia collaboration. According to Etzkowitz and Webster (1998), as faculty become more knowledgeable about business, they are able to take the role of someone in industry and relate to them from a business stance, protecting their intellectual property in which they and the university have a financial interest. The relationship of the faculty member to the university has also been revised to take account of this change in orientation to knowledge as potential intellectual property. There has been a substantial increase in the number of IPR applications from IIT Delhi faculty members since last three years as can be seen from the given chart. (Chart 4.1)

Chart 4.1 IPR Applications filed by IIT Delhi



There are more than 23 departments and centres in IIT Delhi, but not all contribute in terms of developing new technologies and getting intellectual property rights. The given pie-diagram reflects the IPR status and percentage share of different departments that are engaged in research that may create inventions at a later stage.

Chart 4.2: IPR applications filed/granted across different departments in IIT Delhi (1997-2002)



4.2.2 Industrial Consultancy and Project Assignments

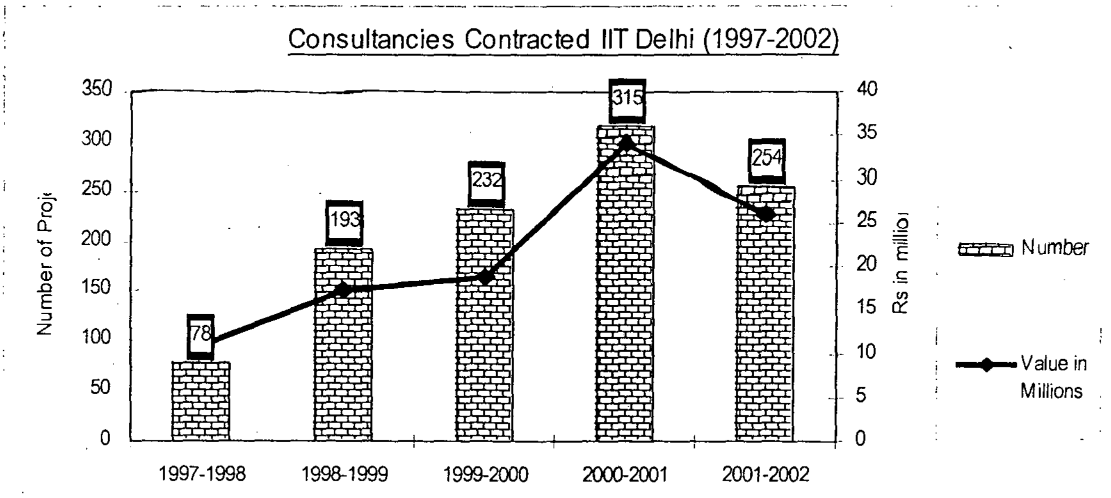
Technology transfer from an academic institute to industry is believed to be a step-by-step process, where scientists and researchers make incremental efforts in pursuance of various short and medium term[36] innovative consultancy assignments. Since 1993, TTO has been involved in taking up such projects and giving it to the IIT-Delhi faculty members, individually or collectively. Consultancy is usually considered as the single largest factor in establishing a rapport between academia and industry in advanced countries.

The chart (4.3) reflects that the consultancies are the most popular way of industry-academia collaboration. The numbers of consultancies are increasing, except for the last financial year, which on

[36] In general, the long-term projects are built upon the outcomes of various small and medium term projects.

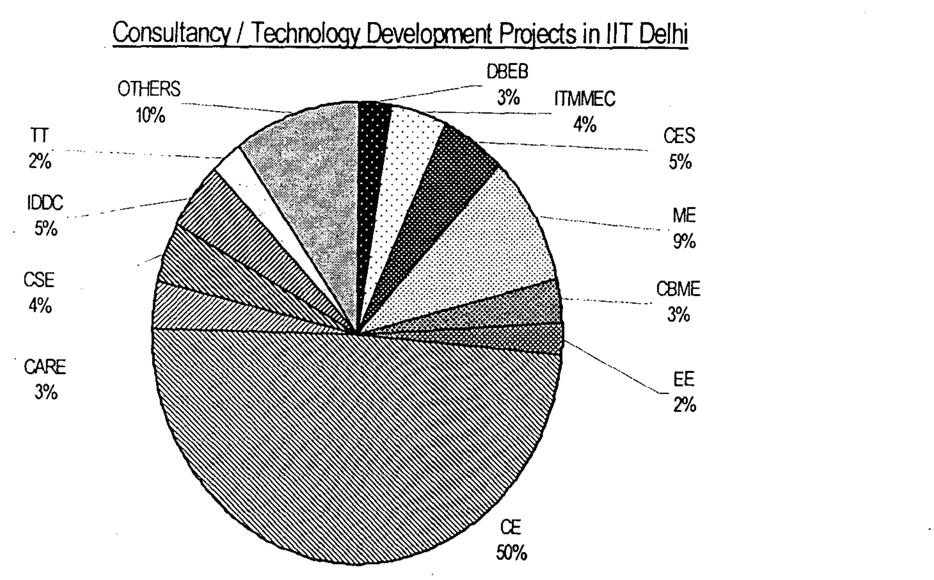
an average for a period of five years, have earned the institute Rs 21.4 million annually. It is convenient for faculty to be a consultant to industry since they can conveniently manage their time for the same.

Chart 4.3 Consultancies Contracted



However as per the recommendations of the TTO review committee in May 2002, it was decided that TTO would focus on its prime objective of technology transfer and liaison with industry and will not engage itself in sponsored research and routine consultancy assignments involving testing, evaluation, vetting of designs, in routine HRD programmes or short courses etc. It may however, handle projects from industry aimed at development of products, processes, techniques and models involving investigation and research inputs having potentiality in technology development and transfer.

Chart 4.4: Consultancy/Technology Development Project across Different Departments (1997-02)

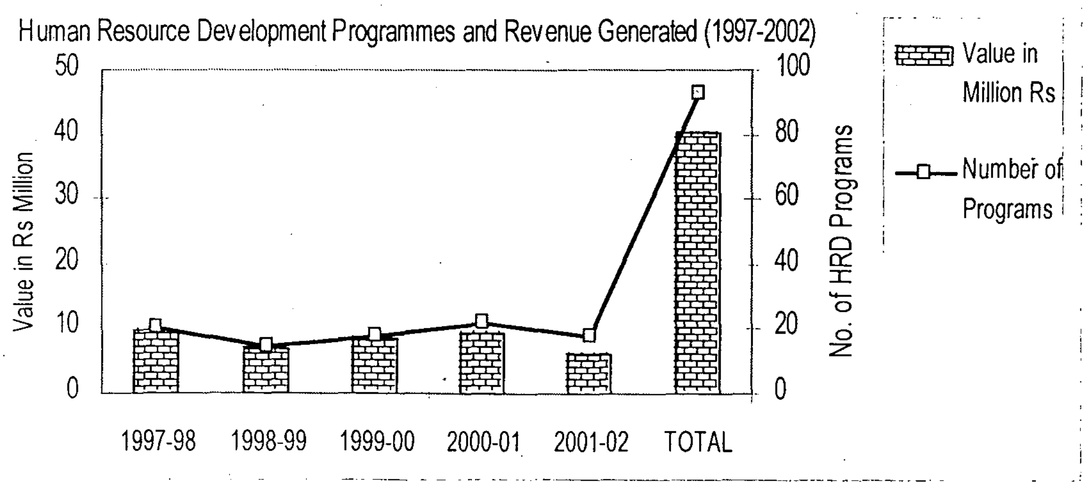


As is evident from the chart (4.4), the department of civil engineering has the maximum number of projects but on closely studying the nature of projects it shows that very few of them can be scaled up for further development and technology transfer. This statement is supported by the fact that the number of IPR applications filed by civil engineering department is comparatively very low with respect to other departments like Textile Technology, Physics or Electrical Engineering.

4.2.3 Human Resource Activities

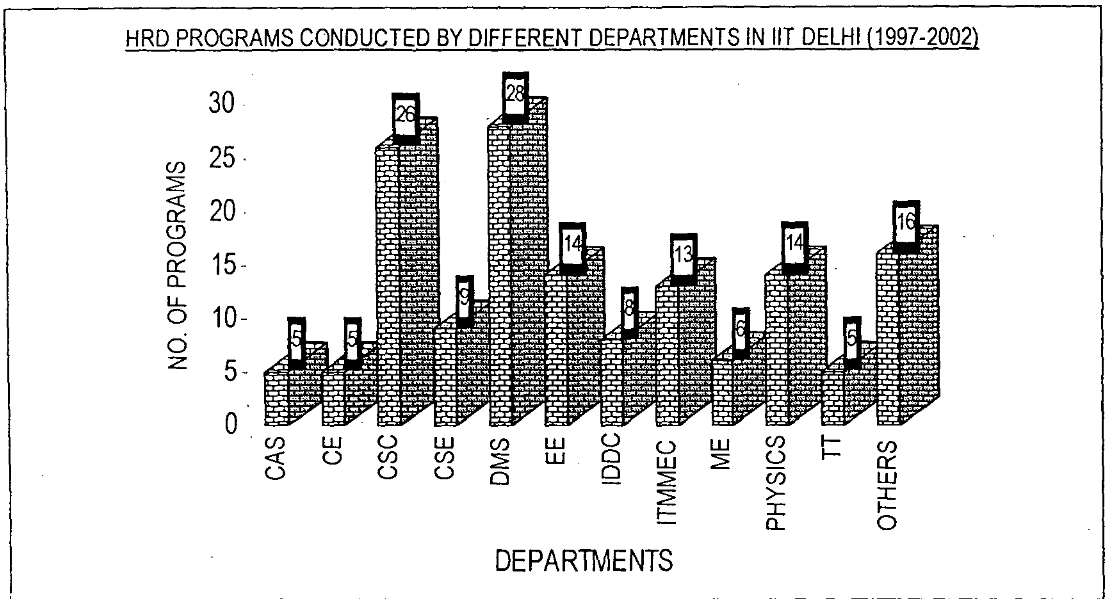
Human Resource Development programs are believed to be activities that initiate projects on technology development and transfer apart from the traditional importance they hold in knowledge transfer. Specialised programmes are conducted by different department in IIT that not only generate revenues for the institute, but also contribute in knowledge exchange benefiting the faculty, students and people from industry and other participants. The given chart (4.5) gives an account of number of programmes held annually and the revenue generated.

Chart 4.5: Human Resource Development Programmes and Revenue Generated



The chart 4.6 gives the number of HRD programmes conducted by different departments in IIT. Thus we see that there are certain departments, which are actively involved in this exercise. These programmes also provide for an environment where industry and academia interaction takes place, which often result in better understanding of subject matter and knowledge enhancement as also in technology development projects and consultancy assignments for the academic institutes.

Chart 4.6: HRD Programs Conducted in IIT Delhi



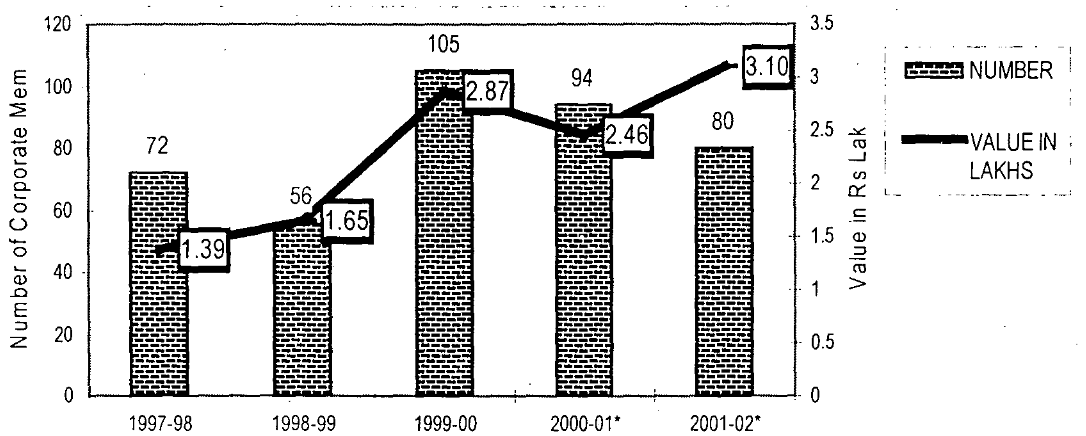
The departments like Management Studies and Computer Services have the maximum number of Development and Training programs, as these are in great demand by the people in industry and also in government departments. Specific 'tailor-made' programs are also designed and conducted for select industry / government personnel by the different departments. Here (chart 4.6) we do find that departments like Physics, Electrical Engineering and Computer Science are active implying that there are specific subject areas where industry is highly interested.

4.2.4 Corporate membership of TTO

Under the information support services, started in 1992, TTO has a corporate membership scheme in which industry, industry associations, R&D organizations and financial institutions are invited to access details of the technological developments, research activities and in general engagement of faculty in different projects and consultancy assignments of the institute. This is comparable to the technology transfer offices elsewhere in the world for instance in Japan, the membership to a TTO confers the right to see lists of available technologies, sign confidentiality agreements to obtain detailed information about these technologies, and have first rights of refusal in licensing. After six to nine months, if no member takes a license, non-members are able to sign confidentiality agreements and negotiate licenses.[37]

In the TTO at IIT Delhi, the corporate membership generates on an average a sum of Rs 2.3 million annually (based on 1997-2002) see chart (4.7). Here there is very little exchange of information for mutual benefit and for firms it becomes more of a prestige issue to be associated with a premier institute like IIT. Small firms usually also use IITs name for enhancing their brand image and 'goodwill' especially for procuring loans from banks and other financial institutions.

Chart 4.7: Corporate Membership and Revenue Generated at TTO (1997-2002)



The corporate membership fees of Rs 10000 is charged from an organisation whose annual turnover is 1 billion and above (Category A) while for the medium scale industry (turnover between Rs 25 million and 1 billion) the corporate membership fees is Rs 5000 (category B). The R&D organisations and financial institutions need to pay the same amount (category D) while small scale industry are required to pay Rs 1000 only if their annual turnover is less than Rs 25 million (category C). The scheme also tends to benefit the faculty at IIT Delhi as it keeps them informed of details on industry, in and outside India.

[37] The given statement is in reference to the TTOs of three major National Universities, the Tokyo Institute of Technology, Tohuku University and the University of Tokyo in Japan as given in Kneller (1999)

Table 4.1:

Corporate Membership: Number of Firms in Large (A), Medium (B), Small (C) and R&D (D) Sector

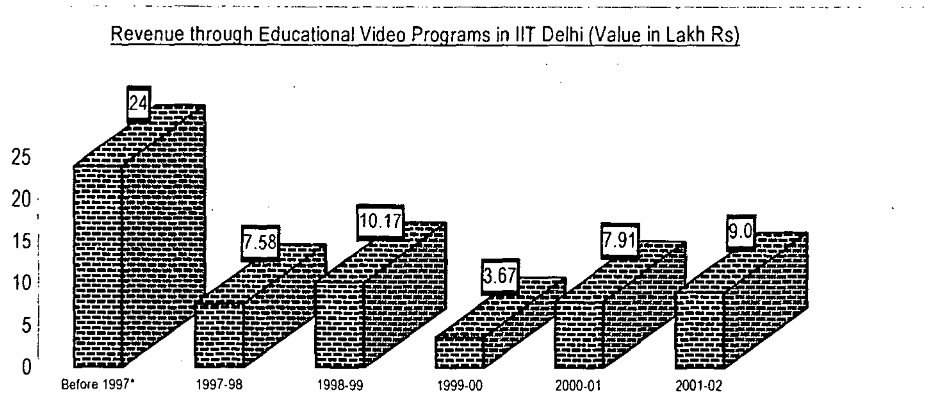
Year	Category A	Category B	Category C	Category D
1997-98	10	23	34	5
1998-99	9	19	22	5
1999-00	14	32	48	11
2000-01	13	24	45	10
2001-02	11	19	41	9

From the table (4.4), it is evident that small-scale enterprises having an annual turnover of less than Rs 25 million constitute nearly 58 percent of all categories of firms belonging to large and medium scale industries. If we compare this with the cases of technology transfers, we would find that most of the licensees are these small and medium scale firms, looking for low cost technologies, which do not require further investments, or even if they require, it is minimal.

4.2.5 Marketing of Educational Video Programmes

TTO under its portfolio of activities, also markets educational video programmes in the form of cassettes and compact discs.

