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Analysing the Contribution of Technical Education to India's Core-HRST

A Case Study of IIT Madras

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Dissertation submitted in partial fulfilment of the requirements for the Degree of Master of Philosophy in Applied Economics of the Jawaharlal Nehru University

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MPhil Programme in Applied Economics

2005 – 2007

Centre for Development Studies

Trivandrum

June 2007

I hereby affirm that the work for this dissertation, 'Analysing the Contribution of Technical Education to India's Core-HRST: A Case Study of IIT Madras' being submitted as a part of the requirements of the MPhil Programme in Applied Economics of the Jawaharlal Nehru University, was carried out entirely by myself. I also affirm that it was not part of any other programme of the study and has not been submitted to any other University for the award of any degree.

20th June 2007

Anant Kamath

Certified that this study is the bona fide work of Anant Kamath, carried out under my supervision at the Centre for Development Studies.

Sunil Mani
Fellow
Centre for Development Studies

Narayanan Nair
Fellow and Director
Centre for Development Studies

In fond memory of

Dr. Raja Ramanna

Musician, Physicist, Parliamentarian,

Institution Builder, Natural Philosopher, Friend,

and above all,

An Exemplar of Humility

Acknowledgements

The first and most important mention of gratitude must undoubtedly be made of my supervisor Prof. Sunil Mani, who guided me through this dissertation. Prof. Sunil Mani encouraged my interest in science and technology manpower right from the early days of the coursework and has always been by my side through the many troubled moments and bouts of opposition I have had to face with regard to this study. Without exaggeration I can say that he has been my pillar of support.

I must also mention at this point Prof. D Narayana – a great amount of credit being due to him for his pragmatic guidance through most of the empirical part of this study.

There are a large number of individuals who have contributed bricks and mortar to this dissertation and I consider it imperative to list every one of them and thank them for the comments, suggestions and above all the good amount of their time they have given me to help me construct this piece of research.

At CDS, I have benefited greatly from the first discussions I had with Prof. KK Subrahmanian at his home. I must also thank Prof. Pushpangadan for his suggestion to undertake a case study of one single institution – an idea that became one of the cornerstones of this dissertation. I gratefully remember the session I had with Dr. Shantakumar on some basic nuances of the issue at hand. Prof. Mohanan Pillai and many other faculty members I must thank for their critiques (during my forgettable proposal seminar presentation in June 2006), without which this dissertation would have surely derailed. Of course, I must specially mention Prof. KJ Joseph who always provided the push of encouragement all through the MPhil programme.

I have had the privilege of interacting with many eminent individuals outside CDS who have had first hand experience with the issue involved in this dissertation. First inspirations for putting together my ideas came from the late Prof. MNV Nair, and Dr. Radha Das, formerly of the Atomic Energy Commission. Regular interaction with Dr. Chandramohan of the Financial Express, an alumnus of CDS and an old family friend, was also stimulating. Three academicians with whom I have had thought provoking discussions with are Prof. Pulapre Balakrishnan of IIM Kozhikode, Prof. K Nagaraj of the MIDS and Prof. Henny Romijn of the TU/e, the Netherlands. Prof. Balakrishnan and Prof. Nagaraj showed special interest in this study right from the outset and provided a good amount of advice, for which I am most thankful. There is also Prof. Paul Appasamy of the Madras School of Economics who has been a constant source of help and guidance.

Globelics 2006 we had organised at Kovalam was a haven for interacting with internationally renowned scholars and many other luminaries. My interactions with Prof. Bengt-Åke Lundvall and Prof. Charles Edquist provided me many ideas, as did Prof. Patarapong Intarakumnerd who supplemented my understanding of this issue in a developing country perspective. Prof. Amiyakumar

Bagchi's critique of the conceptual framework used in this study was a useful note of caution, and Prof. Ashok Parthasarathy's inputs helped me understand the many peripheral concerns involved with this study.

I turn now to IIT Madras. Here I must first thank Dr. Suresh Babu for his support and initial guidance on the placement routine at IIT Madras. Dr. Usha Titus, Registrar, IIT Madras I must thank for giving me the permission to conduct the study, as well as the IIT administrative staff for some vital data I was in need of. The long discussion with Prof. Krishna Kumar was most beneficial in understanding the demand-side of this issue. The Placement and Training Office at IIT Madras along with Lt Col Jayakumar and Hema were always welcoming. Most importantly I must mention the ever reliable 'Subbu' without whom the interviews would have been almost impossible. I am most grateful to the team of students – Sairam, Gautam, Siddhartha and Naresh Babu; and especially Priyank, Richie and Rahul – who brought (rather dragged) the students for interview. My deep thanks to the fifty BTech/Dual Degree students whom I had interviewed and interacted with. My stay at Taramani House, as well as my regular visits to Tifany's Food Court and Gurunath (where most interviews were conducted), has been most memorable.

Through the last couple of years, a few individuals have stood by my side and have given me the encouragement I have always needed. These include my old cronies Sriram, Svetha, Hanika and Nithya from MSE, and Supriya in Bangalore. In this regard I must also mention Dr. Ajithkumar in Cochin, Mr. Jerome Nirmal Raj in Bangalore, and Dr. Leela Gulati in Trivandrum.

My academic experience at CDS has been most beneficial thanks to my motivating teachers and course coordinators who have guided me through my MPhil programme, and the large team of non-teaching staff at CDS who have always been there for any help. Mr. Phil Roy has been a very close friend of mine throughout – sometimes fishing me out of pools of trouble (and at times falling into the pool himself) and never ceasing in warmth and enthusiasm. Thanks to the friendly canteen 'chechis' and the many interesting ism's of the scholars at CDS, my days here can, without exaggeration, be remembered as the golden days of my life.

Here I must mention the circle of PhD scholars – Nandana, Subbu, Harilal, Nathanael and Alice – who have been really great company to spend time and share ideas, humour, and life with. My unforgettable fellow batch-mates – Alex, Nirmal, Sumalatha, Prabhu, Rijesh, Rajeev, Sajan, Jaishekhar, Shalini and Sreepriya – for travelling the MPhil journey with me, for being together as one undivided batch at all times, for all those memorable trips we made together, and for comic relief throughout the course. Most important in this entire set are my good friends Jyoti and Prabhat, and of course, Neethi.

But all this has been possible, above all else, only with the undying love and support of my parents and grandparents, and of the Grace from above.

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Abstract of Study

Almost all economic activities undertaken today are marked by a high intensity of knowledge – either as a vital resource itself, or as a catalyst to supplement other economic activity. India has been very keen in participating and competing internationally in knowledge-intensive products and services, aiming at becoming a 'knowledge economy' and a 'knowledge superpower'. But the fact remains that its standing in Core-HRST (Human Resource in Science and Technology) and R&D labour force is disparagingly low, in spite of the existence of a large supply of S&T graduates (or HRST-E) and the presence of high quality educational institutions in its innovation system like the Indian Institute of Technology (IIT). These institutions have been created, besides other reasons, primarily to supply highly skilled S&T manpower for the other actors in the Indian NSI, but paradoxically the Core-HRST, as mentioned above, is in crisis and its future is rather bleak. One of the many reasons for this is the phenomenon of even the most highly skilled S&T-qualified students migrating to non-S&T disciplines and careers.

Despite acknowledgement of this phenomenon by state and academia, and despite this phenomenon being ubiquitous across developing countries, research on technical education establishments in a Systems of Innovation framework, *even in the fairly vast literature on NSI, is evidently scarce. In the Systems of Innovation perspective, this phenomenon can be interpreted as a result of* 'institutional discordance' between the technical education system as an actor and the other actors in India's Innovation System. *This becomes all the more important in the context of the future of India's innovative capabilities – it having a disparagingly low R&D manpower and at the same time aiming towards a becoming a knowledge economy. This dissertation keeps this discordance as its cornerstone and analyses* the contribution of the technical education system in building India's Core-HRST stock, i.e., how far it has delivered its role as a primary actor in India's Innovation System.

This discordance is studied taking the special case study of one institution – IIT Madras. Though graduates from here are carved out to become the potential manpower in India's innovation system, for various reasons they have been moving out of the innovation system and a preference for non-S&T professions seems to have developed. On gathering qualitative information through primary survey method this study explores as to how and why such preferences have developed, in the context of the implications they could have on the future of our innovation. Since no such study has been conducted in the Indian context, the need of the hour is a ground level exploration; hence this study seeks to be more exploratory than anything else.

The survey was undertaken among members of faculty from almost all departments and a sample drawn from the population of undergraduate students, to find out what their perceptions are with regard to taking up R&D and Core-Engineering as a line of work, especially with more 'attractive' alternatives available to them; and what in their opinion are the push- and pull-factors in and around their environment that move their fellow graduates away from R&D and Core-Engineering related professions in general. Close examination of the economic, non-economic and institutional factors revealed through the survey suggested an interaction mechanism among these factors that has a tremendous influence over their choice of placement offer at IIT and in the long run their choice of profession. This interaction mechanism aimed at understanding the incentive structure at ground level for even the best qualified engineering or S&T-graduates to stay within the innovation system.

With the backdrop of institutional discordance within India's innovation system, using the case study of one prominent institution, this study aims at analysing whether technical education in India has really contributed to building India's Core-HRST Stock.