Chart 4.8: Revenue through Educational Video Programmes



* Approximately 24 lakhs is the cumulative amount since 1993

The total revenue earned by TTO through the marketing of these educational videocassettes is Rs 62.33 lakhs till 2001-02. The given chart (4.8) also shows that the average annual earnings through sale of educational programmes in the given period of five years has been Rs 10.39 lakhs.

4.3 Technology Business Incubation Unit (TBIU)

TBIU was launched in IIT Delhi as a part of the ICICI/World Bank funded Technology Institution Programme (TIP) in the year 2000, with the aim to encourage technology entrepreneurship among the faculty members, students and scientists. The scheme being administered by TTO, provides limited space for a limited period of time, which is not more than two years, in the IIT campus to new entrepreneurs, start-up companies and technology based organizations to facilitate conversion of embryonic concepts into commercially viable propositions or packages by up-gradation/up-scaling through research and development. For initiating the technology start-ups, 100 percent fund support is met by Venture Capitalists/Angel Investors/Corporations/family/friends. TTO helps in seeking "seed capital" from venture capitalists and angels. As a policy measure, five percent equity is given to the institute by the incubatee firms.

TTO also provides the necessary technology expertise and infrastructure of the institute including conference and meeting room, telephone-facsimile-internet facilities and most important of all the research facilities of the institute.

There have been six Technology Business Incubatee Residents, the details of which are given in the Table: 4.2

Table: 4.2 Incubatee Firms in IIT Campus

S.No	Name	Technology Area
1	Info-Plex Technologies (P) Ltd.	Internet Kiosks
2	Trigyn Industries Ltd. (formerly M/s eCapital Solutions Ltd.)	Wireless Applications
3	RISUG	Phase III Clinical Trials for Male Injectable Contraceptive
4	INRM Consultants (P) Ltd.	GIS Technologies
5	SINTEX ESCO	Energy Conservation Bansal Unit
6	Kritikal Solutions Pvt. Ltd.	Low cost computing, Ad-hoc Networking, Computer Vision and Network Stimulator

Kritkal Solutions, the first technology start-up, established by IIT students and promoted by IIT faculty, under the tutelage of TTO was admitted in September 2002. Of the above six, two have already exited from the TBIU for not being able to sustain in the IT meltdown environment as also due to the death of promoter of firm 1(TTO Newsletter, Sept. 2002)

There are three potential incubatee projects in waiting: Student Faculty led Nursery Incubation with 5 students and 2 faculty members in the area of convergence of wireless and communication technologies in a seamless mode without boundaries; another technology start-up with 3 alumni and 2 faculty members in the Biotechnology area; and R&D Unit of a 1st Generation Technology Company with 3 young engineers turned entrepreneurs and 2 faculty advisors in Wireless Embedded System Applications (Sengupta, 2003).

4.4 Technology Transfer from IIT-Delhi

IIT-Delhi has one of the best pool of faculty and research staff in the country and as a result it produces not only bright graduates but also quality research work which is accepted, used and practiced by industry, government, other academic institutes, individuals and so on.

Earlier it appeared that IIT followed a linear model of innovation in IIT Delhi, which is now witnessing a slow shift to the Chain-link model of innovation (for details see Kline and Rosenberg, 1986) which incorporates information and performance feedback at each stage. The linear model either expresses in terms of "market pull" or "technology push", and is considered as insufficient to induce transfer of knowledge and technology. Researchers note that there should be an interface strategy in order to integrate "market pull" and "technology push" through new organisational mechanisms (e.g., OECD 1980; Rothwell and Zegveld, 1981).

Generally in an academic institute having a technology transfer office the innovation trajectory comprises of the following stages:

- Conceptualisation of idea
- Development of Technology or Know-how
- Disclosure of Technology to TTO
- Assigning of Technology or Know-how by the inventor to the academic institute
- Approaching the Licensee

- Unconditional assigning of the Technology by the academic institute to TTO at a nominal fee to negotiate and transfer
- Technology Transfer Agreement signed after negotiations with the entrepreneur
- Payments received as per agreement
- TTO and inventor agree to complete the innovation as per the policy and guidelines of the academic institute

An innovation trajectory is often launched by a basic breakthrough discovery or a radical innovation. These breakthrough discoveries can be inspired by theoretical insights, by practical needs of society, or by dictates of the consumer and the market place (Graff et al., 2002).In the realm of their knowledge of the field of research and perception of industry, inventors conceptualise ideas, which have a certain rationale, and social & economic significance. These ideas further flourish when they tend to solve specific problems of industry or they meet the needs of society or even when they aim at formulating improvements in the existing technology, product or process.

In the Indian context, unlike the technologies developed at CSIR laboratories, which emphasise more on import substitution and utilization of locally available raw materials (Qureshi et al., 1984), most of the technologies developed in IITs and transferred to industry, are concerned with solving the immediate needs of industry and society. Many of these inventions aim at improvement in the quality of product and process and reduction in cost of production. Some of the technologies have been developed specially to enhance the performance thereby increasing productivity.

Commercialising the technologies from IIT has resulted in success, partial success or failure or even at a stage where the technologies are yet to be commercialised. A process which has been licensed to an entrepreneur and is successfully productionised, marketed and is generating sales is designated as 'success'; while a process that has been licensed but which could not be productionised and marketed hence could not generate any sales is termed as 'failure'. The technologies that had generated sales, at a given time but is not currently generating sales has been termed as 'partial success' while those where the technology has been transferred and are in the process of development and are likely to generate sales have been termed as 'developmental'.

In this study the firms were asked specifically if the technology is in use and whether it is currently generating sales or not. If the technology is a laboratory technology having a captive product it was asked whether the use of technology from IIT has benefited the firm in cost reduction or has enhanced its market share. . Based on the queries it was found that the out of a total of 31 cases of technology transfers but information available on 28, the number of 'successful' cases were 10, 'Partial Success' were 6, 9 were 'Failures' and 3 were in "Developmental' stage.

Before we move on to the technology transfer stages, it would be worthwhile to look at some of the important guidelines that TTO follows on technology transfer.
These are as follows[38]:

(a) TTO attempts to transfer/license the intellectual property generated in the institute to industry particularly those in the SME sector, irrespective of whether it is in Public or Private sector.
(b) The guiding policy for the know-how transfer in the institute is in favour of 'non-exclusive'. TTO is the facilitating organisation to effect know-how, transfers and ensures commercialisation in due course by the licensee so that the R&D efforts in the institute get consumed by the society at large. Both know-how transfer fees as well as the 'periodic royalty' payments are determinants of commercial exploitation by industry. The money considerations for the know-how transfer are arrived at through a series of negotiation involving the inventor, the industry unit and TTO.
(c) Whereas inherent nature of technology is definitely a determinant of the price to be offered for transfer, this needs to be balanced appropriately with the licensee's ability to invest in the development forming part of the product for commercialisation and the ultimate royalty return to the institute.
(d) As explained earlier that know-how transfers are affected on 'non-exclusive' basis for a price consideration comprising lump-sum 'know-how transfer fee' and 'periodic royalty' negotiated mutually amongst TTO. Inventor(s) and the industry unit, the 'know-how transfer fee amount is not the only criteria for determining the transfer. Most importantly TTO ensures that the 'know-how transfer is actually translated into a saleable commercial product so that the technology gets a place in the market and the resulting revenue may yield royalty in future.

[38] Source: Official documents, TTO

4.4.1 Marketing of Technologies

When a university invention is available for transfer, usually the first line of strategy is to seek out established companies involved in that technological field–or in a closely related field–that are known to have the capacity to incorporate the new technology into current R&D or existing product lines or launch a new product based on the technology (Ziedonis, 2001). Most often it is the university inventor who provides marketing leads through his or her personal contacts or knowledge of companies actively pursuing R&D in the given technology field. The TTO personnel leads by calling on professional contacts in industry and analysing the industry to discover new firms that may be actively working in the given technology field (Graff et al., 2002).

At TTO, with the available response from 28 cases of technology transfers, the initiators of the process was almost evenly divided between inventor, entrepreneur and TTO while nearly 20 percent cases were initiated through mutual friends.

4.4.2 Three Stage Technology Transfer Model

Going through the technology transfer cases in IIT Delhi, we could base the technology transfer process on a three stage Technology Transfer Model given by Thursby and Thursby (2000) that involves multiple inputs in each stage. The three stages follow a sequence of steps typically involved in licensing university inventions. First stage outputs are invention disclosures that are filed by the faculty when they believe their research results have commercial potential. In addition to faculty, first stage outputs include government and industry research supports as well as the TTO. Disclosures are intermediate inputs to second stage in which the TTO applies for patents on those disclosures they believe can be patented and licensed. Inputs for this stage also include a measure of faculty quality to capture patent potential. In turn patent applications and disclosures are used along with other licensing inputs in a third stage to produce license agreements.

First Stage

The technology transfer process begins formally, when the TTO receives invention disclosure from faculty or researcher. The inventors are influenced by the possibility of earning a substantial fraction of eventual royalties (Graff et al., 2002). An invention disclosure needs to describe a novel technology in sufficient detail, so as to assist the TTO personnel in conducting an in-house review of the invention, so as to assess both the legal patentability if it is desired, and the commercial potential of the invention.

Second Stage

The TTO on the select disclosures further decides to patent or license the invention based on these parameters that a firm has expressed interest in asking for a license, that the invention very clearly meets the legal criteria of being patentable (novelty, non-obviousness and industrial applicability), that the technology has favourable market prospects, that the faculty has credibility and a good track record of previously marketed inventions, and that the TTO is encouraged by the inventor. In making the decision to patent, it is emphasised that, despite the importance of potential earnings from the commercialisation of a new invention, the patenting process does not impinge upon the faculty inventor's overarching academic objectives (Castillo et al., 2000). We also need to note here that patenting is effectively seen as a part of university's technology marketing channel. (Graff et al., 2002)

Third Stage

In this stage, the license agreements get formalised and are signed by the licensee and the TTO. Based on studies, researchers[39] model the invention disclosures for university as a function of observable and unobservable inputs. If we attempt to classify the observable and unobservable inputs in the three different stages of transfer, we could see them in the given table (4.3):

Table 4.3: Identifying Observable and Unobservable Inputs at different stages of Technology Transfer

Technology Transfer Stages	Observable inputs	Unobservable inputs
<u>STAGE 1</u> Receipt of Invention Disclosure	Faculty size, Research funds, Number of personnel in TTO	Faculty's propensity to disclose, Probability of invention discovery
<u>STAGE 2</u> Screening and Patenting of Disclosures	Number of disclosures, Number of personnel in TTO, Faculty Quality	Propensity to Patent, Commercial aggressiveness of Institute
<u>STAGE 3</u> Formalisation and Signing of Technology Transfer Agreement	Disclosures and Patent Applications, Faculty Quality, Number of personnel in TTO	Institute's Propensity to license inventions, Distribution of Industry interest in Institute's inventions. Aggressiveness of TTO personnel in finding potential licensees, Market Conditions

[39] This model is particularly based on studies done by Thursby and Thursby (2002), Graff et al. (2002)

Observable inputs are faculty size, which means knowing the number of faculty in each of the department or centres, research funds and the number of full-time equivalent personnel in the TTO. The unobservable inputs are the faculty's propensity to disclose and the probability of invention discovery. The propensity to disclose reflects both the direction of faculty research and its willingness to disclose, and it can be influenced by the policies of university administration as well as the perceived potential for monetary gain. The probability of discovery is conditional on the level of research effort (research support and faculty size) and split of effort between basic or applied research. In terms of an individual invention the probability of discovery represents the "black box" probability that a given amount of research effort will result in an invention which is assumed to be independent of the university (Thursby and Thursby, 2002).

Faculty may not realize the commercial potential of their ideas, but often they do not disclose inventions because they are unwilling to risk delaying publication in the patent and license process. Faculty who specialize in basic research may not disclose since they are unwilling to spend time on applied research and development that is often needed for businesses to be interested in licensing university inventions[40] (Mansfield, 1995; Zucker et al., 1994). Some faculty may refuse to disclose for 'philosophical' reasons related to their notions of the proper role of academic scientists and engineers. Thus one major challenge for the TTO is to obtain faculty disclosures. The TTO on an average receives 35-40 disclosures annually and after the disclosures are screened for their novelty and industrial use the select disclosures are further put up before the standing committee. The fund support for research and development is formally discussed and the standing committee makes a decision. There has been a considerable growth in the number of disclosures of inventions by the IIT faculty. Here there is a need to know whether the growth in disclosures is due to a reorientation of faculty research toward the needs of industry and away from basic research, or whether the growth is due to a greater willingness on the part of the faculty to disclose as well as publish the results of their research. In other words, there is a need to know if the propensity of the faculty to disclose inventions has increased either because they are more willing to license as well as publish their research or because their research has shifted toward topics of more interest to the industry? It is the latter element of faculty propensity that has been the focus of policy discussions. However this issue requires yet another study to arrive to some conclusive answers.

---

[40] This is regarding faculty who are successful in both applied and basic research.

In stage 2, according to Thursby and Thursby (2002), the post-invention disclosure action involves the TTO in evaluating the patent and commercial potential. It is generally observed that TTOs apply for patents when it is easy for them to find the licensees. The new patent applications are considered as a measure of the second stage output as against patents awarded not only because of the substantial time lag between application filed and issue of patents, but also because patent applications are a better measure of a university's interest in commercialisation than are patents awarded. It should be noted that so far none of the technologies transferred have been awarded patents and all of them are in 'patent/copyright filed' stage.[41] The observable inputs to the patent stage are the number of disclosures, number of personnel in the TTO, and a measure of faculty quality. The latter is included to adjust for possible differences in commercial quality and novelty of disclosures across universities. The unobservable input–the propensity to patent depends upon TTO personnel and is indicative of the commercial aggressiveness of the academic institutes' administration.

In the case of IIT Delhi, TTO on an average files patent for almost one out of every three disclosed inventions. It was also observed that faculty members in IIT Delhi were more interested in publishing their research outputs, or presenting them at a conference or a seminar so that they could continue to compete on the academic research front.

License agreements executed by the university are based on the number of disclosures and patent applications as well as the size of the TTO office. Both disclosures and patent applications are included since some licenses are executed without patent protection and the facts that a patent application is made, may well provide information about the perceived quality of patentable disclosures. The other observable input in the third stage is faculty quality, which also matters in the likelihood of finding a licensee. The unobservable inputs are the university's propensity to license inventions as well as the distribution of industry interest in university inventions. The former reflects the ability and knowledge as well as aggressiveness of TTO personnel in finding potential licensees, while the latter highlights the market conditions that are independent of other inputs. We need to note that an invention may be licensed during any phase of the patenting process, and similarly, it may be patented before, during, or after a license is negotiated.

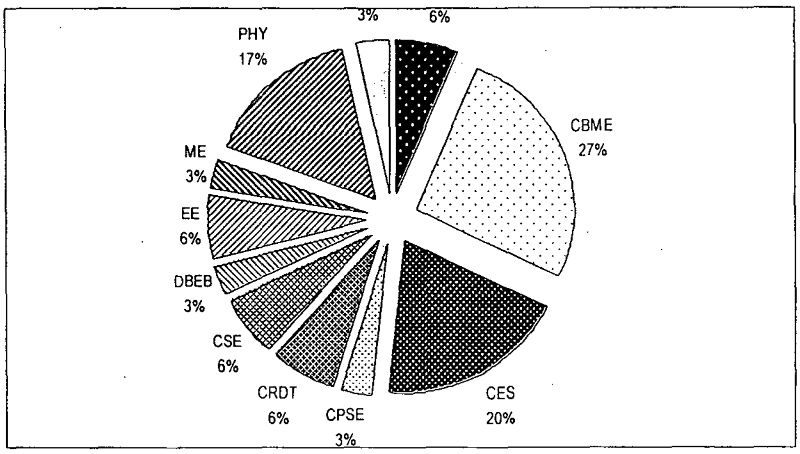
---

[41] In the latest amendment to the Patent Act, (Section 11 B of the amended Patent Act (1970) fresh request has to be made for all pending applications that are yet to be awarded, and until and unless this request is made the patent office will not examine the cases.

4.4.3 Technology Commercialisation

Technology transfers from IIT Delhi involve licensing as the most popular mechanism for commercialisation, though equity participation has started getting attention after the Incubation facility was initiated in the year 2000.

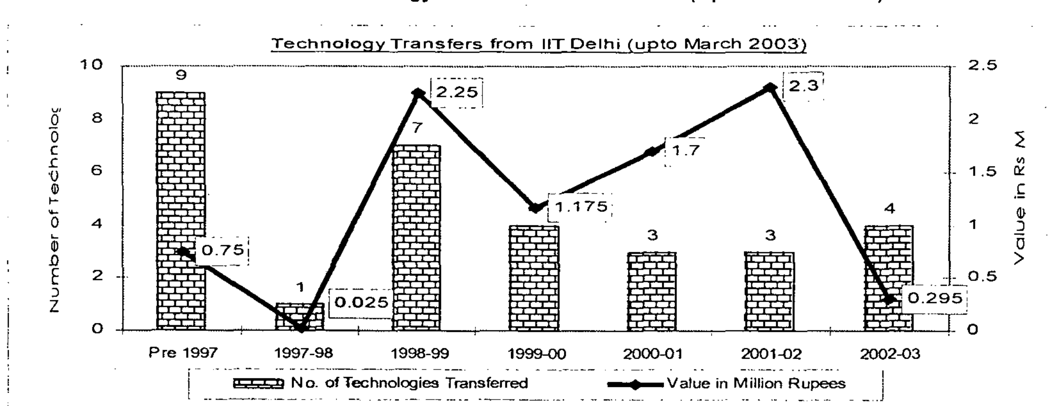
Chart 4.9: Distribution of Licensing Agreements across different departments at IIT Delhi (1992-2003)



Thus, out of the 23 departments and centres in IIT Delhi, 11 have been able to develop and transfer technology to industry; this however does not mean in anyway that the other departments are not active, there are departments and centres, by their very nature who pursue research and are more active in getting consultancy assignments and research projects, as already seen in section 4.2.2 .

The trend in the number of technology transfers from IIT Delhi can be seen from the chart (4.10), which also gives the number and value of the technologies on a year to year basis. The value of technology here does not imply that the TTO has already realised the entire technology transfer fees.

Chart 4.10: Technology Transfers from IIT Delhi (Up to March 2003)



On the basis of relevant information available on 28 cases of technology transfer, the inferences drawn are as follows:

1. Based on the definitions of four categories given earlier of 'success', 'failure', partial success' and 'developmental', the categorisation of technologies shows that 35.71 percent cases were 'success', 32.11 percent were 'failure', 21.43 percent were 'partial success' meaning thereby that they had generated sales at one point of time but are not currently generating sales. Also 10.71 percent cases were in 'developmental' stage.
2. The 10 'success[42]' cases reveal that
    a. 60 percent were not patented at the time of transfer
    b. 70 percent had non-exclusive license terms
    c. 50 percent were valued at less than Rs 30000.
    d. 33 percent technologies were educational kits and
    e. 30 percent belonged to Energy Studies, 20 percent to Physics and Applied Electronics while Biomedical Engineering, Computer Science and Electrical Engineering had a share of 10 percent each in the successful commercialisation of ten technologies.
3. The 9 cases of 'failures' show that
    a. 67 percent had exclusive license terms for a period ranging from 3 to 5 years
    b. most of them had an intellectual property right protection filed at the time of transfer
    c. the average value of these technologies was Rs 2.4 lakhs, ranging from Rs 2.0 to 5.0 lakhs.
    d. 78 percent cases belonged to Biomedical Engineering while the other two cases were from Polymer Science and Physics each.
4. The six 'partial success' indicate that
    a. 50 percent were transferred on non-exclusive basis
    b. 50 percent were not patented at the time of transfer
    c. Average value of 6 technologies was Rs 3.75 lakhs ranging from Rs 0.2 to10 lakhs.
    d. 33 percent belonged to Energy Studies, and 16 percent each to Electrical, Mechanical, Computer Science and Textile Technology.

[42] According to the TTO executives, the number of 'success' cases were 12, but because of non-availability of information and relevant data the success of two cases were not corroborated.

The three cases in the developmental stage were from Physics and Rural Development Technology, with two of them having non-exclusive terms of license. One of the technologies did not have an IPR protection application.

The value of all the 31 technologies that were transferred or which still are in the stage of being transferred, whether they were commercially successful or not, amounts to **Rs 9.795 million**. But the net realisation from the firms has been just **46.65 percent** amounting to **Rs 4.57 million**. Here in three cases, since the technology transfer is still not complete in the sense that the licensee firms have not yet started commercial production/use, the entire realisation is yet to accrue. This figure however excludes the realisation from royalties (if any) and simply gives the net realisation till June 2003 from all 31 cases of technology transfers.

The reason for such poor realisation can be attributed to lack of mutual trust, IIT not being able to provide the deliverables as per the agreement or similarly industry not keeping its promise of paying up after the transfer of technology. On discussion with the firms, the reasons for not paying up the full technology transfer fees were as follows:

1. that the technology transfer was not complete
2. that IIT did not keep its promise of providing complete know-how or other deliverables like diagrams and designs, prototypes and manuals etc. or even if they did they did not serve any purpose.
3. that the faculty did not cooperate with them to the extent that they could have done on the technology transferred, although the co-operation clause was there in the agreement.
4. that the use of technology has not generated any sales or there is no market for such a technology or for products based on the transferred technology.

On the other hand, TTO said that the reason for non-realisation of agreed technology transfer fees from the select firms was because of several reasons namely

1. the firms got the know-how and relevant information at the time of demonstration and/or discussion
2. the firms did not show interest in the technology as the technology itself indicated that it would not yield any profit for them.

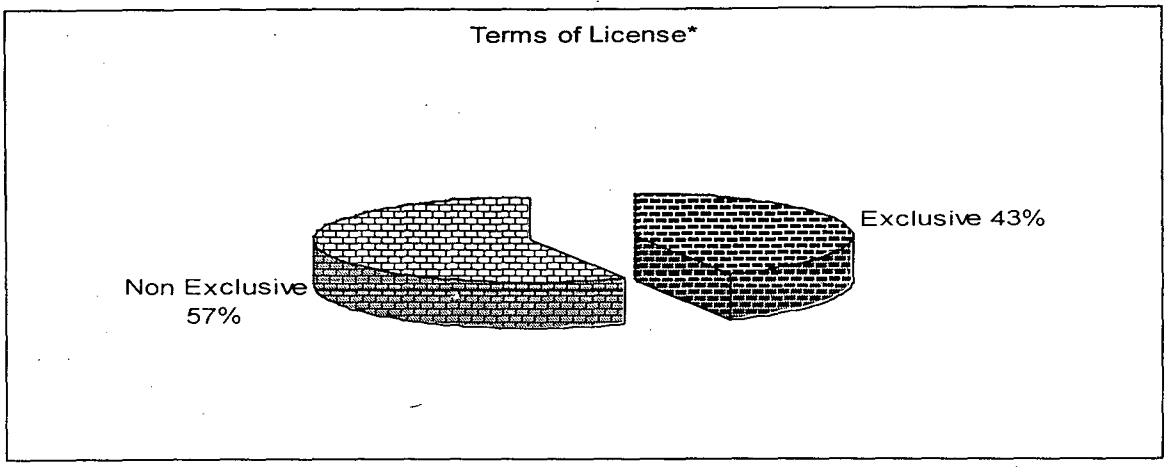
3. the firms could possibly give the 'know-how' to a third party and simply pronounce that this technology does not work.
4. the firm does not want to pay for reasons best known to them.

Based on the outcomes of the different cases of technology transfers in IIT Delhi it has been observed that the majority of licensees belong to the small and medium sized industry category wherein the small-sector having an annual turnover of less than 25 million, encompassing a major share. The ratio of licensees belonging to SMEs and Large Scale Industry is about 3:1 according to the study. However the notion that the patents facilitated in the commercialisation of the inventions was evenly balanced since many technologies that were transferred had been fully developed and did not require much investment in further modification and development. Yet there are cases where firms from the SME sector came forward to invest in embryonic technologies which had been subject to IPR protection and got transferred. The available literature also supports this view. Colyvas et al. (2002) suggest that intellectual property rights are likely to be most important for embryonic inventions, and unimportant for inventions that are useful to industry 'off the shelf'. They further observe that though patents allowed the universities to collect revenues, but did nothing to facilitate technology transfer.

4.4.4 Terms of License: Exclusive Vs Non Exclusive

As has already been discussed in chapter 3, that exclusive licensing is most often necessary to interest the firms in private industry and is used to attract potential licensee when the market is limited and the niche has to be created by the firm. Non-exclusive licensing is more appropriate when the potential market for a technology is big such that it would not affect the licensee even if there are many competitors selling the same or similar product/service. Non-exclusive license is also given when there are many potential direct applications of a technology. In IIT although the guiding policy for the know-how transfer in the institute is in favour of 'non-exclusive', yet the percentage break-up between exclusive and non exclusive license terms indicates that the terms are in favour of industry and given the amount of technology fees for different technologies, it appears that the industry gets the exclusive rights at a price they desire for the desired technology. (See chart 4.11)

Chart 4.11: Terms of License



* Terms of license given is based on number of technology transfer agreements signed except for 3 cases, where information was not available.

4.4.5 Premium and Royalty Earned: The Initial Payment Advantage

The lack of mutual trust between industry and academia is still the biggest barrier in successful collaboration. Also since technology by its very nature is dynamic the fear of obsolescence is always there, thus there is an attempt by the academic institutes to get the maximum possible technical fee as was decided in the agreement by initial advance payment. The Table 4.4 gives the percentage break-up of initial and balance payment received by TTO indicative of the above discussion. The table also gives the percentage of amount not realised by the technology transfer office for the respective departments and centres at IIT Delhi.

Table 4.4: Premium Earned Through Initial Lump-Sum Payment and Non-realisation by TTO

Invention Area	Percentage of Average Value of Initial Payment (1st Lump sum)	Percentage of Average Value of next Payment (2nd Lump sum/ Balance)	Percentage of amount not Realised for technology transaction
Applied Electronics	49.60	50.40	0.00
Biomedical Engineering	37.50	0.00	62.50
Energy Studies	97.87	2.13	0.00
Polymer Science	No Data	No Data	No Data
Rural Development	85.71	50.0	14.29
Computer Science	27.27	4.54	68.18
Biotechnology	100.0	0.00	0.00
Electrical Engineering	57.89	0.00	42.11
Mechanical Engineering	0.00	0.00	100.0*
Physics	25.36	1.57	73.06
Textile Technology	100.0	0.00	0.00

* Totally based on royalty earnings through unit product sales.

Looking at the given figures for non-realisation (table 4.4) shows that realisation has been extremely meagre in select departments whereas in some departments, there has been 100 percent realisation in the initial payment stage. However for the invention area where realisation has been poor, the numbers of technologies transferred are also more than one, while 100 percent realisation is possible because only one technology has been transferred in the given invention area. Moreover these are relatively recent developments when the TTO realised that it is best to realise the technology transfer fee in the first lump-sum payable at the time of signing the agreement.

In the technology transfer cases, only 30 percent of the technology transfer agreement had annual royalty clause and which on an average varied between 3-6 percent of the sales price after commercialisation.

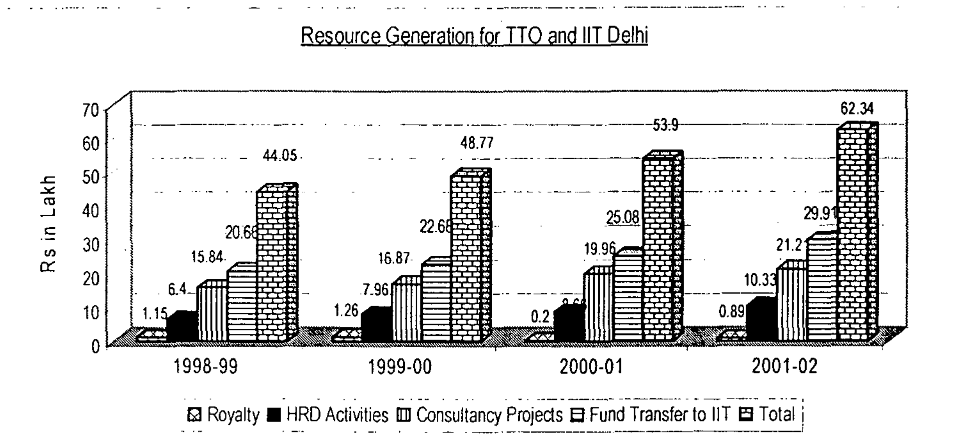
4.4.5 Sharing of Licensing Revenues

The most common formula in sharing of revenues in academic institutes is the equal sharing formula where the inventor, the department and the academic institute get 33 percent each. The other fairly common alternative is an equal 50-50 sharing between the university and the inventor (Graff et al., 2002). In IIT-Delhi the revenue sharing formula is 60:20:20, where the inventor gets a sixty percent share while IIT-Delhi and the Technology Transfer Office get twenty percent each. The share of the inventor has been set high because the administrators think that the likelihood of a successful technology licensing is less and that they want the average return to faculty to be respectable. More so it works as an incentive for promoting the inventors to work on new areas and technologies or on novel applications. The point that needs to be noted here is that once the sharing formula has been written in the earlier licensing agreements, they become established as a norm and it becomes very difficult to negotiate thereafter. The sharing of royalties by TTO and IIT elucidates the fact that compensation is offered for research and collaboration efforts of the larger team of employed personnel and it is the use of those resources within the institute that indirectly led to the invention. This measure considers the notion that the benefits from the proceeds should go to the entire institute that was responsible for the invention's success.

4.5 Resource and Assets Generated for TTO and IIT Delhi

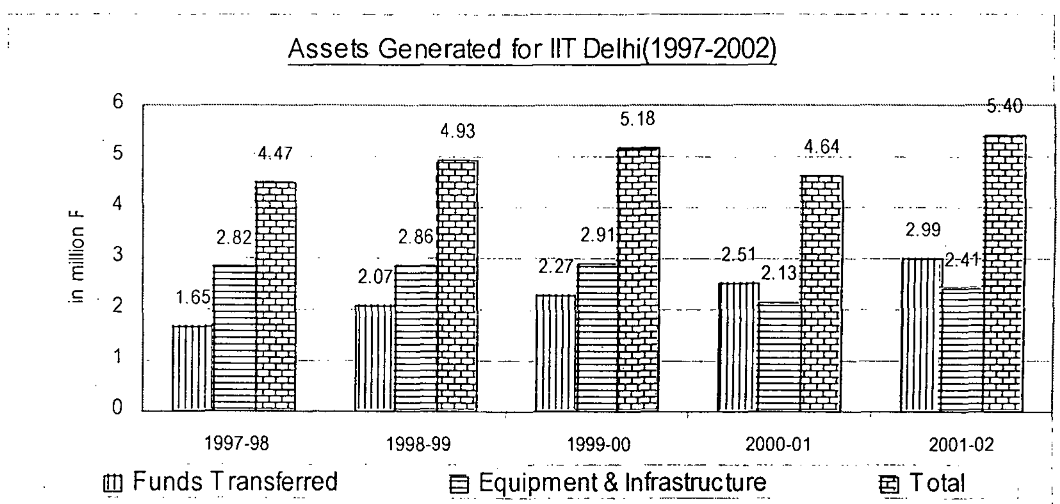
If we look at the resource generation value for TTO and IIT Delhi (*Annual Report*, 2001-02), we would notice that there has been a steady increase in Funds transferred to IIT Delhi which includes technology transfer, yet if we look at the technology transfers separately, the increase is not steady on a year to year basis.