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I

The Systems of Innovation Approach as a Conceptual Framework

This study is about certain dimensions of technical education in India. The study adopts the now popular framework in innovation literature – the National Systems of Innovation framework. Given the fact that the knowledge component of production and trade has increased, the study begins with a discussion on the role played by knowledge and learning in the modern day economy, and how knowledge infrastructure is increasingly being considered by many economies – regardless of their stock of knowledge and their learning abilities – as much a priority as the more familiar physical infrastructure. This lies beyond the scope of mainstream neoclassical economics, so a new conceptual and analytic framework – the National System of Innovation that underscores the systemic and institutional nature of innovation – is introduced and discussed. The various components of this framework are unfolded, first with the evolution and coverage of the framework and the elements or actors within a system of innovation. Among the many functions and activities that are undertaken in a system of innovation, competence building is discussed in detail. The chapter closes with a special note on University, being the actor that takes upon itself the role of competence building. Most of what follows is derived from the literature on the National Systems of Innovation, both the early writings as well as recent updates to the framework.

The Knowledge Economy and Knowledge-Infrastructure

The role played by knowledge in an economy is more influential today than it ever was in the past. Almost all economic activities undertaken today are marked by a high intensity of knowledge – either as a vital resource or as a catalyst to supplement economic activity. Any agent participating in economic activity would undertake learning as a step in the process of acquiring knowledge and building upon knowledge stock; a process inevitable for survival and endurance in a highly competitive environment. The stock of knowledge accumulated as well as the ease and speed at which learning is performed to accumulate this stock are decisive issues for not only individual firms or industries, but also for nations and regions at large. It would therefore not be exaggerating to quote Lundvall's (1992) proposition that probably the most important process in the modern economy is learning, and probably the most fundamental resource in the modern economy is knowledge.

Accumulating knowledge as a resource and developing the skills required for the learning process calls for building a particular kind of infrastructure known as 'knowledge-infrastructure'. More precisely, knowledge-infrastructure is the complex of public and private organisations and institutions whose role is the production, maintenance, distribution, management, and protection of knowledge; these possessing technical and economic characteristics not dissimilar to physical infrastructure (Smith, 1997). The knowledge-infrastructure in an economy decides the kind of innovation the economy can undertake, as well as the efficiency at which it takes place. It supports, in a learning-intensive economy, a substantial portion of economic activity, since knowledge (whether formal or tacit) is in some cases the very basis for industrial production in such an economy (Smith, 1997). Building knowledge-infrastructure would require the active participation of not only the state but also private and other bodies, to devote resources for the large investment required in fostering the growth of physical and human capital. The development of this knowledge-infrastructure is therefore as important as developing the more familiar physical infrastructure; both these types for infrastructure in fact requiring some degree of concordance between each other for innovation activity.

Carlsson (cited in Edquist, 1997) mentions four types of institutional infrastructure, which could also be termed 'organisational infrastructure required for knowledge building', as termed by Coriat and Weinstein (2002).

(1) industrial research and development
(2) academic infrastructure
(3) state policy
(4) other institutions

Depending on what kind of innovation activity the state, industry or firm plans to undertake, the appropriate mix of these four will be formulated. Though it may seem sometimes that state policy overrides the other three, it need not be so, since the state would also draw heavily from the other three for research and policymaking. The efficiency of each institution's working and the harmony between them are what almost wholly determine the development of an economy's learning capability (Johnson, 1992).

But for many economies around the world, devoting meagre resources to create knowledge-infrastructure is simply unaffordable, given the many other urgent priorities at hand. Especially in the case of developing countries, new products and processes are rarely innovated at home due to various constraints, and they need to be imported. Only a small part of the total technical learning in developing countries is really 'homespun' (Dalum et al, 1997). Despite the fact that building knowledge-infrastructure at home may be unaffordable, developing countries might still be keen on competing internationally in knowledge-intensive products and services. In this case knowledge-intensive goods and services would appear as unavoidable items in their import list, and would consequentially contribute a substantial amount to total import cost.

Apart from the import cost aspect, it must be noted that knowledge bought from abroad cannot always be applied in the importing country in its original form, and will necessarily need modification to suit economic conditions and consumer preferences at home. Adaptation of imported technology for domestic conditions requires a variety of skills on the part of the importing country to conduct the incremental innovation to modify the imported technology for home purposes. So the 'adaptation-incremental innovation' process in developing economies, considered a form of learning, becomes an extension of import of knowledge, just as import of knowledge itself is an extension of learning (Dalum et al, 1997). This only means that even for a knowledge-importing economy the appropriate knowledge-infrastructure still needs to be built.

Hence, whether an economy is a renowned radical innovator in the global market or a borrower-modifier-adapter of imported technology, building knowledge-infrastructure is a must. To cite an example: South Korea, a reputed indigenous technology developer today, gives high emphasis on the building of knowledge infrastructure (here in the form of highly skilled human resource). But this emphasis was observed in Korea even during the early years of its industrial development when it was only a borrower and adaptor of imported technology (Kim, 1993).

The National Systems of Innovation Concept

The kind of economy we have been discussing about in the previous sections differs greatly from the economy as understood by neoclassical economics. Mainstream neoclassical approach understands the economy as an entity constantly striving, among other things, for stability and equilibria, with government and other such institutions preferably operating passively. This type of understanding cannot be applied to the economy of today, which is characterised by a highly dynamic nature, which is actively assisted by government and other institutions, and which seeks to be malleable to especially technological change. An economy that considers knowledge as a fundamental resource cannot consider aiming at equilibrium and other such 'static' objectives. It has to be as dynamic as possible by incrementally amending its production and trade activities to the changing structure of knowledge. Under the influence of Schumpeterian thought, the understanding of innovation processes in a dynamic economy was recognised by scholars such as Freeman and Lundvall as out of bounds for the neoclassical perspective (Sharif, 2006). One of the reasons cited for this by Johnson (1992) was that innovation is a continuous dynamic process and not a discrete event uniquely localised in space and time, which makes it off limits for the neoclassical approach.

On these lines, in the late 1970s and early 1980s, the need for a new perspective to understand competitive behaviour in a dynamic and knowledge intensive economy began to be called for. Such was the circumstance under which the National Systems of Innovation (NSI) approach was developed in the OECD. Though it is hard to say exactly which of the two spheres – theory (as academic research) or application (as the policy making process) – contributed more, it can be said for certain that it was mainly as a result of the *interaction* between these two spheres that the development of the NSI as a system of understanding was formulated (Sharif, 2006). On a parallel, the criticism of Kline and Rosenberg's Chain Link Model of Innovation by academics called for a rethinking of innovation theory, signalling the requirement for a new analytical framework to understand innovation processes in a competitive economy.

Defining the NSI in precise terms and drawing out its analytical boundaries has not been an easy task. One of the definitions says that an NSI is a 'set of institutions that (jointly and individually) contribute to the development and diffusion of new technologies, which provide the framework within which governments form and implement policies to influence innovation processes' (Metcalfe, 1995). It is also defined as 'an overall context of economic and technical behaviour that shapes technological opportunities and capabilities of agents in it' (Smith, 1997). Richard Nelson, one of the chief contributors to the development of the NSI approach, defines the NSI as a system of interconnected institutions to create, store, and transfer the knowledge, skills, and artefacts which define new technologies. These institutions include private firms, working individually or in collaboration with universities and other educational bodies, professional societies and government laboratories; private consultancies and industrial research associations (Nelson, 1992). In most definitions we see a stress on the fact that it is an idea of a 'system' of interacting institutions, therefore making the NSI a *systemic* approach to the understanding of a knowledge intensive economy and the innovation process.

One must keep in mind at all times Charles Edquist's (1997) warning, that the NSI approach is not in any way a formal theory providing or establishing stable relations between variables.

Also, the NSI as a systemic approach to innovation need not only be at a 'national' level. The approach is extended to all geographic and functional levels as systems of interconnected institutions function not only at a national level but also within regions (regional systems of innovation), within sectors of the economy (sectoral systems of innovation), between groups of nations, etc. In the light of this fact, a better term to use for the framework could be the 'Systems of Innovation' (SI) approach, which would accommodate the fact that systems of interconnected institutions exist at the local, regional, national, or international level, or even within and between sectors in an economy.

Again, the Systems of Innovation as a framework for understanding is applicable not only to those economies and systems within economies engaging in radical innovation, but also to systems of institutions undertaking incremental innovation (since, as seen earlier, incremental innovation and adaptation also includes learning processes and requires appropriate knowledge infrastructure).

Practically every economy in the world today undertakes learning through trade of knowledge-intensive goods and services. Neither is any region in the world today excluded from the knowledge trade, not can any region claim to be self-sufficient in knowledge, however developed it might be. Countries and regions that are technologically highly advanced might appear technologically self-sufficient, but the truth (evident in the trade of advanced technology) is that developed countries undertake almost two-thirds (about 63% of export *and* 64% import) of global hi-tech trade (UNESCO, 2005b). This, and such other evidence, only reinforces the fact that the SI as a conceptual framework is applicable to understand innovation in virtually every economy competing in the global market, whether knowledge-creating or knowledge-importing, whether technologically advanced or poor.