Chart 4.12: Resource Generation for TTO and IIT Delhi



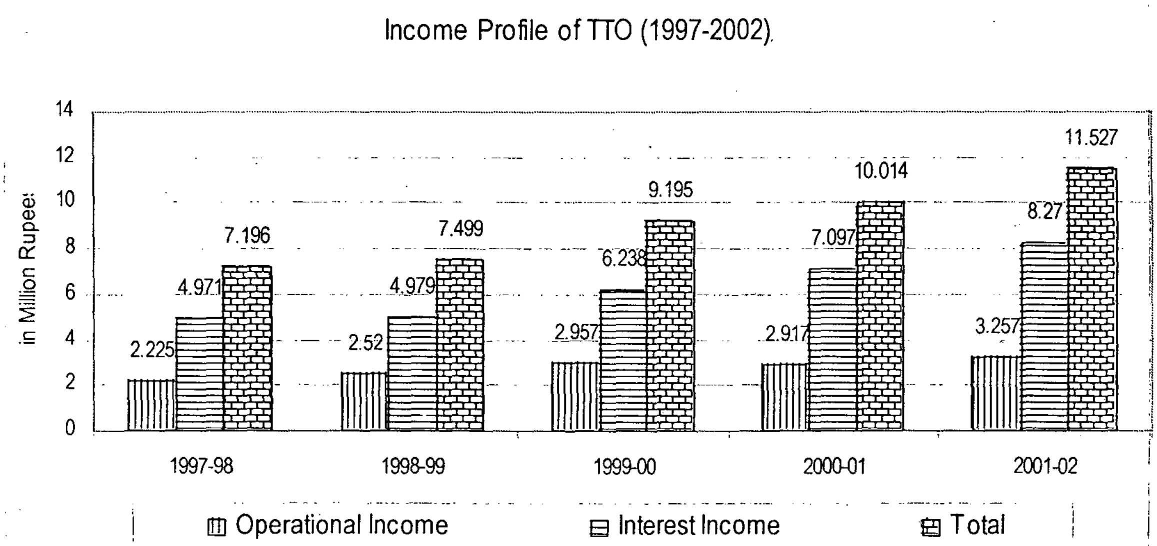
The establishment of TTO and as such the sharing of revenue has generated assets for IIT Delhi. During the past five years the assets generated can be seen from the given figure (Chart 4.13)

Chart 4.13: Assets Generated for IIT Delhi



Evaluating the income profile of TTO in the past five years (chart 4.14), it is evident that TTO has been able to generate little revenue through technology transfers but as the different activities are also part of the technology transfer process, the income generation through them may well result in technology transfers in the future. Here one also needs to mention that majority of the income comes through the interest accruals from the seed money invested as company and bank deposits.

Chart 4.14: Income Profile of TTO



4.6 Observations and Emerging Issues

Most of the technologies developed in IIT are generally low cost technologies and have mostly benefited small and medium enterprises. Some of the technologies have been licensed to more than one firm.

The technology transfers in IIT Delhi are mostly based on good relations at the individual level of the faculty with industry personnel. It has been the case in IIT-Delhi that much of the institution R&D cooperation with industry is based on the direct and personal contacts of researchers and their industrial counterparts. Thus whilst the technology transfer office's function may, in theory, be considered as essential, practice demonstrates that many industrialists tend to bypass these formal structures, most often because of an unsatisfactory previous experience with comparable institutions.

Looking at IIT-Delhi and its interaction with industry after a technology has been transferred, except a few, in all the cases of technology transfers, the contacts have phased off and until and unless the matter became indispensable, there was hardly any communication. It is presumed that the foundation of equity participation lies in close interaction, coordination and communication, therefore the reality of such a mechanism needs to be carefully evaluated[43].

The notion that IPR facilitates in technology transfer holds partially true. Based on the empirical study, patents and copyrights actually facilitated in the transfer only when the technologies were 'embryonic' or for that matter when the projects were turn-key projects. The protection also helped in select study areas like computer science. The observations by faculty and TTO executives supported this fact that new areas like biotechnology and not so new information technology attracted industry attention if it had IPR protection. IPR also helped if the technology had a high market value.

Information on the availability of IIT Delhi technologies is disseminated through various channels both online as well as offline to industry units. In a 'non-exclusive' know-how transfer, the transfer period is generally redundant, the reason being that the institute reserves the right to transfer the know-how to a third party without any reference to the licensee. TTO attempts to muster as many licensees as possible for a given know-how with an elongated license period to yield periodic royalty.

The general lack of academic recognition for commercialisation and rewards for publications, as opposed to patents, has been a major barrier in IIT. This has resulted in many academics facing the dilemma of either publishing their results for short term revenue and academic recognition or withholding them until they are patented, with the risk of technology by its very nature of becoming obsolete[44].

---

[43] In one of the previous studies done on IITs, (Nath, 1992) the author states, "their contact with industry is few and far between. Neither are they able to advise the industry how their technologies can be improved in a cost effective manner nor are they able to provide any technological breakthrough for adoption by the industry. Indian industry uses the facilities in the IITs peripherally either for testing or for measurement or for few simple projects of not great consequence. There is no substantial fall out from the projects undertaken by the IITs or from the results flowing from their research. "

[44] This observation is supported by the studies of Rahm (1995)) who finds that the behaviour of industry linked researchers are manifestly different from those who pursue traditional university-bound research; they respond to transfer demand more favourably. In the context of Biotechnology, Blumenthal et al. (1986) shows that while the faculty members with industry support, experience pressure to withhold or delay publications and redirect research agendas, they tend to be more productive in terms of research publication. According to the author it is assumed that the faculty members will get involved in the technology transfer activities, if they believe that their effort will lead to significant rewards.

The other important finding based on the observations of TTO executives and faculty members is that many of the younger generation faculty are more inclined towards the proposition that university is 'entrepreneurial'. There are more number of senior professors and scientists, who prefer not to do research for commercial gain and expend their 'extra' time also in teaching and/or doing research for knowledge augmentation in the sense that it is a 'public good'.

The TTO observed that they have to be extremely careful with the terms of license. If it is an exclusive transfer, the clause on the time period becomes very crucial. This is important because for a particular technology if nothing is happening on either development of the technology or products thereof, or no steps are being taken for making it commercially successful for a certain period of time, then the TTO should have the right to annul the exclusivity feature and thus search for new industrial partners. This issue is being considered by the TTO.

The TTO executives also expressed their experience that, the technology transfer agreements were also signed by firms to seek loans from financial institutions. The collaboration of a small or medium enterprise with a premier academic institute like IIT Delhi helped to a great extent in getting finance from the funding institutes, venture capitalists and so on.

Since industry is restrained to take up incomplete know-how, for up-scaling of research it is necessary to demonstrate technical viability and economic feasibility of the process know-how. Many a times the inventors are not confident about actual commercial potential of the know-how to be developed. Even today many scientists are more concerned with the publication of their research outcomes than pursuing the planning of research and development activities beyond pilot scale results for opening up opportunities for productionisation. It is evident from looking at majority of technology development proposals, where significant areas like economic assessment, cost-benefit analysis, planning of project that includes technology utilization etc. have got minimal or no importance at all, that there is a need for many scientists and inventors to have a business approach.

Lack of cooperation and coordination among different departments, among faculty members, technicians and administrators tends to hamper the development in the commercialisation process and also leads to delay in the entire innovation process. Applied research is multidisciplinary in nature and needs cooperation of different professional capabilities. In the operation of projects, the boundaries of research departments in the institute are rarely transcended.

The firms reported that they feel TTO negotiators hold unreasonable expectations over the value of their inventions underestimate the cost of further R&D required and as a result, hold out for too much on licenses. They reported that technology transfer process from universities was complex, cumbersome and bureaucratic or that the TTO staff seemed to be unprofessional and to a certain extent inexperienced, failing to treat them as valued customers.

Among firms there appears to be a range of attitudes towards technology transfer opportunities from academia: many firms simply ignore such technology transfer; some firms who have attempted to license from the academic institutes have been frustrated and given up; but a minority of firms, mostly in the new science-based industries, actively utilize academic research and technology transfer to their own competitive advantage[45] (Graff et al., 2002). This factor holds true partially in the case of technologies that have been transferred from IIT since many of the technologies that were transferred and were successful, have benefited small and relatively new firms belonging to the new science-based industry. The successful transfers were in the area of Computer software, Optical Fibres (Physics), Packaging, Energy, and Textiles.

It has been observed that many a times the problem of commercialisation of technologies rests on intra-institutional factors. In an academic environment where there is freedom of thought and expression and there is lot of intellectual discourse happening, the 'tradable' know-how no more remains a 'tradable' commodity. Thus the intellectual property of the faculty and researchers tends to lose its 'commercial value'.

The interaction between the academia and industry has been flawed by the lack of mutual trust, which has emerged to be the biggest problems in technology commercialisation. Long-term relationships are subject to having faith in each other, which is seen lacking especially in the cases of 'failures'. Based on

---

[45]The given statement is based on review of different studies done in American research universities asking opinion of different firms on licensed technologies obtained from universities.

the inputs from either entities in general the perspicacity of either of the collaborative partner, can be summarised in the form of a table (4.5)

Table 4.5: Perception of Academia and Industry about each other

The perception of IIT by Industry	The perception of Industry by IIT
Visits to industry by IIT faculty are occasional	Industry is reluctant to promote research in new areas.
IIT considers industry as a funding agency rather than as a collaborative associate.	Industry does not come forward and look for new technologies/projects and research developments.
The projects in IIT are academic in nature and there is reluctance on the part of faculty to further develop into a commercially viable venture.	Industry still goes for blanket import of foreign technology and does not rely on indigenous technology.
IIT does not like reviews of their project's progress by industry.	Industry uses IIT simply for testing and calibrating their new products and processes.
There is break in the continuity of certain projects, as some research students, if they are associated in the project, leave the institute.	
IIT does not conform to a time bound program. Completion of formalities delays the technology transfer process	

5.0 Interaction of IIT Delhi with Industry: Three Case Studies

In the previous chapter, based on twenty eight cases of technology transfers, it is evident that there were efforts made by the technology transfer office to commercialise IIT technologies and to carry certain activities that lead to enhance better academia-industry interaction. In some cases the efforts resulted in extremely good outcomes, while in some cases the efforts did not pay-off. In this chapter an attempt is made to understand and critically analyse the cases of technology transfer, microscopically.

Industry today, constituting of many Small and Medium Enterprises (SMEs), faces foremost difficulty for carrying out R&D that requires very long term view, huge amount of money, time and effort especially when the anticipated results are often ambiguous. On the other hand the academic institutes, whose main objective is to teach and carry out research, have much to offer to industry in terms of knowledge dissemination that includes novel and breakthrough technologies emanating primarily from basic research.

This chapter is divided into three sections. The first section briefly addresses the response of firms towards the technological choices and innovation in order to be competitive and/or sustain their leadership in the marketing environment. The second section discusses in detail three individual cases and the last section presents the concluding observations.

The three cases were chosen based on certain factors which included success and failure, availability of information and availability of the person concerned both in IIT and in the given firms.

5.1 Innovation and Technology Choices - Response of Firms

Studies have shown that the firms operate in a market environment, which also influences their innovative activities. The technological environment of firms termed as technology regimes (Basant, 1997) can be seen and described in various dimensions, for example, in mature markets, where product competition is in terms of price. A firm's technological response to market pressure is likely to be towards process innovations aiming at reducing operating costs. Conversely, in the emerging markets, where competition is product related, the technological response of a firm is towards product development innovations in order to improve quality/design or features. Thus for the firms, the relevant strategic decision in this context places two choices which are not mutually exclusive. Firstly the firm can internalise the process by pursuing activities broadly categorized under the rubric of R&D or as a second choice they could use existing markets to purchase the requisite technology. In the second option, many firms also look forward to academic institutes apart from the public and private research laboratories to source their technologies.

The prime question that the firms face in exploiting innovation is why they face difficulties in recognizing the potential of an innovation and what can be done about resolving it. If we look more closely at the firms, these difficulties can be broadly related to two factors. The first is the manner in which firms collect and process information and the second is the uncertainties that the firms face both with regard to technology and market (Afuah, 1998). The ability of a firm to recognize the potential of a technology which could be a successful innovation depends on its strategy, its size (for details see Scherer, 1971), structure, the macro and micro environment in which it operates, its personnel and the ability of decision makers at the top management level. The uncertainties that the firms largely face are as to what technology is likely to invade an existing technology and which markets are likely to open up. The firms can reduce uncertainties by analyzing the trends in markets and technological evolution, and taking control of its future by its strategic decisions and actions. Here the firms usually use the Porter's five forces model to determine the competitive forces exerted on each industry along the innovation, value-added chain of suppliers, manufacturers, complementary innovators, distributors, or customers[46]. The other tools that most of the firms opt to overcome the uncertainties are their capability to comprehend the need to be a successful supplier or a manufacturer, complementary innovator, distributor, or customer. The firms finally determine how many of these needs are within their capabilities or how soon could they acquire them.

[46] Porter, M.E., Competitive strategy: Techniques for analyzing Industries and Competitors, New York, Free Press, 1980 in Allan Afuah's book, Innovation Management: Strategies, Implementation and Profits pp8.

According to Afuah (1998), an innovation can originate not only from any of the functions of a firm's value chain, but also from its local environment, as discussed above, and it also includes research laboratories and universities. The effective transfer of technologies from any of these sources however, is a function of the nature of innovation, the timing of the transfer, the cultural differences between source and sink, and the absorptive and transferring capabilities of the source and the sink. The cultural difference factor gains much importance when in the transfer process the source of invention is an academic institute and the sink a private firm.

The following section focuses on three cases of which the first is a 'success'; the second is a 'failure' while the third is a 'partial success.'

Before we analyse the cases individually, we should note that there are complexities involved in the process from laboratory to market and that one has to very carefully evaluate the development at each stage ensuring feedback from the interest groups and parties involved thereby eliminating the obstacles in the path of having a successful innovation. The commercialization process has eight stages[47],

1. Conceptualization or idea generation
2. Definition/Assessment
3. Design and Development
4. Demonstration or pilot test
5. Reassessment
6. Production/Manufacturing
7. Sale (or other commercial transfer)
8. Use

The progress of an invention to the stage of its commercialisation goes through these stages although these may be different with respect to time frame, organisational approaches, and associated risk factors. The reasons of failure of an innovation would be rooted in one or more stages of the

[47] Commercializing Infrastructure Technologies: A Handbook of Innovators, Civil Engineering Research Foundation Report, 1997 in http://iti.acns.nwu.edu/clear/infr/cerf2/cerf_ch5.html.

commercialisation process. The successful cases would have possibly satisfied the requirements at each stage of the process.

5.2 Individual Cases

5.2.1 Case 1

The case deals with the technology developed at the Centre for Biomedical and Engineering namely Heat Sealable Coatings for Packaging Application which was transferred to a Delhi based firm. This firm founded in the year 1964, was a commercial printing establishment and was subsequently incorporated as a Private Limited Company in the year 1976. The gross sale figures of the company in the year 2002-03 is Rs 140.82 million which has increased by 6.25 percent from Rs. 132.53 million in 2001-02. It recorded a 42.8 percent increase in financial year 2001-02, compared to the previous year's sales which was Rs 92.79 million. The net profit for the company shows a slight decline in 2002-03 at Rs 22.76 million from Rs 24.10 million in the year 2001-02. The net profit however showed a drastic increase year before last when it witnessed a growth of 258 percent, from an absolute figure of just Rs 6.73 million in 2000-01. Here it needs to be mentioned that the technology was transferred from IIT in late 2001.The company has got a covered area of nearly 32000 square feet at two locations having a total power back-up with 120 percent capacity of installed power.

Business Area

The company is equipped with sophisticated state of the art printing machinery, finishing machinery and testing equipment and is one of the reputed paper and board packaging manufacturing house of North India. It specializes in multi-colour cartons, blister cards and point of sales packaging material, which are also exported. The company has a in-house facility for structural designing, pre-press, printing, spot and full coating including Ultra Violet (UV) on latest automatic machines for multi-colour cartons, product and process literatures, labels, blister cards, micro flute cartons and point of sales material. The firm also has a quality control department where the paper and board is checked for callipers, grammage, heat sealing, stiffness etc. and where it has a regular system of quality control on the running job to maintain consistency in the printing and other processes. The online rejected material is shredded before disposal. The major clients include Ranbaxy, Gillette India and other pharmaceutical and consumer durable companies. The company has no foreign collaboration.

As there are different kinds of heat sealable coatings being used worldwide, the inventor developed a heat sealable acrylic-based resin. The invention involves the methodology to coat any kind of paper with the developed resin so that after the coating, the paper can be stored and can be used as and when the need arises. The coated paper is used for sealing this paper with moulded Poly-Vinyl Chloride (PVC) films. At the time of application, sealing is activated under heat and pressure. The advantage of the process is that the packed products are always visible due to the transparent PVC film. These coated papers can also be used for packing with polystyrene-based films and products.

Case Background

The initial approach for the technology transfer was made by the inventor, although the firm came to know about the technology through a friend, who knew the IIT professor and the entrepreneur. The firm was facing a specific problem with regard to manufacturing process that had its application in packaging and on being approached by the inventor incidentally it decided to acquire the said technology.