There is a milieu of activities carried out by a System of Innovation. The most evident of these would be research and development (R&D) activities and other processes leading to the creation of new knowledge. Other, sometimes imperceptible, activities include the following:

(1) Competence building, relating to the training of skilled manpower (which will be discussed in greater detail shortly).
(2) Formation of new product and finance markets that facilitate R&D and innovation activities, and that facilitate commercialisation of new knowledge.
(3) Communication of quality requirements for new products, from the demand side.
(4) Creating new organisations and changing/modifying/restructuring the existing organisations, for innovation
(5) Networking through markets and other mechanisms
(6) Interactive learning between the organisations in an SI
(7) Creating and changing the institutions that surround the functioning of the organisations of an SI.

The Elements in a System of Innovation

The Systems of Innovation is an approach to understand innovation processes, wherein institutions evidently hold the central place. The term 'institution' in economics and social science parlance is synonymously used for both

(1) rules, norms, habits, laws, common practices etc., and,

(2) organisations like profit-making and non-profit-making firms, universities and educational institutions, R&D labs, bodies managed by the state, etc.

Almost every definition of an NSI lays emphasis on the institutional interrelationships between organisations besides their individual functioning within the innovating economy; the NSI itself thus being defined primarily in institutional terms. The earlier neoclassical approach to the economy and the Chain Linked Model of innovation seem to assume away institutions, but the SI framework holds them as the principal elements of the system. In almost all versions of the systemic approach to innovation, institutions are treated not as bystanders but as core determinants of innovation process; a stand quite in contrast with most other models of innovation (Edquist, 1997; and Edquist & Johnson, 1997).

In this study, a clear distinction is made between (1) and (2). Rules, norms habits, etc., coming under (1) are termed 'rules of the game' in the SI. These 'rules of the game' include patent laws, technology policy, intellectual property rights regimes, tax laws and incentives, environment and other regulations, R&D investment routines, etc. (Edquist, 2005). On the other hand, there are what are called the 'elements' or 'actors', coming under (2), which include all major organisations and bodies constituting a nation's or region's innovation system. 'Organisations' can be defined as the formal structures that are consciously created and have an explicit purpose (Edquist and Johnson, 1997). They include private firms and business enterprises, universities and other educational bodies, the government and its various organs and agencies responsible for innovation policy, competition policy et al, venture capital organisations, etc. Understandably, both (1) and (2) differ greatly between countries and even between regions within a country. It is in this regard that SIs across countries and regions are vastly different from one another.

A short examination of the major actors within a system of innovation would be beneficial before moving further. Most of what follows on the roles, functions and importance of each of these actors, has been derived from the existing literature [including Lundvall (1992), Gregersen (1992), Christensen (1992) and Mowery & Sampat (2005)].

- *Private Enterprise*: this is probably the most significant actor in a system of innovation of a competitive open economy. As mentioned at the outset of this chapter, private firms consider their stock of knowledge and flow of information as highly important concerns for their profitability and endurance in the market. The process of learning is undertaken by this actor very intensely, necessitated mostly for its survival in the market. The pressure for performance brought about due to factors like globalisation has lead to innovation activity to take priority in many of these firms; causing in turn, private enterprise to be probably the largest contributor to innovation. Competition might not be the only pressure that calls for innovation; even cooperation and inter-organisational linkages might foster a culture of innovation. This was seen for most of the twentieth century in the West, where the demands of the Cold War led the United States government to prioritise military R&D, which in most cases was undertaken by private firms.

- *Government*: though government is presumed more a user than a producer of technology, it is this actor that defines the trajectory of innovation in an NSI. The State gives direct support to science and technology (S&T) activities in a country, considering it a necessary condition for economic and social development. As Gregersen (1992) says, the government and public sector plays exceedingly the role of a *pacer* that draws out the direction of an economy's innovation trajectory and regulates the type of technology production. Just as the private sector is probably the most prominent producer of technology, the public sector is probably the most prominent user of this technology. But in many socialist-inclined countries, the public sector remains both a major producer and prime user of technology, and is the chief motivator of R&D.

- *Education System*: this is an actor that has received relatively less attention in the literature on systems of innovation. In significance it equals private enterprise and government, since the education system provides most of the skilled manpower for innovation activity by these two actors. Especially for technology capability building, it is important that a nation's educational system is well equipped and geared to supply quality scientific manpower. University as an actor also conducts its own research and innovation, sometimes quite in contrast from the kind of R&D done by private firms since the incentive system in University is not oriented towards profit or survival in the market. This makes it possible for knowledge to be developed for its own sake. Universities and educational bodies therefore combine the functions of education, training and skilled manpower supply, as well as conducting advanced research for academia and industry. The nuances of University's role as an actor will be dealt with in more detail shortly.

- *Finance System for R&D and Innovation*: this is an actor that supplements the other actors and ensures the effective functioning of the SI as a whole. For universities and educational bodies the financial system is extremely important since even non-profit and academic research also inevitably requires funding. However, an efficient finance system for R&D is more vital for the private sector, since technologies today have relatively shorter life-cycles and continuous innovation and hence a constant network and flow of funds is crucial. Even trading technology, whether import or export, requires monetary backing – the lack of which may sometimes deter many developing countries from undertaking advanced technology production, despite other assets like manpower they might possess. R&D being an expensive activity in the contemporary era, even large firms would depend on external sources for finance; dispelling the notion that a market for innovation finance is the concern only of small firms (Lundvall, 1992). The finance for R&D and innovation can come from various kinds of systems: a capital market oriented system, a credit based government-influenced system, a credit based government-independent system, etc (Christensen, 1992).

To a large extent, the capability set of any participant in the economy is defined by one's surrounding institutional environment. Economic activities can never be undertaken in isolation, and economic agents have to give due consideration to the institutional framework one is in. One could even go to the extent of saying that more than the individual abilities of actors it is the relations and interactions between them that determine the progress of the economy. It is impossible for any actor in an SI to involve in the process of knowledge creation or learning without being influenced by the institutional setup around. Processes like learning (by producing, searching and exploring), accumulating earned knowledge and 'remembering', developing innovative ideas and projects, are all affected by the institutional setup at all points, at all interactions and all feedback mechanisms (Johnson, 1992 and 1997).

Hence, technology, production, research, etc., are all institutionalised processes and not isolated. And since innovation is an interactive and in most cases a cumulative process, the focus on institutions becomes all the more important.

Learning and Competence Building in a System of Innovation

Learning is generally of four kinds – imprinting, rote learning, feedback and an organised search for knowledge (Johnson, 1992). The fourth of these involves relatively more institutional interaction than the other three. The various actors in the economy take a great deal of initiative and devote a considerable amount of expense to undertake an organised search for knowledge. In the SI framework one of the key components of an organised search for knowledge, besides innovation and R&D, is competence building (Edquist, 2005). This refers to building human capital by constructing the institutional infrastructure involved in training human labour and building skills.

There is no universal formula for competence building, since each economy trains human labour and builds institutions in accordance with the kind of innovation activity it seeks to undertake. A planned change in an economy's future innovation activity will involve, to a great extent, redirecting the training given to its manpower, i.e., redirecting the competence building strategy appropriate to future innovation activity. It goes without saying that competence building becomes a much more formidable task for economies eager to undertake radical innovation, or for developing economies that are keen on shifting from adaptive-incremental innovation to more radical innovation.

Even processes like reverse engineering, learning and adaptation, or incremental innovation require certain skills on the part of the labour force in the importing country. These skills are of varying degrees across countries; the highest degree possessed by those countries undertaking radical innovation. Even if knowledge can be accumulated through time through imported commodities; technological skills in the long run are embodied only in a country's own people i.e., in the manpower it possesses. Countries that are deficient in highly qualified skilled labour will have to resort to actually importing the manpower, which would mean incurring extra costs for giving incentives to attract manpower from abroad. Offering opulent incentives to bring personnel from abroad may not be affordable in the long term for the developing countries. This boils down to the fact that training one's own manpower turns out to be one of the only viable routes to develop and maintain a country's future technological capability.

Reiterating the Korean case as a classic example for human capital building at all levels of economic and technological development, a study by Porter in 1990 (cited in Kim, 1993) showed that efforts in building human capital in Korea were the strongest among eight industrialised (Denmark, Germany, Italy, Japan, Sweden, Switzerland, the UK and the US) and two semi-industrialised (Singapore and Korea) nations. In fact, a large section of senior personnel in government, business and academia in Korea were exposed to foreign training – an asset that gave strong backing to Korea's efforts to train its manpower for more advanced R&D and indigenous innovation in the long term[1].

University as an Institution in a System of Innovation

Education institutions are vital parts of knowledge infrastructure since they contribute directly to competence building. Universities as one of the educational institutions in an SI play an extremely important role, not only as places where manpower is trained, but also as the arena for R&D of considerable relevance to industry and government. A schooling/training system in an economy, says Nelson (1993), even influences workers' *attitude* towards technical advance. Empirical evidence shows that economies like the United States and Germany that offered university training in response to industry needs surged ahead noticeably in scientific fields, than those economies like Britain, France, Israel and Argentina that didn't push universities enough to adapt to industrial change (Nelson, 1993). The latter set of countries could also easily include India, as a country in which most university training, especially in the sciences, has rarely addressed industry needs; the university at large existing as an institution keen

[1] Incidentally, Korea stands out as having one of the highest figures (in 2001 in Asia) for percentage of young workforce (aged 25-34) with higher education – nearly 40% of population in that age group. This has far reaching benefits for Korea's future.

more on examinations and credits. It must be mentioned at this juncture that the above points do not in any manner imply University as an institution set up solely to cater to Industry, or as subservient to Industry's needs. In some cases, research and innovation by University might even shape activity in Industry.