The agreement for technology transfer was signed in late 2001 with the terms of transfer being non-exclusive. The technology transfer fees included lump sum payment payable as advance at the time of signing the agreement; however the agreement did not include any royalty to be paid by the licensee. Although the agreement did not confer the right of exclusive manufacture or use of the technology, the firm did not have any problems especially with regard to competition. The firm at that time did not even know if other related firms in the region were using a similar technology in manufacturing a similar product. The firm was ignorant of sources other than IIT Delhi offering a similar know-how in close vicinity so that they could exploit the terms and conditions of technology transfer at the time of negotiations between them and the TTO.

The know-how "to apply acrylic based resin coatings on paper which can be sealed with transparent Poly Vinyl Chloride (PVC) films" was transferred and it required frequent visits by the inventor at IIT-Delhi to the firm's manufacturing unit for testing, calibrations etc. before it was complete and ready to function and operate. The firm was earlier dealing in imported products before going in for indigenous manufacturing. So far no modifications or further development have been made in the technology, which is indicative of proper development of technology at IIT Delhi and right installation mechanism at the firm's manufacturing unit

The technology in discussion was not patented at the time of transfer and it did matter to the firm if it were covered with any form of intellectual property right. On being specifically asked if the IPR on invention facilitated technology transfer, the response was a firm "no" in this case.

The present state of innovation is that it is successful and the technology is still being used.

Firm's opinion

The nature of relationship between IIT Delhi and the firm has been friendly and the firm did not have any difficulty in dealing with the technology transfer office[48]. In fact in response to a direct query asking the firm to identify the important factors contributing to the success of technology transfer, the firm said it was because of close interaction and discussion, frequent meetings with the inventor and due to proper testing of the technology. The testing facilities at IIT Delhi were not used; rather the technology was tested on-site at the manufacturing unit of the firm.

The firm also responded in affirmative stating that the collaboration with IIT Delhi has been very successful. Since the technology is used to manufacture products meant for captive consumption, it is not possible to attribute the degree of success of innovation in terms of number of units of products sold or in terms of the volume of sales generated, however when asked about the benefits of the technology transferred, the firm responded by stating that there has been an increase in productivity and that it has effected reduction in the overall cost of manufacturing. The cost reduction has been stated to be as high as 30 percent.

TTO's opinion

The technology transfer office did not have any problems in dealing with the firm during technology transfer. The entrepreneur had an understanding of the technology that was transferred and also the fact that the adoption of the same would resolve the problem, his firm was facing. The other positive factor was that the inventor was very much involved in the whole process of technology transfer, which

[48] Here the TTO did not have much role to play as the technology transfer was initiated by the inventor at the behest of a mutual friend who knew the entrepreneur and the inventor. The formalities of signing the agreement were completed by TTO.

meant that he knew all the problems and threats with respect to technology since its inception stage. TTO facilitated the technology transfer and did not have any difficulty with either the terms of transfer or with the payments. Since the terms were non-exclusive, it had the option to sell the technology to others; and because the fee was paid in one lump sum as an advance payment without any royalty clause, there were no hassles to follow-up on payments. At the IPR level, as the technology has not yet been granted patent, the only problem lies in the issue to know if the technology transfer fees exceeded the cost of protecting the invention.

Inventor's opinion

The inventor has been working in the area of polymer technology and has been a consultant in this field to different organisations both public and private. The inventor had developed this technology and since its equivalent had to be imported and was very costly, he eventually approached the firm to convince the benefits of the technology developed by him in IIT. Thus the interaction was much more than what is generally required on the part of the inventor. The success of a technology transfer also lies in interaction at the individual level. There are still many difficulties with regard to the system that is followed. The technology transfer office acts as an intermediary agency, and did not have much role to play in this case but at the same time it did facilitate in certain matters. In general, in his opinion, in the early stages it is the advantages and attributes of the technology that need to be discussed on a one-to-one direct interaction with the buyer of technology, rather than asking for feasibility study, business plans and like from the firm. It not only helps in framing opinion about the firm but also results in assessing if the entrepreneur has an understanding about the technology and his interest and integrity in the venture along with his financial virtue.

In this case the success of the technology transfer was based on the nature of technology which solved the firm's problem, the close and frequent interactions which helped in building mutual trust and most importantly on the willingness of the inventor and entrepreneur, to make the innovation complete and successful.

Inferences drawn and Lessons learnt

The firm no doubt had a better understanding of the user-needs and as such when it encountered a problem, it decided to approach for a timely solution. As a result the client base of the firm increased.

The firm also ensured proper implementation of the technology as it eliminated technical defects through appropriate testing. The firm made effective use of outside technology and scientific advice through frequent interaction. The involvement of senior management contributed to its success.

The success of technology transfer in this particular case can be clearly attributed to the close interaction, frequent meetings and discussion between the entrepreneur and the inventor. The inventor having a long experience in consulting has had the ability to understand the issues and provide the solutions. That the firm and the academic institute were in close proximity, interaction could happen and it did happen that, there were frequent visits by the inventor and the entrepreneur to each other's place of work during the technology transfer process and thereafter. The other factor determining the success of innovation was that there was a specific problem that the firm faced and the inventor was able to comprehend and understand the specific needs of the entrepreneur. Having got the solution to the specific problem the firm had no difficulty with the technology as it met the desired specifications.

The fact that entrepreneur was himself a product of IIT could have added to the success, as he was able to properly and effectively communicate with the inventor at IIT Delhi and had discussed the problems in hand directly without involving any intermediary. Thus there was an effectual and professional collaboration between the two entities, academia and industry.

If we analyse the case based on the eight stages of commercialisation process, it is evident from the case study that at every stage, the entrepreneur and inventor had a thorough understanding of the development, the problem was well defined, the assessment was done, the development took place in consultation, a reassessment was done at the time of testing and finally at the implementation stage, prior to going for a full scale production, the firm and the inventor put extra efforts to check for any shortcomings. Further the firm has accounted for the benefits accrued for its use and acknowledges IIT. The role of TTO cannot be ignored as it facilitated the development at many stages if not at all. The patent was filed by TTO, assessment was done in consultation with involved parties and matters pertaining to payments and drafting of agreement clauses and so on were carried on smoothly by the TTO.

The discussion with the top management of the firm also indicated that the firm is planning to approach IIT Delhi with a specific problem, which could have a potential of yet another technology transfer from the academia to industry. This decision, if it unfolds, has strong positive implications, as it would be the first time since the creation of TTO that the same firm has shown trust and is confident to come back for a second technology transfer in less than three years time.

5.2.2 Case 2

There were five technologies developed at the Centre for Biomedical and Engineering (CBME):

(1) Vaccine Carrier of capacity 1-1.5 litres

(2) Portable refrigerator of 7 to 10 litres

(3) Blood Storage Unit of capacity 40 litres

(4) Deep-Freeze of Capacity 7 to 10 litres.

(5) Water Cooler of cooling chamber capacity of 40 litres

The firm, to which these technologies were given, specialises in Air-conditioning that includes making moulds and dyes for various applications be it air conditioners, speedometers or fans. The company manufactures and sells its own air-conditioning equipment in the market that is spread all over India especially in the north and has offices in different parts of the country including Delhi, Maharashtra, Tamil Nadu, Punjab and Rajasthan. The entrepreneur although not a technical graduate has a rich experience in the air-conditioning business for the past thirty years. He heads a group of small companies, which is also into manufacturing of security systems. The annual turnover of the group has varied between 150 to 200 million in the last few years.

Out of five technologies in consideration, one (Water Cooler of cooling chamber capacity of 40 litres) was on non-exclusive terms. Two technologies, namely the Vaccine Carrier of capacity 1-1.5 litres and Portable refrigerator of 7 to 10 litres were transferred to the firm on an exclusive basis for a period of five years and also had a royalty clause payable to TTO at 3 percent of sales after its commercialisation. The current status is that none of the technologies in consideration have been commercialised. The two technologies that were transferred have not been developed beyond the prototype stage. The rest of the three technologies have not been transferred for reasons of non-commercialisation of the two technologies already sold by TTO.

Case Background:

The entrepreneur was approached by the TTO executive, after the entrepreneur had been to IIT Delhi on an informal visit and had come to know of the technological developments in the institute through a friend. The discussions further developed and on being pursued further by TTO the technology transfer agreement was signed in July 1998 for licensing of a complete package of technology for five products. The agreement stated that for each of the products, specifications of individual components/items would be provided along with a block, a schematic and a circuit diagram. Further two prototypes would be given for each product manufactured at IIT Delhi. The successful working of the prototypes meant that the temperature of cooling chamber in the case of vaccine carrier, portable refrigerator, deep freeze and blood bag storage unit would be maintained/controlled at a given range with slight variations by keeping polio vaccines or selected load of eatables or blood bags as the case may be. This would be demonstrated before the firm's representatives in IIT Delhi premises for a given period as specified in the agreement. The firm had agreed to manufacture the components such as outer casing, cooling chamber, water cabinet, and insulation chamber as deemed fit by the inventor and also to meet the cost of development of two units of the products.

The development of technology at CBME, IIT Delhi also required an imported component, which was imported and finally the prototypes of two product technologies [(1) and (2)] were developed. The demonstration was done and the technology was transferred. The progress in the development of prototypes for the rest of the products[49] was fraught due to payment problems.

A similar technology, based on thermoelectric device, was transferred to another Delhi based firm at a higher price, which is also at present not commercially successful. According to the entrepreneur and CEO of the firm, the product–a Water Cooler— required an imported component (Thermoelectric Device), and after the sanctions posed in 1998 due to the Nuclear Tests conducted at Pokharan, there were problems in imports on grounds of these components being used for National Defence Applications. Although the component is now available in India, the firm has not probed into this aspect.

[49] The prototype for water cooler has been developed and a demonstration was done.

The primary concern for the firm has been that the TTO has not yet issued a 'go-ahead' certificate for mass-scale production. The prototype demonstration was also an eye-wash for the entrepreneur as he had no idea of the technology in detail, and what was shown was not delivered, the designs and specification details about the components was also not properly given/explained. During the negotiations, this entrepreneur had been told that another Delhi based firm had already purchased five technologies at a price higher than what he was being offered to him to buy this technology.

Firm's opinion

Technology 1 & 2 (Vaccine carrier, Portable refrigerator)

- Both the technologies were widely known and products thereof are very much available in the market as against the claims made by TTO executive(s) and the inventor.
- There are better products in the market be it in terms of performance, design, aesthetics and affordable price.
- The prototype shown and delivered seems unacceptable to develop further for mass production on these grounds:
  - The weight is too heavy to be called a portable device
  - The design itself is not aesthetically sound, that it attracts the customer.
  - The vaccine carrier box, which would ultimately hold the vaccines, is very small.
  - The prototype developed has a separate tank for water for cooling that makes it even heavier (approximately 20 kg)
    - The prototype for portable refrigerator has an aluminium chamber inside, which makes the storage compartment look odd as compared to the competitor's products which uses light fibre material.

The major concern for the entrepreneur is that even if the technology is further developed there will be no market for it to sell. There are similar and better products in the market, which are basically imported especially from Taiwan that are successfully selling in the market. The temperature range is higher from minus five to sixty degrees as against IITs technology that gives minus five to thirty degrees. The design of imported products is such that it attracts the customer at the sight of it, as claimed by the entrepreneur. The Distributors of the imported devices are based in Pune as also at different locations in the country.

The inventor has already filed patent for all the technologies, but it hardly matters to the entrepreneur, as the whole technology transfer process according to him has been a breach of trust.
The entrepreneur did not raise objections at the time of transfer as he did not have reasons not to believe TTO and IIT-Delhi and their promises about the technologies.

TTO's opinion

Two technologies were transferred, while the prototype of the third technology (water cooler) was demonstrated after a long period gap. There was no interaction between the two entities despite heavy correspondence from TTO and very little response from the firm. The agreement was such that the prototype should be built as per the specifications of the inventor, but this was not done. The other factor that led to the failure of the innovation was that the entrepreneur had limited knowledge about the technologies that were transferred. TTO also placed its view that if the entrepreneur had the will to develop the technologies further, there was no reason why they or the products thereof could not be commercially successful. If the entrepreneur had any problem including design, he could have approached the inventor and/or TTO, but this was not done.

The fact that five technologies were to be transferred based on the same principle of having thermoelectric device as a necessary component for all, it might just be possible that with the technological know-how of two technologies available with the firm, the firm did not show any interest in the other three technologies, and could develop products thereof based on the know-how already transferred.

The Inventor's opinion

"The firm has not moved ahead", this was the first response given by the inventor. Although the full know-how of technology was given to the firm, the entrepreneur did not develop the technology further although he could have done it. The firm had the necessary facilities and could have resolved the problems in consultation with IIT. The prototype was developed entirely at the Centre for Biomedical and Engineering laboratory and the design department (IDDC) was not involved. The prototype was properly demonstrated before the firm's representatives and the firm was further asked to develop the products based on the prototype.

The main problem according to the inventor lies in the fact that industry believes that when a technology is transferred, it would start functioning and operating the very next day, which does not happen except in a very few cases. The onus after the transfer lies more on the entrepreneur and firm's ability rather than on inventor, to develop it further as there are limitations within the academic institutes.

Inferences drawn and Lessons Learnt

The technology at the time of transfer was novel in India and there was a market for the products. The prototype developed had problems. The problem was not with the technology per se but with the prototype designing and development skills.

The specifications were such that the portability feature was defeated. The dimensions of both portable refrigerator and vaccine carrier could have been better designed to make the device more handy and appealing. These modifications could have been done before giving a demonstration. In this case, the Instrument Design and Development Department (IDDC) could have helped. The TTO also should have made efforts to coordinate with IDDC and the inventor.

At the same time, the entrepreneur if he had a problem with the prototype, he should have expressed his dissatisfaction at the time of demonstration and even if he faced problems in design and its function ability, he should have contacted the inventor or TTO to resolve the matter. The absence of mutual trust has been the prime reason for failure.

The novelty of technology, the large market potential as assessed by TTO executive, and the unrivalled functional aspects are all subject to inquest.

In this case, the problem lied in the process of scaling up from prototype to mass scale production, wherein the firm was unable to proceed any further from demonstration at the laboratory scale. Although the firm had the capability to scale up in terms of further designing it based on the facilities it has, it got wedged between the complexities of technology development and the invasion of similar imported products at a cheaper price. But it appears that the knowledge about the imported products, being available in Indian markets, came much later and modifications in the prototype could have been done much earlier in consultation with IIT.

Based on the commercialisation process stages, it is evident that the problem started in the very beginning when the assessment was not properly done. This may be because adequate research was not taken up so as to assess the market potential, the threat of competitors entering the market, the possible product design and so on. The design and development as has been discussed emerged to be the most problematic and further if after the demonstration had been done and the problems had not been identified, a reassessment should have definitely been done.

5.2.3 Case 3

The Technology "Automatic Automobile Glass Transmission Measurement Device" (AGTRAM) was developed at the Mechanical Engineering department, IIT Delhi.

The firm established in the year 1973 specialises in Photometry Instruments so as to giving solutions to tasks in measurement of light from any angle for any purpose. The firm also deals in accurate, stable and precise metering, testing, and calibrating instruments as also in customised peripherals. It also provides consultancy and training on designing, developing, manufacturing and installation of photometry instruments. The product range includes luminance meters, Spectro and UV Radiometers, Light Sensors, Sensors for underwater measurements, Goniophotometers, Photospheres, Special Instruments like Colour temperature meters, LED output testers, Auto Glass Transparency Meters, Calibrated Standard Reference Lamps, Thermostat Photometer Heads etc. It also makes special accessories like Photometer Heads for measuring light incident angles, for measuring light incident sensors, for vertical/horizontal/spherical/hemispherical illuminance and so on.

The firm has total staff strength of six people and specialises in unit by unit development of products. The main clients of the firms are individual engineers and scientists in different private firms. However the firm has supplied many photometry instruments to different public sector units, the recent ones being 'large' contracts at Airports Authority of India. The annual turnover of the firm is close to Rupees one million.

The entrepreneur, a physicist from south India and son of an agriculturist, who is more inclined towards electronics, was approached by IIT to 'develop' the automatic glass light transmission device which was conceptualised in the Mechanical Engineering department, at IIT Delhi. The firm had to supply the developed devices to the Delhi Police Department (Traffic), who had planned to purchase at least one piece for each traffic circle in nine districts. Thus the proposed order was that of two hundred such devices. In April 1999, the Delhi Police Traffic Department requested five prototypes of the device for testing which were delivered in May 2000 by the firm but after that there has been no further demand by the New Delhi Traffic Police Department[50].

AGTRAM is a handy and a portable instrument designed for testing the light transmission through the automobile window glasses or similar transparent material in the form of plain sheet. There are two variants of AGTRAM, Version–I and Version–II, which differ in terms of the size of digital display and a printer attachment which Version–II provides. This device basically consists of three parts: a base unit or a control unit, a standard light source and a light sensor unit. The control unit comprises of a push on/off button, a digital display that can freeze or hold the readings, and a print button.[51] The light source is provided in the form of an incandescent filament lamp whereas the Light sensor unit is made up of a photodiode with an attachment that enhances the stability of measurement. A system of magnets in two separate parts is arranged around a ring, which enables the sensor to be clamped on the light source across a sheet of glass from two sides. Thus all a user needs to do is to switch on the machine, couple across the sample (read Glass Sheet) and read on the Liquid Crystal Display (LCD) and if required, store and print the visible light transmission in percentage. The magnetic coupling ensures easy and accurate measurement. The base unit is powered by a 12-Volt DC Battery making it easy for a traffic inspector to use it with the help of any car battery. The rationale for a battery attachment is that since sunlight has different components of light, its quality varies during the day, which invariably results in difference in the readings. The use of battery as an artificial source of light ensures that the rays are controlled and parallel such that they measure transmission between specified frequencies, giving an accurate reading. The other benefit is that the device can also be used in the night.

Case Background

[50] Enquiries were obtained by TTO from Uttaranchal Police Department, Dehradun but there has not been a follow up.
[51] The print option is available on the version–II of AGTRAM.

In 1997, with the rise in number of reports appearing in the newspapers on cases of kidnappings, snatching and even murders it was found that people who committed these crimes made use of the automobiles that had tinted glass, so that they could not be recognised. The Delhi high court then gave a ruling in the same year that the provisions of the Motor Vehicles Act pertaining to visibility inside a vehicle need to be enforced strictly. This ruling was based on a Public Interest Litigation filed by an advocate who had been victimised by the police department with regard to a faulty measuring glass transmission device. The provisions of Section 100 of the Central Motor Vehicles Rules1989, amended in 1993, stipulate that the glass of the wind screen and the rear window of every motor vehicle shall be such that the visual transmission of light is not less than 70 percent and that the glasses used for side windows be such that visual transmission of light is not less than 50 percent. The Delhi Traffic Police was enforcing the rule selectively, since there was no device made in India for measuring the transmission of light through the glass windows of automobiles that could verify whether the vehicles were conforming to the provisions of section 100[52]. This is evident from the news reports in some of the national newspapers. The launching of a drive by the Police Department stood little legal support, with the police using crude methods of measuring the permissible limits of light transmission (Staff Reporter, *The Times of India;* June 29, 1998). Based on these newspaper articles and on being approached by the Delhi Traffic Police Department, the inventor at IIT Delhi conceptualised the AGTRAM with the help of a research scholar[53]. The Delhi Police Department funded this project. The Automatic Glass Transmission Measurement Equipment was 'developed' by IIT Delhi in conformity with the testing procedures enumerated in Indian Standards IS 2553 (part-II) of 1992 and authenticated as acceptable equipment by the court after due testing and approval by the National laboratory, New Delhi. (Pereira M; The Tinted Tale; www.delhitrafficpolice.nic.in/art11.htm)

The project was given to IIT in early 1998 and given the time constraint of two weeks the 'development' and supply task of the optical transmission tester was handed over by the inventor to a local firm. The local firm in turn 'developed' the prototypes. This device thereafter got a patent filed in the name of all

---

[52] According to the entrepreneur who was manufacturing AGTRAM, there was a similar measuring device available in Delhi, which was made in Taiwan, but it showed lot of variations in the readings and was not tested for standards. The other similar measuring device at that time was available only in Bombay at a very high price.

[53] According to a newspaper report, subsequent to the above details, a portable device was developed by the inventor in IIT Delhi for determining the translucency of glass which operated on battery. (Shukla; April 23, 1998)

the three key people involved: the inventor, his student and the entrepreneur[54]. The technology was thus transferred to the firm on exclusive basis with a royalty clause only; that, if the product is sold, it should give TTO a unit by unit royalty amount for each device that is sold. But the instrument, which was specially designed, for the Police Department failed to generate any commercial interest despite getting conformity on the testing procedures as enumerated by the Bureau of Standards and regardless of getting authenticated as acceptable equipment by the Court.[55]

The recent development in this case has been that an independent testing laboratory in Delhi was asked to give a report on the performance of the device and based on the adverse comments by the scientist at the laboratory and the technical committee's recommendation[56]; the project had been stalled for the time being. However, on approaching the Office of Deputy Commissioner of Police (Traffic) New Delhi, although no comments were available from the Deputy Commissioner (Traffic), it was known that the technical committee comprising of Joint Commissioner of Police, representatives from National Physical Laboratory and from Bureau of Police Research and Development (BPRD) would be meeting on 23rd July 2003 to decide upon the purchase of AGTRAMs. Thus the case has been revived till the decision to procure comes through.

Firm's opinion

The users of the device were not interested in placing further orders apart from the six prototypes that were supplied to the Delhi Traffic Police Department. The product has been tested before the magistrate and has been given a certificate of acceptance and despite that the Police department who is the only user till date, has not shown interest. The firm is confident that it can manufacture on a unit by unit basis and complete a large order. The IIT has also not helped him in pursuing the matter and the firm is still hopeful in making the innovation a success. The entrepreneur has also tried to market the device to different police departments in other cities, but his efforts have not reaped any benefits for reasons not known to him.

---

[54] The given information has been obtained by private communication with TTO officials, entrepreneur and firm staff as also through newspaper reports and documents at TTO.

[55] Here one need to mention that the entrepreneur has been to the Traffic Police Departments in major cities including Chennai, Kolkata, Mumbai and Bangalore for acquiring potential orders for AGTRAM with no results.

TTO's opinion

The TTO also agrees that there has been a breach of trust on the part of Delhi Traffic Police in the sense that they did not place any order for such glass transmission measuring devices, which was specially designed and developed for them. There were some problems with regard to intellectual property, which did affect the pace of commercialisation process. The entrepreneur has not shown interest in commercialising the product, especially in resolving the matter with the Police department. TTO also feels that the royalty which should be coming from the firm might not come at all to TTO.

Inventor's Opinion

The role of the firm was in fabrication of the device, which was based on the technology conceptualised by the inventor. The case was handled badly at all levels be it the firm, the user group, or the TTO. The present status is that the technology has been copied by a third party, who is in turn selling the equipment being used by the Punjab Police and the Delhi Traffic Police[57]. The equipment being that of a standard variety has also not been verified.

The inventor is not dismayed that his technology has been copied and is being used so openly by others for his primary objective is to teach and do research.

<u>Inferences drawn and Lessons learnt</u>

Since this innovative product has a huge market potential it required additional efforts by TTO to help the firm in making it commercially successful. The TTO should have asked the independent testing laboratory the reasons for giving an adverse report. Even if the report had certain problem areas efforts should have been made to solve them jointly by the Firm and IIT professor. Also, the TTO approached a firm, which is a specialist in unit by unit manufacturing of equipment, and does not have an expertise in mass scale production. Had the firm procured the 200 units order from the Delhi Police Department, it would have been very difficult for the firm to complete the order in a stipulated time. The firm, with due regards to the efforts made by the entrepreneur, was not able to pursue the case and resolve the matter given the fact that more than five years have passed. This could perhaps be due to the limited human and financial resources that the firm has.

---

[56] This emerged out of a private discussion with the Entrepreneur as well as the TTO Executive in separate meetings.
[57] The Delhi Traffic Police however did not confirm to this.

This is a classic case where the reason for failure of an innovation does not recline on the entrepreneur/inventor nor to the factors like market non-acceptance but it does to the user needs in a different sense. Although the technological innovation might not have generated interest in the user, but then the user also did not show interest in any other similar or competitive product. The fact that there is a demand for such equipment and that there is no other alternative mechanism available for measuring transmission of light through tinted glass, is something which cannot be denied. The provisions under section 100 of the Central Motor Vehicle Rule 1989, that had to be pursued, have not been followed.

In this case if we analyse and seek the problematic stage(s) out of the eight stages in commercialisation process, we could identify the last three: Production, Sale and Usage. The maximum difficulty arose in the use as the user group itself was not interested. Since the production is based on unit by unit manufacture of products, it ensures precision but has to compromise on scale. There is no sale/production so far as the 'promised' order that of 200 units has not been placed and no revenue has been earned except for the development fee for six prototypes. Had the user group and the influencing forces taken interest, the sales would have been better.

Here it may be mentioned that the manner in which a user perceives the 'benefits' of a technology also decides whether the technology needs to be acquired and adopted[58]. The 'benefits' of the technology are not necessarily the advantages stemming from the use and application of the technology but it may also mean the personal 'benefits' to select individuals for not selecting the technology. It can also be said that success of an innovation depends on the interest of key individuals who are the decision-makers and once their involvement ceases, the problems get started. In this case, after the then Deputy Commissioner of Police (Traffic) left, the process has certainly slowed down if not clogged. Thus the strategies like Influencing Key Decision-Makers precede all factors for a successful innovation.

[58] This section was written before the technical committee decided to meet on July 23, 2003; the outcomes of which are still awaited.

5.3 Concluding Observations

The success and failure of technology transfers depend on the constraints of demand and supply, the marketing and management capability of firms, the R&D strength and the interaction between the academia and industry. It also depends on removing the barriers in the process of technology transfer which include insufficient mission orientation of the key personnel, conflicting policies, concerning legal rights to patentable inventions, institutional barriers to information flow, poor and antiquated methods of information and retrieval, poor understanding of process and low value being placed on technology transfer functions. It is believed that innovation is a manageable process and that it is bad decisions rather than technical and informational deficiencies that influence the success of innovative efforts. Also, effective collaboration, use of careful planning, organic and open management style with both commitment and enthusiasm for each technological transfer, ensuring the presence of important individuals and paying attention to post-technology transfer developments are the factors affecting to the success of technology commercialisation.

6.0 Summary and Conclusions

In the current era of globalisation, the survival of firms depends to a great extent on their international competitiveness. Studies have underlined that in the building up of long-term international competitiveness, there are not many options but to build up technological capabilities. The process of building up technological capabilities in developing countries has often been conceived as an outcome of technology purchase from outside and from technology generated within the country through own research and development efforts. In a globalising world there are limits for firms to be competitive by using technologies imported from abroad. This in turn compels the firms to look for alternative sources, and among them one of the most important sources is the academia. There have been an increasing number of technological co-operative agreements because it has been so difficult for firms to develop all the technologies that they need (Fernandez, 1991). Lately academic institutes have got much attention in being a proactive constituent in generating and sharing knowledge as also in creating technological innovations contributing to the economic development of a nation.

In the context of economic reforms the academia in general are also being forced to resort to generate funds internally. Academia has been a centre of knowledge creation and dissemination but at the same time it has had to respond to the falling financial resources, to become selective and to redefine its strategic aims. It too has restructured, relied more on networking and franchising, and crucially on the commercialisation of its research and training resources (see Webster, 1994b). There are studies which show, that to build and sustain their research capability; academics need to turn their attention wherever the resources are available. Academia transfer has been an offshoot of this economic necessity (Lee, 1996). Looking at the efforts of government in the last fifty years, India appears to be placed in a much better position, wherein a wide array of institutions have been built across the country. In addition to the university and national research laboratories, there are premier technological institutes like IITs which come under the ambit of technical education, the development of which has been rather impressive despite the fact that academic sector does not appear to figure in the priority list in terms of government support on research and development expenditure. The origin and distinguishing characteristics of IITs, their funding, outputs and industry cooperation all attempt to build an awareness among industry of their capability to foster better industry-academia relations by offering their R&D outputs (See chapter 2). There has been a growing amount of literature and progressive work on promoting the interaction between academia and industry. The present state of academia-industry interaction in India also shows the growing concern of policy makers towards building up of infrastructure and other such mechanisms that promote better relations between the two collaborative partners. The literature survey highlights the knowledge transfer from academia to industry through various channels be it in the form of publications and patents, consultancies and research contracts, licensing and equity participation, informal meetings and personal exchanges or through recruiting and joint ventures (See chapter 3).

Drawing from the experiences of United States of America and United Kingdom, the IITs are increasingly developing interface with industry by establishing technology transfer offices (TTO). The TTOs are a recent institutional innovation and even more recent in India. Their prime function is to foster interface between academia and industry and serve as a channel to commercialise new technologies to firms. They are also charged with coordinating the legal protection of academic research outcomes in the form of intellectual property in order to make them more marketable and valuable in industry.

The technology transfer office functions to bring the academic institute and industry closer and to have fruitful interaction, but just how well the TTOs are achieving this objective is debatable. Normally the measures of its success and efficiency in operations are judged by, the number of technology transfer agreements signed, the number of research consultancy and sponsored projects undertaken, the number of patents filed for, and granted to the academic institute and from all of these the amount of revenue it generates. A closer look at these figures through the empirical study of the IIT Delhi TTO has revealed where the action in technology transfer really is and what the odds for success might be.

In the twenty eight cases where information was available out of a total of thirty one technologies that have been transferred from IIT Delhi up to March 2003, most of the technologies that were transferred have been low cost technologies and transferred to the small and medium enterprise sector and of them 35.71 percent cases were termed 'success'; 32.11 percent as 'failure'; 21.43 percent were 'partial success' meaning thereby that they had generated sales at one point of time but are not currently generating sales; while 10.71 percent cases were in the 'developmental' stage of commercialisation.

The invention area that has the maximum representation in technology transfer cases in IIT Delhi is Biomedical engineering followed by Energy Studies and Physics. The 'success' of these cases tend to depend on observable inputs (number and quality of faculty, research facilities, fund support etc. in the department) as also on the unobservable inputs (faculty's propensity and their interest to get involved in research for industrial application). Thus it can be said that the observable and unobservable inputs in the case of the given three subject areas, have been high.

Given the outcome of the study that 54 percent cases belong to complete and partial failures, the common factors responsible for the failures include lack of mutual trust, lack of commitment of key people involved, poor understanding about the process, the user-needs not being satisfied, failing to influence Key Decision Makers for technology procurement when either partner tries to outsmart the other for short term gains, the very nature of technology that it becomes obsolete and so on (see chapter 4 & 5).

The above given figures for failures and the findings based on technology transfers from the academic institute shows that TTOs can bridge the difference between failures and success in meeting their objective of promoting industry-academia interaction and enhancing commercialisation of technologies. However one has to critically see the functioning of the TTOs. Technology commercialisation involves a set of core skills including identifying customer needs, developing product concepts, designing products and processes, prototyping, and also manufacturing which the academic institutes rarely posses. The role of TTO should be such so as to facilitate the inventors and the institute with these skills. But the TTO at IIT Delhi, though in its nascent stage, indulges more into all other activities rather than concentrating on core technology commercialisation activities. From the cases of technology transfers including the individual cases discussed separately (chapter 5), the 'success' have been mostly due to the individual interest of entrepreneur and inventor. The TTO has yet to equip itself with core commercialisation skills like developing product concepts, designing products and processes, prototyping and so on. It needs to facilitate the availability of facilities if it cannot possess them. Rather than concentrating on filing patents, marketing educational video programs and holding trainings schedules, the office should also focus on the said core skills. This however does not mean that other activities of TTO are not important, they are indeed necessary. The focus should shift from identifying a partner for commercialisation to identifying customer needs and develop product concepts.

The technology transfer offices which are not so old have a crucial responsibility to increase awareness about the importance of technology transfer among university faculty members and researchers and encourage them to disclose their inventions so that they themselves develop expertise in managing the technologies. However for the system to be sustainable it would depend on the willingness of inventors to transfer their inventions to TTOs, the interest of various firms in TTO inventions, and the effective use by the TTOs of provisions in their license agreements that requires the firms to develop the technologies they buy[59].. As the industry is restrained to take up incomplete know-how, thus for up-scaling of research it is necessary to demonstrate technical viability and economic feasibility of the process know-how. Lack of cooperation and coordination among different departments, among faculty members, technicians and administrators tends to hamper the development in the commercialisation process and also leads to delay in the entire innovation process.