It may be the case among some nations that they have not been able to progress much on the innovation front due to institutional problems like a 'lock-in' to a particular trajectory of production and innovation, hard to get out of without incurring costs heavily. In other words, institutions may have become so dependent upon a routine of economic activity that it may be highly infeasible for them, financially or otherwise, to go in for sweeping structural or functional changes in especially innovation related activities. The risk involved in switching processes or products may be assumed by agents to be greater than it actually is, and stunted innovation activity as the price paid for risk minimisation may unfortunately become an entrenched feature in the system. This problem turns out especially severe if the institutional framework is too rigid to accommodate revolutionising changes. The repercussions of this might be quite serious, in that the organisation may be left behind in the locked-in trajectory of functioning, losing out heavily in a competitive market and stagnating while the rest of the economy progresses rapidly (derived from Perez, 1985, quoted in Johnson, 1992). This sort of 'inertia' leads to a gap between rate of institutional change in an organisation and rate of technical change in the environment around it. In other words, progress on the technological front might be much faster than progress on the institutional front, leading to what is known as 'institutional drag'[2]. Mismatch problems between groups of institutions in a system of innovation would then follow (Johnson, 1992).

Though it has been supposed that educational bodies like universities might be able to easily break free from this trajectory (one of the many reasons being the incentive system for innovative research in universities), it might be the case that the universities themselves might be causing this drag. That is to say, the mismatch between rates of technical change and institutional change might occur because educational institutions

[2] This phenomenon was reported to have been a cause for concern even a century ago, long before the knowledge economy as in today's context was ever thought of. But this phenomenon is not be confused with institutional *time lags* which are in fact quite natural in a process of knowledge diffusion, since institutions differ in the time they take to learn and assimilate new knowledge.

might themselves be locked in old and rigid trajectories. A good example of this is India, where a severe clash exists between rapid technological progress in Industry and structural-functional rigidity in University. Links between University and Industry and minimisation of institutional drag in science and technology exist only in a handful of institutions like in the IITs; with the vast majority of organisations in either sphere completely ignorant of each other. It is doubtful as to how a system of innovation in an aspiring knowledge-economy like India will function to full efficiency with minimal institutional interaction such as what is prevalent. Society seems to be very keen on technological change, but is very rigid as far as institutional change (especially for University) goes. In other words, there is in general a higher degree of resistance to institutional change than to technological change. Society seems to desire the latter, but poses stiff barriers to bring about the former (Edquist & Johnson, 1997).

We began the chapter with the importance of knowledge and knowledge infrastructure in an open and competitive economy. The NSI framework, which will be the basis for analysis throughout this study, was dealt with in detail. An important endeavour within a system of innovation was seen to be competence building, which provides the skilled workforce required by all the actors in the system. The economics of education and training has definitely undergone a great deal of research, yet rarely through a Systems of Innovation perspective. Edquist (2005) suggests that competence building (as a serious issue especially for developing countries keen on knowledge-based economic activities) must be given more attention by scholars involved in especially the Systems of Innovation approach. Most competence building literature has been outside the Systems of Innovation concept, and an important task for future research would be to integrate education/training systems and innovation systems in one single analytical framework (Edquist, 2005 and Lundvall, 1992). This study, in essence, inclines principally towards this sort of integration in the Indian innovation system context.

The next step would be to see the efforts in India, focusing specially on technical education. The importance of competence building in technical education increases as the country moves from being an imitator-adapter to a radical innovator.

II

Technical Education in India

There is estimated to be a total of around fifty million graduates in India across various disciplines (NCAER, 2005). Around a quarter of this fifty million is S&T educated, which means that there is no severe shortage of S&T qualified graduates in India. But merely a large stock of around thirteen million S&T qualified people would not yield any benefits for scientific R&D or technological innovation if these individuals were not, in the first place, engaged in S&T related professions. This is exactly the situation in India, evident from the fact that less than five million (only around 35%) of the thirteen million S&T graduates are engaged in science and technology related professions. These details will be taken up again in the later sections of this chapter, but the underlying idea behind mentioning this in as an introductory note is to help one appreciate the idea that there is a large institutional structure for technical education in India with a large number of science and engineering qualified graduates being churned out every year, yet there exists simultaneously a severe shortage of S&T manpower. This dissertation deals with primarily this issue, understanding it in the special case of one institution. But before taking up the case study and its nuances, it is important to be familiar with the background and institutional framework, i.e., the structure of technical education[3] in India and its various features.

Beginning with the situation at the outset of Independence, the chapter describes the trends in technical education, particularly after the 1990s. There are two broad segments the chapter is divided into: one on the institutional setup of technical education and the other on India's manpower scenario. Preceded by a brief note on the structure of technical education in India along with the role played by the apex body, the AICTE, each of these sections looks at various features like growth, regional distribution, etc. of engineering education institutions and technical manpower. An important note on Human

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[3] The term 'Technical Education' is defined by the AICTE, i.e., 'Programmes of Education, Research and Training in Engineering & Technology, Architecture, Town Planning, Management, Pharmacy, and Applied Arts & Crafts, and such other Programmes or areas as the Central Government may, in consultation with the Council, by notification in the Official Gazette, declare' (AICTE, 2006). In this study, it will be used to refer to education specifically in Engineering & Technology.

Resource in Science and Technology (HRST) is included after the two broad sections, which serves as an introduction to the note on the manpower predicaments in India's national system of innovation. The sections on HRST and the dilemmas serve also as a sort of prelude to the next chapter on the research problem.

Despite the attention technical education has received, a reliable and regularly updated information base (especially dealing with quantitative information on technical education) is evidently absent in India. There exist only a small number of sources; hence most of the data used in this chapter comes through only these, as listed below.

- *India Science Report*: The seminal India Science Report gives a comprehensive description of the science & technology and engineering human resource that India has. Formulated by a group set up by the National Council for Applied Economic Research (NCAER), the report acknowledges for most of its information, the University Grants Commission (UGC), New Delhi; the Institute of Applied Manpower Research (IAMR), New Delhi; Department of Science and Technology (DST), Government of India; the Registrar General of India, Ministry of Human Resource Development (HRD), Government of India; as well as the team that conducted the primary survey for the report. Concepts like HRST-E, HRST-O and Core-HRST used in this chapter have been derived mostly from this report.
- *Research and Development Statistics 2000-01:* A report periodically published by the Department of Science and Technology (DST), this also gets most of its information from the UGC and the National Technical Manpower Information System (NTMIS). Some data also has its sources from the All India Council for Technical Education (AICTE).
- *Manpower Profile of India:* This publication has been brought out annually, since 1993, by the Institute for Applied Manpower research (IAMR). This information bank with facts and figures showing various facets of manpower in India forms the primary source for most data in this chapter. The Manpower Profile in turn has varied sources from which it obtains its data. These include NTMIS, UGC, DST, Ministry of HRD and AICTE, as well as the International Labour Organisation (ILO), United Nations Development Programme (UNDP), Engineering Labour Market Information System, Directorate General of Employment Training, etc.

Though it might occur that the most prominent data source for technical manpower – the NTMIS, as well as popular data sources like the DST's *Pocket Data Book* and the HR Ministry's *Selected Educational Statistics* or *Facilities for Technical Education* have not been referred to directly for this study, the fact is that most data in this section is obtained from the sources listed above that point to the NTMIS and the other above-mentioned publications of the DST and the HR Ministry. Thus, it could be said that indirectly the NTMIS along with the UGC and Ministry of HRD form the most important sources for most data shown in this section.

Situation in 1947

Britain's pursuits in India ranged from agriculture and natural resources, to industry, banking, communication, and trade. The latter set of interests in particular required building skilled manpower from among the local populace, there being a limit to which technically trained labour could be imported from Britain or anywhere else. To supplement their industrial effort, institutes imparting industrial training were set up by the English. They were but only a handful in number scattered across the country catering primarily to industries in their respective region. An example of such an institute is what is today the College of Engineering Guindy at Madras, which was set up in the 19th century to train manpower for a gun carriage factory in its proximity. Policy initiatives for industrial training and education during the early twentieth century were undertaken, the most prominent one being the Governor General's Policy Statement of 1913, which stressed the importance of education in scientific and technological fields for India. Efforts from Indians in this period were also noteworthy, best exemplified by the contributions from the house of Tata to the founding of the Indian Institute of Science at Bangalore. By 1947 only 44 engineering colleges and 43 polytechnics (including pharmacy and architecture institutions) existed, with an intake capacity of 3200 and 3400 respectively (AICTE, 2006).