The given considerations and the working of the TTO however show that the TTO Delhi has a shortage of working personnel. The success of technology transfer also depends on observable and unobservable inputs at different stages of technology transfer process; the TTO's infrastructure and the number of staff, number of patents, technology transfers etc. (observable) as also their aggressiveness and propensity to market and patent the technologies (unobservable) play a crucial role in the success of commercialisation of technologies.

According to Graff et al (2002), earlier the flow of knowledge and technologies between academia and industry got affected due to two types of problems: one legal and one institutional. Legally it was still quite difficult to exercise control over university inventions through intellectual property rights. The basic argument was made that the likelihood of firms to invest in the development of university-spawned technologies would be greater as their degree of control over the university invention is greater and as the magnitude of the investment necessary to make the developments is smaller. Institutionally there was lack of coherent policies and infrastructure within universities that continued to obfuscate and

[59] In some cases in FITT, the technology transfer agreements require prospective licensees to submit the business development plans for the technologies they want to license and then to include 'bench mark' or 'milestone' clauses. Such clauses enable the TTO to revoke the license if the licensee does not

hinder the flow of technologies. The developments in the Indian context especially based on the individual case studies of IIT Delhi, tends to align with the above-given findings. At the legal level, although the institutes retain the right to their inventions, the degree of control over inventions raises doubts in the minds of those who would like to invest in development of academic institute's spawned technologies. At the institutional level there is a lack of infrastructure and coherent policies that require development of the linkages through flow of technologies[60]. All the IITs do have an Industrial and Research Department primarily to promote industry-university interaction, and are relatively in a much better position as compared to the general universities. The establishment of TTO in Delhi as the first and only autonomous organisation among all the IITs dedicated to technology transfer and protection of intellectual property rights of the institute's inventions can be seen as a move in strengthening the infrastructure addressing the above mentioned institutional problem. In the United States, universities seek to fill this organisational gap by developing technology transfer offices to coordinate the issues and problems on commercialisation of technologies and legal protection of intellectual property rights (IPR).

It is well known that academic institute are not in a position to develop new discoveries into commercial products, they need to attract commercial licensees to invest in further development and it is believed that academic institutes' owned IPRs facilitate the commercialisation process by providing the source of exclusive rights to assure firms in industrial sector that the successful products would be profitable. The patents and copyrights also tend to encourage industry to share the costs of academic research. But in reality the situation at present is still at such a level where it does not matter to industry if the technologies have IPR protection. This observation was supported by the empirical study which shows that patents, designs and copyrights actually facilitate in the transfer only when the technologies are 'embryonic' or for that matter when the projects are turn-key projects. The IPR protection also helped in select 'new' study areas like computer science, and biotechnology. IPR also helped if the technology had a high market value and a market niche.

In order to explain the rise in number of IPR filing applications, it has been found that the remarkable increase in the propensity of TTO personnel to patent and license faculty inventions has resulted largely from an increased willingness of faculty (in select departments especially in textile technology in IIT

---

meet the development 'milestone' set forth. Though the FITT appears to have little experience in using such clauses, it is intended to be used mostly in cases of exclusive licenses and that there is a possibility of licensees objecting to it.

[60] In a universe of over 250 universities and very few institutes of national importance in the country, a handful of them have the infrastructure, the rest of them do not even have facilities for developing technologies not to speak of transferring them to industry.

Delhi) and institute's administrators to engage in licensing. But Patents granted to academic institutes reflect only a very small part of the practical value of academic research. Although patents allow the academic institutes to build reputation, and collect revenues, the question that remains to be answered is whether they play any role in facilitating technology transfer.

Considering that additional development is required to convert the licensed technology into a viable product before a firm even can begin the long approval process, long lag times exist before the receipt of any royalties by the academic institutes.[61] The solution to this problem can be seen in terms of the firms going in for an alternative technology transfer mechanism of equity participation, which may provide an early financial return. If the firm has an Initial Public Offering (IPO) or is acquired before achieving a viable product/technology, equity may provide a shorter time horizon to revenue realisation.

In order to better understand the difficulties faced in commercialisation process, three individual case studies were taken up. The cases were such that they belonged to 'success', 'failure' and 'partial success' category each. In the individual cases discussed, the 'success' **Case 1** where the technology 'heat sealable coatings for packaging application' was transferred to a firm dealing in printing and packaging applications the factors contributing for success were attributed to a thorough understanding of the problem, the technology development process and its implementation by the entrepreneur. The inventor also having vast experience in consulting was able to explain the benefits of the new technology to the entrepreneur. Close interaction, mutual trust, satisfaction of users' need and R&D strength, all these factors added to the success of commercialisation.

The foremost difficulty in most of the cases of 'failure' rests in the inability on the part of firms to scale up from the prototype stage to the mass production level. It requires adequate commercialisation skills on the part of the TTO to help the licensee or buyer of technology to up-scale so that it is possible for him/her to start commercial production/use. In **Case 2** the absence of proper coordination, lack of mutual trust between the entrepreneur and academic institute, poor understanding of the commercialisation process and insufficient mission orientation of key personnel flawed the commercialisation process. This case also draws our attention to the issue that it could be possible to

[61] In the present study, the official documents as well as several respondents in my survey expressed frustration with licensing as a transfer mechanism due to this time lag.

integrate the efforts of two important departments of the institute to solve the problem. Here, the design department could have assisted the involved biomedical and engineering department in the design and development of prototype, which appeared to be the main concern of the entrepreneur. Moreover, in the post liberalisation era, when imports restrictions have been relaxed and that, highly competitive international competitors exist, there was every possibility that a similar and cheap imported product would have invaded and captured the market. The reason given by the entrepreneur of not going ahead with the production because of an imported and attractive simile selling in the market would not have arisen if a market research had been done earlier. But it appears that both TTO and the entrepreneur did not give emphasis on market assessment.

The **Case 3** which was a 'partial success' in the sense that it could sell only six prototypes unfolds many issues. This technology 'The Automatic Glass Transmission Measurement Device has its application in measuring visual transmission of light through automobile windows, which under the provisions of Central Motor Vehicle Rule 1989, stipulates a minimum requirement of light being transmitted through the glass windows of automobiles. Despite the device getting a certificate of acceptance from the high court the user of the device did not place further orders and did not buy the equipments. The problem in commercialisation in this case is that the end-user of the product did not show interest in its use. In this case the fate of the innovation depended on the commercialising strategy that of influencing Key Decision Makers. There are key individuals; whose presence and interest influence the success or failure of technology. Here, since there was no problem with either the technology or its development, and that a ready market was available for the product, the problem rests in understanding the role of State as operating machinery, since the end-user is the State Traffic Police department.

Looking at the present interaction level between the industry and academia in India, the immediate concern for the policy makers should be to address to these important issues. Whether there is a need to set up guidelines as a part of policy for industry associating itself with academia particularly to increase awareness and also if there is a need to market academia in a professional manner. In order to strengthen the industry-academia interface, policy makers can influence developments by providing more information on the potential benefits of such relationships. For instance academic institutions could be seen as a source of highly trained and technologically literate graduates who would become the work force of scientists, and engineers and provide the key ingredient for the growth of technologically advanced industrial or R&D centres.

Through the compendium of technologies, it is apparent that there are 'no takers' so far for many technologies that have been developed in IIT. This could mean that either the technologies are such that they are not marketable and industry perceives that acquiring them would not be profitable or it could mean that industry is not yet 'ready' to accept the 'cutting edge technologies' so as to understand the benefits these technologies could bring to them in terms of profits, new markets, new users, cost reduction and so on. The fact that there are 'no takers' so far for many technologies could also mean that industry does not trust academic institute's spawned technologies for their requirement. While the more plausible reason could be that the technologies have yet to reach the 'right' buyer. The academia-industry relations have room for cultural reform and fortunately, rather than unfortunately cultural differences do exist between the two sectors and they must be respected rather than criticized as barriers.

An obvious factor that is correlated with the level of revenues generated by a TTO is simply its' age and professional experience. A young TTO such as the one at IIT Delhi, needs time to build up a portfolio of technology transfer agreements, patents, and contracts; to develop an expertise in intellectual property management; to structure transfer agreements in such a way so as to manage the many contingencies that can arise with technology transfers; and to be able to cope with 'defaulters' very cautiously.

The scope of future work lies in broadening the set, and include inventions and technologies at all the seven IITs in India. Further research is also possible in analysing different activities of the TTO at IIT Delhi and similar industry liaison establishment in different IITs. There is a also a need to know if the propensity of the faculty to disclose inventions has increased either because they are more willing to license as well as publish their research or because their research has shifted toward topics of more interest to the industry. It is the latter element of faculty propensity that has been the focus of policy discussions. However this issue requires yet another study to arrive to some conclusive answers.

References

- Adams J D; *Fundamental Stocks of Knowledge and Productivity Growth*; *Journal of Political Economy;* Vol. 98; 1990; p.673-702 in Thursby J and M Thursby; Who is Selling the Ivory Tower? Sources of Growth in University Licensing; *Management Science*; Vol.48, No.1; January 2002; p.90-104.
- *Annual Reports* of FITT; 1996-97; 1997-98; 1998-99; 1999-00; 2000-01; 2001-02.
- Anonymous; "Education in India"; *Global Journal of Engineering Education;* Vol. 2, No.3; 1998; p.317-326.
- Anonymous; "IIT grants likely to be performance-based now"; *The Economic Times;* October 08, 2003
- Anonymous; "Infotech bigwigs bid to take over IITs"; *The Times of India*, December 13, 1999
- Anonymous; "Should a business group be allowed to take over the IITs"?; *The Times of India*, December 19, 1999
- Baker N, Rubenstein A H; *The Effects of Perceived Needs and Means on the Generation of Ideas for Industrial R&D Projects;* IEEE trans; *Engineering Management*; 1967 in Qureshi et al.; 1984.
- Basant R; Technology Strategies of Large Enterprises in Indian Industry; Some Explorations; World Development; Vol. 25; No. 10; p.1683-1700; 1997.
- Bell E R J.; *Some Current Issues in Technology Transfer and Academic Industry Relations*: A Review Paper; The Oxford Trust, Oxford UK; 1993 p.1-17.(unpublished paper) in Y S Lee, Technology Transfer and the Research University: A Search for the Boundaries of University- Industry Collaboration; Research Policy; Vol. 25;1996;p.843-863
- Berman E; "The Economic Impact of Industry-Funded University R&D"; *Research Policy*; Vol. 19; 1990; p.349-355.
- Bhattacharya S; "Joshi's Stick for IIT: No funds without research"; *The Indian Express;* December 04, 2002.
- Blake D A; *The University's Role in Marketing Research Discoveries*; *Chronicle Higher Ed.* (May 12) in Feldman M, I Feller, J Bercovitz, R Burton; Equity and Technology Transfer Strategies of American Research Universities; *Management Science*; Vol.48,No.1; January 2002;p.105-121.
- Blumenthal D, M Cluck, L K Seashore, M A Stoto, and D Wise; *University-Industry Research Relationships in Biotechnology: Implications for the University*; *Science* 232; p. 1361-1366; June 1986 as in Lee, 1996.
- Blumenthal D; *Academic-Industry Relations in the Life Sciences*; Working Paper; Health Policy Research & Development Unit; MGH; Boston; 1992 in Webster A; International Evaluation of Academic-

Industry Relations: Contexts and Analysis; *Science and Public Policy;* Vol. 21, No.2; April 1994b; p.72-78.

- Bok D; "Universities and the Future of America"; Duke University Press; Durham, N.C.; 1990 in Lee, 1996.
- Bok D; *Beyond the Ivory Tower: Social Responsibilities of the Modern University*; Harvard University Press; Cambridge, Mass.; 1982 in Lee, 1996.
- Bongirwar D R; *Transfer of Indigenous Technology and the Challenges for Commercialisation*; Technology Transfer and In-house R&D in Indian Industry (Ed. by B K Pattnaik); Allied Publishers Limited, New Delhi; 1999
- Braczyk, H J., P. Cooke, and M. Heidenreich (Eds.), *Regional Innovation Systems* University College London Press, London/ Bristol PA;1998 in Etzkowitz H, L Leydesdorff; The Dynamics Of Innovation: From National Systems And "Mode 2" To A Triple Helix Of University-Industry-Government Relations; (www.deydesdorff.net/rp2000)
- Brooks H, The Government of Science, MIT Press, Cambridge, 1968
- Calvo J L; "Una Caracterizzacion de la Innovacion Technologica en los Sectores Manufactureros Espanoles: Algunos Datos"; *Economia Industrial*; 33; p. 139-150; 2000 in Valentin E M M; "Theoretical Review of Co-operative Relationships Between Firms and Universities"; *Science and Public Policy*; Vol. 29, No.1; February 2002; p.37-46.
- Castillo F, D Parker, and D Zilberman; "Offices of Technology Transfer and Privatization of University Discoveries"; Department of Agricultural and Resource Economics; University of California; Berkley; 2000.
- Cataldo P; "Building and Industrial/Academic Alliance: The Two Directions of Technology Transfer"; *Educational Technology*; May 1989; p.33-34.
- Central Bureau of Education, India; Development of Higher Technical Education in India; Interim Report of N K Sarkar Committee; February, 1946.
- Chauhan R C, Y Sahoo, and S Vijay; "Modular Technical Education Model: A New Paradigm in Meeting Critical Infrastructure needs of Developing Nations"; Massachusetts Institute of Technology, Cambridge, MA; 2001 (www.delft2001.tudelft.nl/abstract1120.doc)
- Cohen W, R Florida, L Randazzese and J Walsh; *Industry and the Academy: Uneasy Patterns in the Cause of Technological Advance* in Noll R.G. (ed.), Challenges to Research Universities, Ch.7., Washington D.C.: Brooklings Institute Press; 1998.
- Cohen W, R Nelson and J Walsh; "Links and Impacts: Survey Results on the influence of Public Research on Industrial R&D"; Mimeo, Carnegie Mellon University;2000.

- Colyvas J, M Crow, A Gelijns, R Mazzoleni, R Nelson, N Rosenberg, and B Sampat; "How do University Inventions get into Practice"; *Management Science*; Vol.48,No.1; January 2002;p.61-72.
- Dasgupta, P, and P David; "Towards a New Economics of Science", *Research Policy*; Vol.23; 1994; p.487-522.
- Department of Science and Technology, GoI, *Annual Report*, 2000
- Desai A V; "The origin and Direction of R&D in India"; *Research Policy;* Vol.9;No.1; 1980;p.74-96.
- Doctors S I; "The Role of Federal Agencies in Technology Transfer", MIT Press; Cambridge; 1969 in Qureshi et al.; 1984.
- Dosi G, C Freeman, R Nelson, G Silverberg, and L Soete; (eds.); "Technical Change and Economic Theory"; London; Pinter Publishers; 1988.
- Etzkowitz H, "Incubation of Incubators: Innovation as a Triple Helix of University-Industry-Government Networks"; *Science and Public Policy*; Vol. 29, April 2002; p.115-128.
- Etzkowitz H, A Webster; "Entrepreneurial Science: The Second Academic Revolution"; Capitalizing Knowledge (H Etzkowitz, A Webster and P Healey (Eds.)); State University of New York Press; 1998.
- Etzkowitz H, L. Leydesdroff; The Dynamics of Innovation: From National Systems and Mode 2 to a Triple Helix of University-Industry-Government Relations: *Research Policy*; Volume 29; 2000; p.109-123.
- Etzkowitz H; "Conflict of Interest and Commitment in Academic Science in the United States"; *Minerva* (Autumn); Vol. 34; 1996; p.259-277.
- Evans D J; "Universities, Technology Transfer and Spin-offs Activities-Academic Entrepreneurship in Different European Regions", University of Glamorgan Business School, (Mimeo); 1998.
- Fairweather J S; "Academic Research and Instructions"; *Journal of Higher Education*; 60(4); p388-407; 1989 in Lee, 1996.
- Feldman M, I Feller, J Bercovitz, R Burton; "Equity and Technology Transfer Strategies of American Research Universities"; *Management Science*; Vol.48,No.1; January 2002;p105-121.
- Feller I, M Feldman, J Bercovitz, R Burton; "A disaggregated examination of patent and licensing behaviour at three research universities"; Western Economic Association Meeting; Vancouver, BC, Canada; 2000.
- Feller I.; *University Industry R&D Relationships* in I. Schmandt and R. Wilson (Eds.), Growth Policy in the Age of High Technology (Unwin Hyman, Boston);p.313-343; 1990 in Lee, 1996.
- Fernandez S E; *Una Tipologia de la Cooperacion Empresarial*; Esic Market; Oct-Dec.1991; p.101-114; in Valentin E M M; 2002.
- *FITT Newsletter*, March 2003
- *FITT Newsletter;* September 2002,

- Freeman C; Technology Policy and Economic Performance: Lessons from Japan; London, Pinter Publishers; 1987.

- Freeman C; The Economics of Industrial Innovation, London, Pinter Publishers; 1982.
- Freeman C; *The Economics of Industrial Innovation;* Cambridge, MA: MIT Press, 1982b in Roberts, E B; What we have learned: Managing Invention and Innovation; *Research Technology Management*; Vol. 31 No.1; 1988; p.11-29.
- Geiger R L; Research and Relevant Knowledge; Oxford University Press; 1993.
- Globe S G W, Levy and Scwartz C M; *The Interactions of Science and Technology in the Innovative Process: Some Case Studies*; NSF-C 667, Columbus, Ohio, Bateelle; 1973 in Qureshi et al.; 1984.
- Gluck M; *Cooperative Research and Development Agreements at the US National Institutes of Health*; Mimeo; Health Programme; OTA; Washington DC in Webster A; International Evaluation of Academic-Industry Relations: Contexts and Analysis; *Science and Public Policy;* Vol. 21, No.2; April 1994b; p.72-78.
- Goswami U A; "Ministry for improved pool of technical manpower"; *The Economic Times*, April 27, 2003.
- Graff G, Heiman A, and Zilberman D; "University Research and Offices of Technology Transfer", *California Management Review*, Vol. 45, No. 1, Fall 2002.
- Henderson R, A Jaffe, and M Trajtenberg; "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting" 1965-1988; *Review of Economics and Statistics*; 81; 1998; p.119-127.
- http://ficci-sedf.org/fsedf/university4.htm; Universities at Cross-Roads-Agenda for the New Government.
- http://iti.acns.nwu.edu/clear/infr/cerf2/cerfch5.html; Commercializing Infrastructure Technologies: A Handbook of Innovators, Civil Engineering Research Foundation Report, 1997
- http:/www.aicte.ernet.in/policiesprog.html
- IIT Delhi at a Glance; *IRD*; IIT; March 2002.
- Indiresan P V and N C.Nigam; Indian Institute of Technology-An Experience In Excellence; [to be published by OUP for the World Bank; IIT Delhi]
- Jaffe A, Trajtenberg M, Henderson R; *Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations*; *Quarterly Journal of Economics;* 1993 in Thursby and Thursby, 2002.
- Jensen R, and M. Thursby; *Proofs and Prototypes for Sale: The Tale of University Licensing*; *American Economic Review*; Vol.91 , No.1; 2001;p240-259 in Feldman M, I Feller, J Bercovitz, R Burton; Equity and Technology Transfer Strategies of American Research Universities; *Management Science*; Vol.48,No.1; January 2002;p105-121.

- Joseph K J, Parthasarathi A; "Academia-Industry Interface: Dynamics, Issues And Policy Perspective"; (Unpublished Paper); 2003.
- Kneller R; "Intellectual Property Rights and University-Industry technology Transfer in Japan"; *Science and Public Policy*; Vol.26, No.2; April 1999; p.113-124.
- Lalkaka R; Technology Business Incubators: Critical Determinants of Success. Annals of the New York Academy of Sciences, Vol. 798; 1966.
- Lee Y S; "Technology Transfer and the Research University: A Search for the Boundaries of University-Industry Collaboration"; *Research Policy*; 25(1996), p 843-863.
- Link A N and J Rees; Firm Size, University Based Research and the Returns to R&D; *Small Business Economics*; Vol. 2; 1990; p.25-31.
- Lundvall, B Å, *Innovation as an interactive process: from user-producer interaction to the national system of innovation*, in: Giovanni Dosi, Chistopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete (Editors), *Technical Change and Economic Theory* (Pinter, London); 1988; pp. 349-369.
- Lundvall, B-Å. (ed.); National Systems of Innovation, London, Pinter Publishers; 1992.
- Mani S, and N Kumar; Role of Government in Promoting Innovation in the Enterprise Sector: An Analysis of the Indian Experience; Discussion Paper in United Nations University, INTECH; April 2001 (www.intech.unu.edu/publications/discussion-papers/2001-3.pdf)
- Mani S; Policy Instruments for Stimulating R&D in the Enterprise Sector, The Contrasting Experience of Two MNC Dominated Economies from South East Asia; Discussion Paper Series #2009-9; Maastricht: United Nations University/Institute for New Technologies; 2000.
- Mansfield E; "Academic Research and Industrial Innovation"; *Research Policy*; Volume 21; p.1-12.
- Mansfield E; "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing"; *Review of Economic Statistics.* ; Vol. 77; 1995; p.55-65.
- Mehrotra R C; "Industry-University Interaction"; *Journal of Higher Education;* Vol. 8; No.1; Monsoon 1982.
- Menon P K B; Technology Incubation Systems in India; DST; 2002; (www.technology4sme.com/ecoach/countries/india)
- Ministry of Human Resource Development, Government of India, *IIT Review Committee*, 1986.
- Morehouse, W; Technology and Enterprise performance in the Indian Tractor Industry, Does Self Reliance Measure up?, *Economic and Political Weekyl;* Dec. 20; p.2139-2151; 1980.
- Mowery D C, A Ziedonis; *The effects of the Bayh-Dole Act on US University Research and Technology Transfer: Analyzing data from entrants and incumbents*; Paper presented at the Science and

Technology Group; NBER Summer Institute, National Bureau of Economic Research, Cambridge, MA; 1999 in Feldman et al.; (2002)

- Mowery D C, R R Nelson, B N Sampat, A A Ziedonis; "The Growth of Patenting and Licensing by U.S. Univesities: An Assessment of the effects of the Bayh-Dole Act of 1980"; *Research Policy;* Vol. 30; 2001a; p.99-119.
- Mowery D C, R R Nelson, B N Sampat, A Ziedonis; "The Effects of the Bayh-Dole Act on US University Research and Technology Transfer"; *Industrializing Knowledge*; Lewis Branscomb (eds.); MIT Press; Cambridge, MA; 1999
- Mowery D C, Shane S; "Introduction to the Special Issue on University Entrepreneurship and Technology Transfer", *Management Science*, Vol. 48, No.1; January 2002, p. v-ix
- Mowery D, R. Nelson, B N Sampat, A Ziedonis; "Learning to Patent: Institutional Experience, Learning, and the Characteristics of University Patents after Bayh-Dole", 1980-1994; *Management Science;* Vol. 48, No.1; 2001b.
- Murali K; "The IIT Story: Issues and Concerns"; *Frontline*; February 14, 2003;p. 65-73.
- Nath N C B; "A Reformulation of Issues based on Indian Experience"; paper presented in an International Workshop on Industry-University Interaction on the theme of Technology, Commercialization and R&D; Bangalore; 24-26 June, 1992.
- Nelson R (ed.) National Innovation Systems, Oxford, Oxford University Press; 1993
- Nelson R and S Winter; An Evolutionary Theory of Economic Change; Cambridge, Massachusetts, Harvard University Press; 1982.
- OECD; Technical Change and Economic Policy (OECD, Paris);1980.
- Owen-Smith J, M Riccaboni, F Pammolli, W W Powell; "A comparison of US and European University Industry Relations in Life Sciences"; *Management Science*; Vol.48, No.1; 2002; p.24-43.
- Palit S K; "The Development of Engineering and Technical Education in India"; *Global Journal of Engineering Education;* Vol. 2; No.3;1998;p.317-326.
- Parthasarathi A; "Acquisition and Development of Technology", *Economic and Political Weekly;* Nov. 28; 1987; p.M131-M138.
- Pereira M, The Tinted Tale; (www.delhitrafficpolice.nic.in/art11.htm)
- Peters L S; *Academic Crossroads; Centre for Technology Policy*, RPI; New York State; October 1987, 1991; in Webster A; International Evaluation of Academic-Industry Relations: Contexts and Analysis; *Science and Public Policy;* Vol. 21, No.2; April 1994b; p.72-78.
- Porter M.E.; The Competitive Advantages of Nations; Free Press, New York; 1990
- Qureshi M A, P S Nagpal, L Singhal, S Pangasa, and V V Krishna; Transfer of Technology from National Laboratories to Industry; NISTADS Publication; New Delhi; 1984.

- *R&D Statistics* (2000-01); GOI
- Raghunath R; Varsity education vital for industry growth; (http://www.indianexpress.com/fe/daily/19971126/html
- Rahm D, B. Bozeman and M. Crow; "Domestic Technology transfer and competitiveness: An Empirical Assessment of Roles of University and Governmental R&D Laboratories"; *Public Administration Review*; Vol. 48; No. 6; 1988; p.969-978.
- Rajagopalan C, C J Singh; "The Indian Institutes of Technology: Do they Contribute to Social Mobility"?; *Economic and Political Weekly*; April 6, 1968; p.565-570.
- Raju V S, "Building Bridges between IITs and Indian Industry", Indo-British Seminar on Industry-Institute Interaction, eds. Michael White, Jehanara Wasi, 1995.
- Rooesner J D and A. Wise; "Industry Perspectives on External Sources Of Technology and Technical Information"; *Policy Studies Journal*; Vol. 22, No. 2; 1994 in Lee, 1996.
- Rothwell R, and W Zegveld; Industrial Innovation and Public Policy; 1981(Pinter, London)
- Rothwell R; "The Changing Nature of the Innovation Process; Paper presented at a conference on New Technology Based Firms in the 1990s"; Manchester Business School; 25-26 Issue.
- Rothwell R; "The Characteristics of Successful Innovations and Technically Progressive Firms", *R&D Management*; Vol. 7, June 1977.
- Roy S; "Our Industry has no confidence in our R&D"; *The Economic Times;* July 09, 2003.
- Sábato, J and M. Mackenzi; La producción de technología. Autónoma o transnacional (Nueva Imagen, Mexico; 1982 in (www.deydesdorff.net/rp2000)
- Sábato, J; "El pensamiento latinoamericano en la problemática ciencia-technología-desarrollo-dependencia" (Paidós, Buenos Aires); 1975 in (www.deydesdorff.net/rp2000)
- Scherer F M; *Technology and Innovation;* Readings in the Marketing Economy (J C Narver and R Savitt); Holt, Rinehart and Winston Inc.; 1971.
- Schwartz J J; How an Organization decides to innovate cited in Technology Transfer in Qureshi et al.; 1984
- *Science and Technology Policy 2003*; Department of Science and Technology, GOI; 2003
- Science Policy Research Unit, University of Sussex; "Success and Failure in Industrial Innovation; Report on project SAPPHO"; Edinburgh; Bishop & Sons Ltd.; February, 1972 in Qureshi et al.; 1984
- Sengupta A K; Technology Business Incubation-IIT Delhi Experience; a presentation at ELITEX 2003; IHC New Delhi; 26-28 April, 2003
- Sengupta AK; Marketing of Technological Competence of Academic Institutes in Technology Transfer and In-house R&D in Indian Industry; (Ed. B K Pattnaik); Allied Publishers Limited; 1999;p.359-366.

- Shane S and T Stuart; "Organizational Endowments and the Performance of University Start-ups"; *Management Science*; Vol.48, No. 1; 2002; p.154-170.
- Shane S, "Selling University Technology: Patterns from MIT", *Management Science*, Vol.; 48, No.1; January 2002;p. 122-137.
- Shane S; "Selling University technology: Patterns from MIT"; Paper presented to the Georgia Tech Conference on University Entrepreneurship and Technology Transfer; November 2000.
- Sheen M; *Time to Build a Technology Infrastructure in the UK*; mimeo; University of Strathclyde; 1992 in Webster A; International Evaluation of Academic-Industry Relations: Contexts and Analysis; *Science and Public Policy;* Vol. 21, No.2; April 1994b; p.72-78.
- Shukla; __; *The Times of India*; 23 April, 1998
- Siegel D, D. Waldman, A Link.; "Assessing the Impact of Organizational Practices on the Productivity of University Technology Transfer Office: An Explanatory Study", Working Paper 7526; National Bureau of Economic Research; Cambridge; MA; 1999.
- Slaughter S and G Rhoades; "Renorming the Social Relations of Academic Science: Technology Transfer"; *Educational Policy*; Vol.4, No.4; 1990; p.341-361.
- Staff Reporter; "Device Designed to Check Degree of Tint in Car Window Panes"; *The Times of India;* June 29, 1998.
- Stephen J Kline and Nathan Rosenberg, *An Overview of Innovation;* in Ralph Landau and Rosenberg (eds.); The Positive Sum Strategy, Washington, DC: National Academy Press, 1986;p.275-305.
- Subrahmanian K K; "Trends in Growth, Specialisation and Technological Dynamism of Indian Capital Goods An Overview"; *Indian Journal of Quantitative Economics;* Vol. 21, No.1; 1985.
- Swaminadhan, in Indo-British Seminar on Industry-Institute Interaction, eds. Michael White, Jehanara Wasi; 1995
- Teece D, G Pisano, A Shuen; Dynamic Capabilities and Strategic Management; *Strategic Management Journal;* Vol. 18, No.7; 1997; p.509-533.
- Teece D; "The Market for Know-how and the Efficient International Transfer of Technology"; *Annual American Acad.;* Vol. 458; 1981; p. 81-96 in Shane, 2002.
- Teece D; Economies of Scope and the Scope of the Enterprise; *Journal of Economic Behaviour Organ.;* Vol.1; 1980; p. 223-247 in Shane, 2002.
- Thursby J, M Thursby; "Who is Selling the Ivory Tower? Sources of Growth in University Licensing"; *Management Science*; Vol.48, No.1; January 2002; p.90-104.
- Thursby J, S Kemp; "Growth and Productive Efficiency of University Intellectual Property Licensing"; Working Paper; Purdue University, West Lafayette; 1999 in Feldman et al. 2002.

- Thursby M, R Jensen, and J Thursby; "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major US" Universities; *Journal of Technology Transfer*, Vol.12; 2001; p.59-72.
- Utterback J H; Innovation in Industry and the Diffusion of Technology; *Science* 183; 1974.
- Venancio L H M; "Intellectual Property & University Role in Innovation in the US: The Bayh-Dole Act", Triple Helix Conference Rio, 2000
- Vidyasagar, M., V V Patel, and G S Deodhare; "Control education: a world showcase"; *IEEE Control Systems;* 16, 2; 1996; p.30-33 in Palit, 1998.
- Webster A; Bridging Institutions: The Role of Contract Research Organisations in Technology Transfer; *Science and Public Policy;* Vol. 21, No.2; April 1994a; p.89-97.
- Webster A; International Evaluation of Academic-Industry Relations: Contexts and Analysis; *Science and Public Policy;* Vol. 21, No.2; April 1994b; p.72-78.
- Webster, A and H Etzkowitz; *Academy-Industry Relations: The Second Academic Revolution?;* SPSG Concept Paper no.12; SPSG, London; 1991 in Webster A; International Evaluation of Academic-Industry Relations: Contexts and Analysis; *Science and Public Policy;* Vol. 21, No.2; April 1994b; p.72-78.
- Ziedonis A.; "The Commercialization of University Technology: Implications for Firm Strategy and Public Policy"; Dissertation for the Haas School of Business, University of California; Berkley; 2001.
- Zucker L, M Darby, J Armstrong; "Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology"; *Management Science;* Vol.48, No.1, January 2002; p.138-153.
- Zucker L, M Darby, J Armstrong; "Intellectual Capital and the Firm: The technology of Geographically localized Knowledge Spillovers"; NBER Working paper #4946; Boston, MA; 1994 in Thursby and Thursby, 2002.
- Zucker L, M Darby, M Brewer; "Intellectual Human Capital and the Birth of US Biotechnology Enterprises"; *American Economic Review;* Vol.88, No.1; 1998; p.290-305 in Feldman et al.; 2002.

Jawaharlal Nehru University Library