Though aspirations to become a 'knowledge economy' began much later in the 1980s and 1990s, the idea of an S&T based economy was at the back of the state's mind since 1947. A big shift from an agricultural-intensive economy to an industrialised nation, it was realised, would be possible mostly through advancement in the potential workforce's skills. The large scale setting up of institutes imparting industry-related training, technical education in particular, was thus deemed a priority at Independence; a priority that was to remain important for all the coming decades. There was active participation from private bodies and trusts, but it was the State that made the largest and most significant contributions in the setting up of technical education institutions. The biggest contribution by the State in this regard would probably be the set of seven world class institutions, namely the Indian Institutes of Technology (IITs), details regarding which will be discussed at a later stage. Besides these, it also built the National Institutes of Technology (NITs, formerly the Regional Engineering Colleges, RECs), various institutes and laboratories undertaking research and teaching in specific areas of science; and has been the foremost collaborator in creating the Indian Institute of Science as it is today. These premier institutes in India are followed today by around three thousand engineering colleges, technical universities, and polytechnics, public and private, distributed across the country (DSHE; Ministry of HRD, 2005; and World Bank, 2000).

Institutional Setup for Technical Education

Structure of Technical Education System in India

In India, students keen on technical education can qualify for admission into engineering degree programs after the completion of twelve years of school education. Most undergraduate courses in engineering and technology last for a period of four years while a postgraduate course lasts for eighteen months to two years. There are instances when institutions might offer a five year integrated programme leading at the end to a postgraduate degree in engineering. Keeping in mind the fact that twelve years of school education or junior college is out of bounds for a large section of the population, diplomas requiring only ten years of secondary education (what is sometimes called 'matriculation') as qualification are offered. Sometimes a state- or national-level entrance test may be conducted, the results of which are given a large weightage among other requirements for admission. Interestingly, the heavy demand for admission into the highest ranking institutes has bred a number of small units known popularly as 'training centres' or 'tuition centres', that train prospective students for these entrance tests.

At the highest level in the Indian system of technical education are the six Indian Institutes of Technology and the Indian Institute of Science. The former will be dealt with in greater detail in the next chapter. The latter – the Indian Institute of Science, Bangalore – is among the oldest and the most leading centres today for research in the pure sciences, life sciences, and engineering science & technology. Interesting features include centres for research and teaching in electronics and communication engineering, aeronautical engineering, heat and power engineering, high voltage engineering, power engineering, and biochemistry, automation and control systems and electronics design technology, which are in the process of establishment (DSHE).

In partnership with the state governments, the central government established seventeen Regional Engineering Colleges (RECs) spread across the country, with a primary focus on high quality engineering practice. These are known today as the National Institutes of Technology (NITs). Most students admitted belong to the respective state that the NIT is in, but around fifty percent of admission is reserved for students from states other than the ones in which the respective NIT is located. Each NIT is to take around 250 to 300 students annually, for undergraduate study.

The NITs are followed by more than five hundred government-owned, government-aided and self-financing engineering colleges offering degree programs, and more than a thousand polytechnics offering diploma programs. Most polytechnics operate under strict control of the Directorates of Technical Education or Boards of Technical Education of the respective states they are located in, or are affiliated to universities. Technical Universities include the Anna University at Chennai and the Jadavpur University in Bengal, both of which are of extremely high standard. The NITs as well as the Technical Universities and university departments of engineering are for the most part engaged in teaching than research; research activity in engineering science conducted mostly in the institutes of national importance mentioned earlier. Quite unfortunately, with the exception of the technical universities and most NITs, the majority of institutions within and below the second rung are of gravely substandard quality, especially in terms of infrastructure and teaching quality.

The demand for undergraduate engineering education in particularly the south of India is quite substantial, which in most cases far outstrips the capacity higher quality technical institutions can absorb. Simultaneously, there are many engineering colleges of much lower standard, mostly in private hands, that run with a large number of vacancies in admission. A significant development in the last two decades in technical education is the establishment of 'self-financing' institutions run mostly by private parties. Self-financing institutions do not depend on government grants for funding, but recover their costs from students in the form of exorbitantly high fees, and in recent years have got themselves into a considerable amount of controversy in states like Kerala. The Supreme Court, having dealt with a number of cases on the subject, has directed that the government and its agencies should lay down the principles on the basis of which institutions could levy fees (Ministry of HRD, 1998). Many self-financing institutions, though not all of them, take advantage of the fact that there are many individuals (in the majority who do not avail of admission into state-run high quality institutes) who are willing to pay unreasonably high amounts to secure of an engineering degree.

There are wide variations in cost per student between the institutions. Differences stem mainly from the type of ownership and funding source. The World Bank (2000) estimates that in the case of the IITs, the unit cost works out to be Rs. 85,000 per student per year, implying that the cost of producing one undergraduate IITian engineer is about Rs. 350,000 at a minimum. In the RECs, it varies from Rs. 21,000 to Rs. 35,000 per student per year. At the other end of the spectrum, it has been reported that there are a large number of engineering institutions (about 15% of the colleges in Maharashtra and Andhra Pradesh) reporting a unit cost of only Rs. 6000 or less per student per year (World Bank, 2000), attracting great doubt as to the quality of education in such institutions.

The All India Council for Technical Education

The All India Council for Technical Education (AICTE), set up in 1948, is the apex body for technical education in India. Its task at the outset of its establishment was to stimulate, coordinate and control the provisions of educational facilities and industrial development of the post war period. Soon after, it was made the advisory body to assist the Central Government in the planning and development of technical education at the post-secondary level (Ministry of HRD, 1998). In 1987, its distinction was raised and it was given statutory powers by the AICTE Act of Parliament 1987, its main task now being to ensure the proper planning and coordinated development of technical education in India. Qualitative improvement of technical education in relation to planned quantitative growth and the regulation and proper maintenance of norms and standards in the technical education system were set out to be some of its main priorities (AICTE, 2006). The AICTE works in collaboration with the UGC to supervise the number of universities that offer technical education. The hundreds of polytechnics across the country also come into the purview of the AICTE. In a nutshell, the major programmes supported by the AICTE (Ministry of HRD, 1998) are

(1) curriculum review or renewal, for education and training of engineers and technicians
(2) modernisation of the laboratories and workshops and removal of obsolescence
(3) establishment of community polytechnics, technology forecasting, manpower planning, and training of teachers
(4) preparation of norms and standards for programmes of education and training, and
(5) extending the benefits of technical and training to the backward and rural areas

Major Institutes

Of the hundreds of technical education institutions in the country, there are only a handful that can be termed as truly world class or at least eminent at a national level. Some of the institutions considered to be of the highest standard include:

- Indian Institutes of Technology (IITs) at Bombay, Kharagpur, Chennai, Kanpur, Delhi, Guwahati and Roorkee.
- Indian Institute of Science (IISc), Bangalore
- National Institutes of Technology (NITs, formerly the Regional Engineering Colleges, RECs), seventeen in number
- Indian School of Mines (ISM), Dhanbad (declared a deemed University)
- School of Planning and Architecture (SPA), New Delhi

- Indian Institute of Information Technology and Management (IITM), Gwalior and the Indian Institute of Information Technology (IIIT), Allahabad
- National Institute of Foundry and Forge Technology (NIFFT), Ranchi
- National Institute of Training and Industrial Engineering (NITIE), Mumbai
- Technical Teachers' Training Institutes at Bhopal, Calcutta, Chandigarh and Chennai
- National Institute for Training in Industrial Engineering, Bombay
- National Institute of Foundry and Forge Technology, Ranchi
- National Institute of Sugar Technology, Kanpur
- National Institute of Industrial Design, Ahmedabad

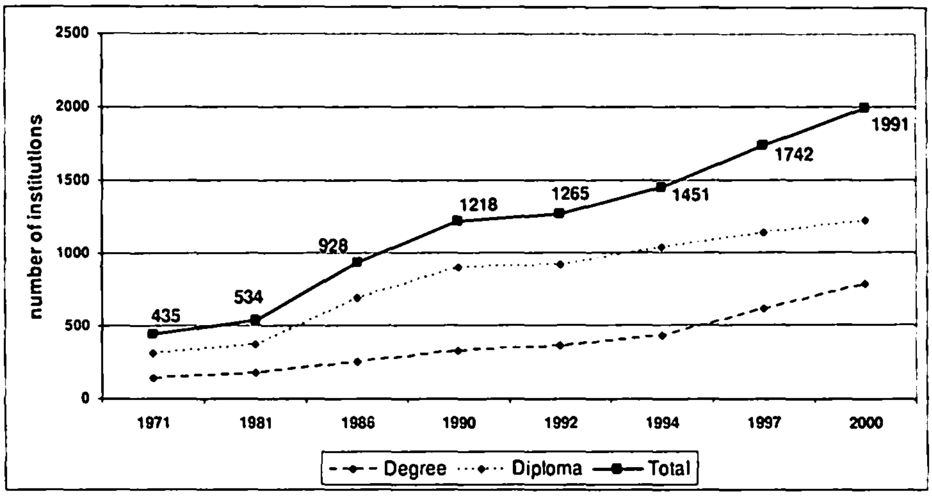
Besides these, there are several engineering colleges and polytechnics managed by State governments in almost every state, affiliated to universities in these states. A World Bank report (2000) on scientific and technical manpower in India gives a flowchart diagram of the structure of technical education in India[4]. The institutions that undertake both research as well as teaching at undergraduate as well as postgraduate levels, and are considered of national importance, comprise of the IITs, the IISc, a few deemed universities, and a few Technical Universities. These could be termed institutions of the first and highest rung. There are then the university departments, the seventeen NITs, and the 250-odd state engineering colleges and government aided colleges in the second rung. Also in the second rung are three hundred or so private engineering colleges. All these institutions offer mainly undergraduate degree courses, though some also offer postgraduate degrees. Undergraduate diploma courses are offered by polytechnics, around 700 of which are government-owned or government-aided and around 500 of which are in private hands. Though the institutions in the first rung are the most prominent ones, one cannot undermine the importance of university-run engineering departments and technical- or engineering universities, since they have contributed a great deal in absorbing prospective students who have not been able to secure admission into the premier institutes.

[4] World Bank (2000) *Scientific and Technical Manpower Development in India*, WB Report No.20416-IN, page 45, figure 1.1

Growth and Regional Distribution of Technical Education Institutes

The stunning magnitude of growth of 522% in enrolment in technical education between 1970 and 2001 could have been possible only with a similar rise in the number of institutions offering degree and diploma courses in engineering. During the period 1981 to 2001, the number of institutions providing general education of undergraduate-and-above levels increased by 155%, which may seem a large figure, but is dwarfed by the increase in the number of engineering, technology and architecture institutions that stands at 390% for the same period (IAMR, 2004).

Figure 1: *Year-wise Growth of Vocational and Technical Educational Institutions*

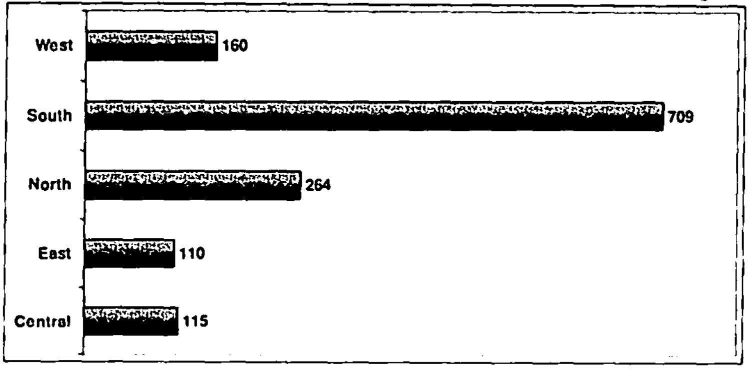


Source: Institute of Applied Manpower Research (2004)

Figure 1 shows growth of vocational and technical education institutions in India. The number of institutions offering diploma courses always outnumbers those offering degree courses. The growth may seem steady on first sight, but a closer look suggests that the highest spurts of growth occurred through the 1980s and in the late 1990s.

A quick look at the distribution of engineering institutes across five regions in India will show that most technical training institutes are situated in the south. In fact, looking at Figure 2, one can see that the number of undergraduate engineering institutions in South India exceeds the total number of institutions in all four other regions combined. A little more than half – around 52% – of all technical institutions in India are in the south. The largest number of engineering institutions in India comes, in fact, from just two states in the south – Andhra Pradesh and Tamil Nadu, the latter having the largest number of technical education institutions in the country. These two states alone have around five hundred out of the 1300 odd colleges (as of 2004) in India that offer engineering courses at the degree level, approved by the AICTE.

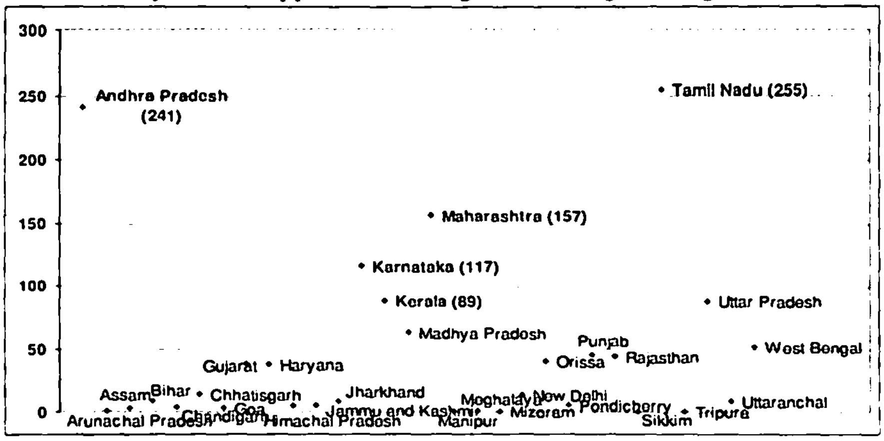
Figure 2: *Number of Undergraduate Engineering Institutions across Region as of 2004*



Source: University Grants Commission (c.2001) through www.indiastat.com

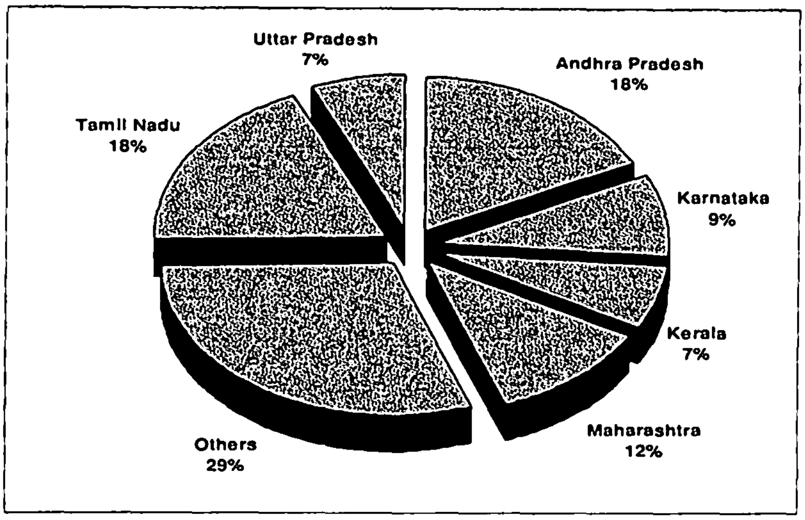
The other two states in the south, Karnataka and Kerala, also occupy high positions in terms of the number of engineering colleges. If not for Maharashtra, the states in the south would have had the undisputed first four positions in the number of colleges offering undergraduate engineering courses. Figure 3 gives a comparative distribution of states in terms of the number of engineering colleges situated in them. The distribution of colleges across the country is so unequal that Tamil Nadu and Andhra Pradesh alone possess a higher fraction of engineering colleges than twenty six other states and union territories put together.

Figure 3: *Distribution of AICTE-Approved Undergraduate Engineering Institutions across States*



Source: University Grants Commission (c.2001) through www.indiastat.com

Figure 4: *Distribution of Undergraduate Engineering Institutions across States (as of 2004)*



Source: University Grants Commission (c.2001) through www.indiastat.com

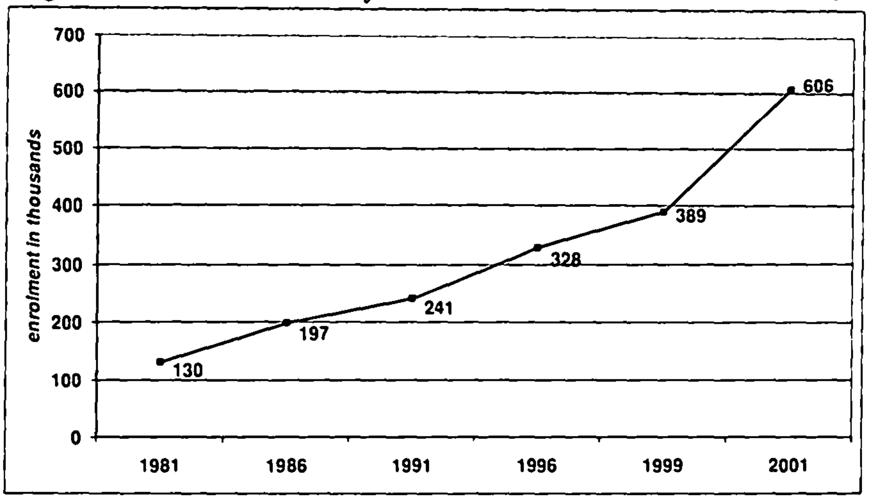
Figure 4 shows that the six states having the largest number of engineering colleges account for around 70% of all engineering colleges in India. Such is the regional disparity in the country, as far as distribution of engineering education institutions go.

Manpower in Science and Technology

Growth through the Years

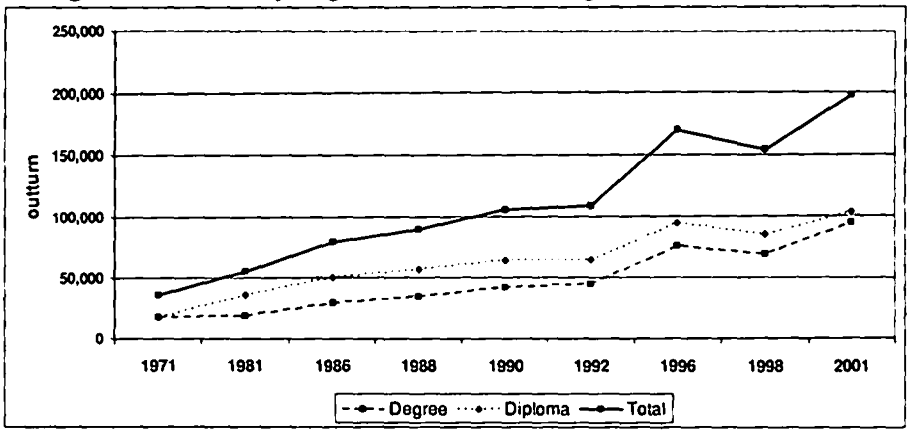
Technical education, chiefly through the attractive job prospects that come after successful completion, has lured generations of young people to strive for admissions into technical institutions, preferably the very best ones like the IITs and NITs. Especially in the last fifteen years, there has been a spurt in the growth of enrolments in engineering courses at the undergraduate level, brought about mainly by the rapid development of certain industries (especially the leap-frogging IT and ITES industries) at home and correspondingly the growing demand for manpower in S&T in India and abroad. The annual increase in intake into engineering courses is the highest among all disciplines at the undergraduate level, nearly doubling over the last six years, and by a magnitude of 522% over the period 1970 to 2000 (IAMR, 2004). Though these numbers are phenomenal indeed, it must be borne in mind at all times that this is no reflection of the number of qualified engineers who actually complete their courses successfully.

Figure 5: *Enrolment into Professional/Technical/Vocational Education*



Source: Institute of Applied Manpower Research (2004)

Figure 6: *Outturn of Engineers in India at Degree and Diploma levels*



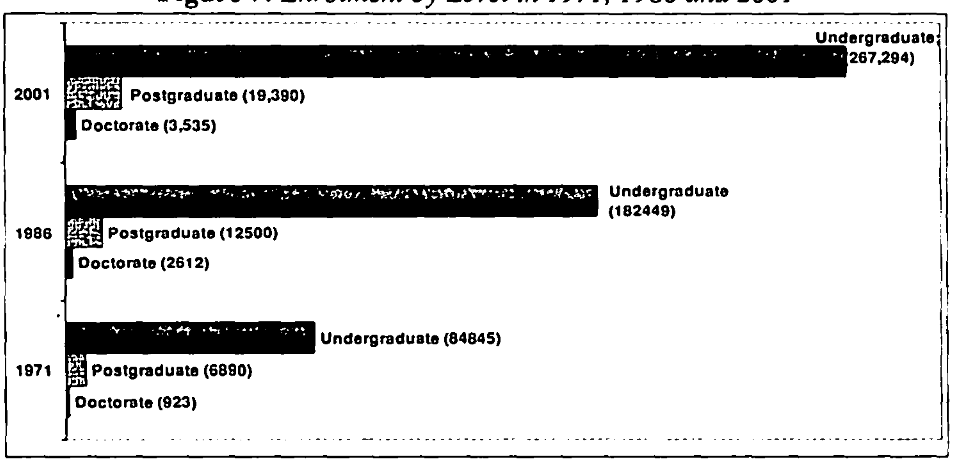
Source: Institute of Applied Manpower Research (2004)

It is commonplace in India – in especially technical institutes of deplorable quality – that the number of people who actually complete the courses they have been admitted into are very few compared to the vast enrolment. Enrolments may range in hundred-thousands as seen above, but the end-of-course turnout at the all India level for all courses together is less than a tenth of the corresponding enrolment. There are a multitude of reasons for this, like the perceived difficulty of curriculum realised during the course, financial constraints, infrastructure constraints or even disillusionment or discouragement during study. Though this does not happen frequently at the IITs or NITs, it is quite rampant in many lower rung institutes across the country. Yet, in absolute terms, the volume of turnout every year is still quite high, with the number of engineering diploma holders always exceeding the number of engineering degree holders.

Figure 6 shows the trend through the last six decades in total outturn of engineers at the degree level.

Of the fifty million or so who have studied at least up to the undergraduate level in India today, about a quarter is educated in science and technology. The fraction of S&T educated among those who have studied up to the postgraduate level is lower at around 19%, while this fraction leaps up to about 33% among doctorate holders. The numbers are more encouraging in the enrolments in than turnout from S&T courses years after year, with about 33% of the ten million enrolments in undergraduate-and-above courses in 2004 being in science related disciplines (NCAER, 2005).

Figure 7: *Enrolment by Level in 1971, 1986 and 2001*



Source: Institute of Applied Manpower Research (2004)

In engineering, the case has been quite similar, in that the enrolment at the postgraduate level is minute compared to the enrolment at the undergraduate level. Though at the doctoral level enrolment is the lowest in absolute numbers (as in any discipline), the fall in numbers from the postgraduate to the doctoral level is not as drastic as the fall from the undergraduate to the postgraduate level. Figure 7 shows the enrolments at each level for three points in time fifteen years apart – 1971, 1986 and 2001. Interestingly, the percentage of women increased considerably through this period at each level. While in 1971 only about 5% of enrolment at undergraduate level (around 3% at postgraduate level and around 1% at doctoral) was female, by 2001, about a fifth of undergraduate enrolment (around 18% at postgraduate level and around 27% at doctoral) was female.

Subject-wise Enrolment

Disparities in the engineering education scenario exist not only with regard to the regional distribution of institutions and enrolment, but also between fields of study. Whereas in fields like electronics & telecommunication and mechanical engineering annual enrolments run into the ten thousands, in fields like leather- and ceramic technology there is a severe dearth of enrolments. While Tables 1 and 2 display the highly skewed enrolment distribution between disciplines, Table 3 shows the increasing stocks of engineers in various disciplines at different points over the decade 1987- 98. At both degree and diploma levels almost half of all enrolments in 2001 were in the fields of electronics & telecommunications, electrical, mechanical and civil engineering.

Table 1: *Annual Outturn at Degree Level across Fields of Study over fifteen years*

Discipline	**1990**	**1992**	**1996**	**1998**	**2001**
Civil	8753	8147	8875	8787	7422
Mechanical	9410	9538	13,582	12,877	17,674
Electrical	5008	3716	8160	7982	8198
Chemical	1616	1587	2411	2622	3962
Electronics and Telecommunications	5083	7322	18,543	18,942	13,485
Metallurgy	524	469	788	987	849
Mining	318	536	508	537	509
Automobile	130	207	336	281	286
Aeronautical	63	75	102	117	132
Agriculture	203	164	359	306	426
Production	913	1030	2132	2092	2414
Sugar	15	15	128	56	24
Oil Technology	59	46	57	39	54
Textile Technology	521	414	581	745	822
Architecture	806	743	1391	1373	1672
Food Technology	49	43	85	97	146
Instrumentation	632	845	1924	2080	2004
Ceramics	49	60	89	68	315
Leather	28	45	61	49	121
Others	7284	9139	15,538	15,173	34,104
Total	**43,454**	**46,133**	**77,646**	**77,208**	**96,620**

Source: Institute of Applied Manpower Research (2004)

The fact that these disciplines have seen dramatic increases in enrolment could be attributed mainly to the allure of the job prospects after study. The World Bank (2000) has estimated that while in branches like mining- and metallurgy engineering there is a shortage of engineers at the degree level, in branches like mechanical engineering and electronic engineering, the number of surplus engineers (as estimated for 1997-2002, qualified by degree or diploma) amounts to a mammoth 50,000 in each of these branches.

Table 2: *Annual Outturn at Diploma Level across Fields of Study over fifteen years*

Discipline	1990	1992	1996	1998	2001
Civil	15,829	14,413	11,599	12,672	11,379
Mechanical	14,510	14,264	18,337	19,201	20,982
Electrical	9547	7545	11,427	12,997	9823
Chemical	693	561	1483	1647	1974
Electronics and Telecommunications	6524	6903	24,360	25,625	13,485
Metallurgy	218	208	361	376	501
Mining	471	471	681	520	453
Automobile	1496	1764	1951	1847	2458
Agriculture	132	124	108	145	150
Hotel Management	439	393	518	543	477
Leather Technology	69	72	174	225	242
Production	432	435	629	647	458
Textile Technology	989	833	1453	1472	1118
Printing Technology	456	366	536	425	579
Others	11,989	15,536	20,937	18,299	38,470
Total	**65,784**	**65,880**	**96,550**	**98,639**	**104,550**

Source: Institute of Applied Manpower Research (2004)

Table 3: *Cumulative Stocks of Engineers across Fields of Study*

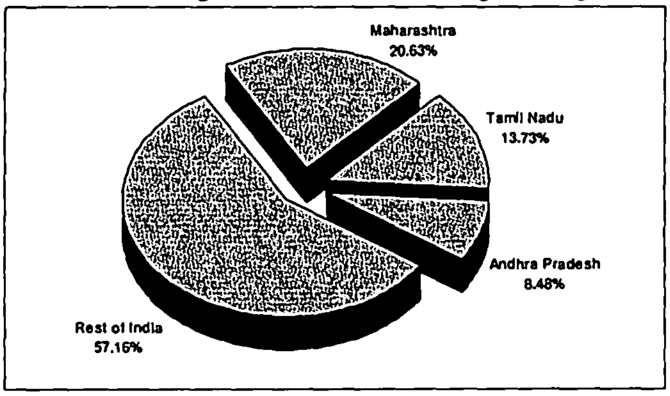
Discipline	1987	1990	1994	1998
Civil	100,320	119,940	147,240	172,930
Mechanical	113,780	131,200	162,930	202,770
Electrical	78,710	87,030	104,420	128,600
Chemical	24,490	27,510	31,960	39,300
Electronics & Telecommunications	29,250	41,830	77,110	143,830
Metallurgy	12,280	13,120	14,460	16,850
Mining	3,740	4,490	5,810	7,470
Automobile	780	1,140	2,060	3,110
Aeronautical	1,420	1,530	1,760	2,070
Agriculture	2,710	3,060	3,730	4,730
Production	3,260	4,860	9,240	16,680
Sugar	1,300	1,250	1,340	1,590
Oil	460	560	730	940
Textile	6,960	7,930	9,180	11,270
Architecture	8,010	9,590	12,260	16,650
Food	780	850	1,020	1,310
Instrumentation	1,780	2,680	5,920	13,050
Ceramic	460	560	950	1,230
Leather	530	610	730	890
Others	21,870	32,440	30,360	13,130
Total	**412,890**	**492,180**	**623,210**	**798,400**

Source: Department of Science and Technology (2002)

Regional Distribution

Intake into engineering courses, degree or diploma, is uneven across various regions in India. A little above forty percent of all enrolment in engineering courses at the undergraduate-and-above level in the country is in just three states – Maharashtra, Tamil Nadu and Andhra Pradesh. This follows logically from the fact that these three states also have the distinction of having around 48% of the total number of engineering colleges in India offering undergraduate courses (IAMR, 2004). The ethnic composition of each region's intake is a subject of further enquiry, exploring whether these institutions in the south pull students from the respective state they are situated in, or whether a fascination for the large clusters of institutions and thus the wider choice of engineering colleges in the region students also pulls students from afar.

Figure 8: *Share of States in Undergraduate-and-Above Engineering Enrolment (as of 2000-01)*



Source: Institute of Applied Manpower Research (2004)

Economies of scale play a great role in these large engineering college clusters, the huge communities of students every year inevitably generating spillover effects on the local economy of the town or district the community is situated in. Within the south, two states – Tamil Nadu and Andhra Pradesh – attract the largest intake year after year. These two states alone together enrol around a fifth of all engineering students in the country, the numbers exceeding admissions in almost twenty other states put together, as shown in Figure 8.

Though it is held in popular opinion that India has a vast pool of scientific manpower (especially in ITES related industries), the truth is that India's standing is rather low in comparison to many other countries in the world. In terms of the ratio of scientists, engineers and technicians (SET) to 10,000-workforce, India is relatively deficient in comparison merely (87.5 as of 2004, as derived from Ministry of HRD statistics) to states like Korea, Israel and China. It is undeniable that Indian manpower in especially ITES has gained prominence all over the world through the last two decades, but the figures show that overall manpower in S&T, especially in scientific R&D, is rather deficient (Ministry of HRD, 2005).

Human Resource in Science and Technology

It was often mentioned in the previous chapter that human capital is one of the most important components of knowledge infrastructure, important both to the creation as well as the dissemination of knowledge (NCAER, 2005). It is in this context that the India Science Report introduces the term Human Resources in Science and Technology (HRST). The Report uses this term as based on the Canberra Manual[5], which defines a country's HRST as comprising of those individuals who fulfil one of the two conditions:

(1) successful completion of education at the tertiary level in any S&T field, or academic infrastructure
(2) not formally qualified as in (a), but employed in an S&T occupation where the qualification cited in (a) is normally required

Drawing from the two conditions above, HRST is divided into 'university-level' and 'technician-level'. The former comprises of those who have successfully completed either an undergraduate or a postgraduate university degree (or equivalent), while the latter comprises those who have completed an award lower than a first university degree and are working in S&T related occupations. It is without doubt that plans to increase stocks of university-level HRST require larger investment in competence building relative to plans of increasing technician-level HRST stocks. Arguably, the former is of more critical importance to the building of a country's scientific capability than the latter. This distinction between university-level HRST and technician-level HRST is formalised into HRST-E and HRST-O respectively. HRST-E (human resource in science and

[5] The 'Canberra Manual' is the fifth in the 'Frascati' family of manuals prepared jointly by the OECD and the European Commission, and is used internationally to measure HRST (NCAER, 2005).

technology by *education*) comprises of that HRST who are educated in S&T, while HRST-O (human resource in science and technology by *occupation*) comprises of that HRST whose occupation is S&T related.

It follows then, that the 25% of the fifty million odd people in India who have had S&T education at least up to the undergraduate level falls into HRST-E. It is said that HRST-E in India grew in the last fifteen years by around 6.9% per year (NCAER, 2005). Looking at the extraordinary growth of enrolment and the volume of turnout every year in engineering education, one could say that the engineering-qualified portion in HRST-E is not in insufficiency at all, in numerical terms. The excessive supply of engineers in some disciplines has even caused difficulty for fresh graduates to acquire jobs – to the extent that the term 'unemployed engineer' has become an oft-quoted cliché. Engineering education seems to be attracting large masses of prospective students at an aggregate level, but on branch-level scrutiny (as seen in the three tables earlier) we see shortages and surpluses of engineers. Also, the quality of the engineering graduates, i.e., of most of the HRST-E stock, is highly questionable, since most have received training from highly sub-standard quality institutions. Besides, various other problems like the brain drain exist, which will be taken up in the next chapter. There is, overall, quite a complex situation as far as engineering qualified HRST-E goes.

We now go on to HRST-O. It is disturbing to note that a large share of HRST-O in India has relatively low educational qualifications. The India Science Report states that only about 53% of the total HRST-O in India is trained at least till the undergraduate level. The rest have studied only until the 12th grade or lower, meaning that more than half of India's scientific manpower is under-qualified. The problem is manifold in those firms and organisations exclusively engaging in R&D (including in-house R&D units of public and private sector industries). At the beginning of this decade, out of around 300,000 personnel employed in R&D in India, only 32% (around 100,000) were performing direct R&D activities, while the rest 68% (around 200,000) were providing non-technical support like administration and were not directly contributing to R&D (Mani, 2002). This means that in those organisations considered the torch bearers for our indigenous scientific capability building, the real think-tanks constitute a meagre one-third of the workforce, and the bulk of employees do not contribute to R&D.

Table 4: *Personnel in India in R&D Establishments by Activity (figures in parentheses refer to percentages of total)*

Activity	1980	1986	1990	1994	1998	2001[6]
Research & Development	64,875 *(35.24)*	85,309 *(36.36)*	105,936 *(35.41)*	114,403 *(36.38)*	95,428 *(30.94)*	93,832 *(31.70)*
Administration & Auxiliary Activities	119,221 *(64.76)*	149,326 *(63.64)*	194,941 *(64.69)*	200,086 *(63.62)*	212,964 *(69.06)*	202,168 *(68.30)*
Total	**184,096**	**234,635**	**300,877**	**314,489**	**308,392**	**296,000**

Sources: Department of Science and Technology (website) for 2001;
Institute of Applied Manpower Research (2004) for rest

Table 4 shows the number of employees and ratio of R&D personnel to total personnel working in R&D organisations. For twenty years the share seems to have remained almost the same, i.e., only around one-third of total employees in R&D organisations engaging in S&T activity and contributing directly to R&D, with the rest two-thirds engaging in other auxiliary and administrative activities, not contributing directly to S&T, or R&D activity.

What is of importance above all is 'Core-HRST', which is the intersection between the HRST-E and HRST-O sets. In other words, Core-HRST is the set of those individuals who are qualified in science disciplines *and* are engaged in S&T related occupations. Between HRST-E, HRST-O and Core-HRST, it is the third that requires the greatest attention to assess the quality and scope of a country's S&T manpower. In India, Core-HRST is in a dilemma, since only around one-third (35.2%) of S&T qualified (HRST-E) are engaged in S&T related professions. And even within this one-third, a very small number is engaged in scientific R&D. Table 5 shows, across a twenty year time span, the percentage of those scientists, engineers and technicians (SET) engaged in R&D among the total SET in S&T professions always remaining below 6%; the problem being acute in the most recent year (1999).

Table 5: *SET Engaged in R&D as a Percentage of Total SET*

Year	1978	1980	1985	1990	1996	1999
SET engaged in R&D as a percentage of total SET	3.37%	3.8%	5.83%	5.85%	2.32%	1.38%

Source: Institute of Applied Manpower Research (2004) *(SET – Scientists, Engineers and Technicians)*

[6] The figure of 296,000 is an approximation given in the highlights of the DST's Research and Development Statistics 2004-05, and the corresponding figures in this table for the year 2001 are derived from percentages of the approximate figure.

In this chapter we have seen the numbers as well as a few key issues surrounding scientific manpower in India, particularly in engineering science and technology. Starting off with the situation in 1947, we have investigated into the institutional setup that exists for engineering education in India – outlining the structure of technical education, the supervising bodies and major institutes, and the growth and regional distribution of the huge number of technical education institutions in India. The next section on manpower saw the level-wise and subject-wise outturn of engineers in various disciplines through the years, as well as the regional disparities in engineer supply, concluding with a short note on India's standing in the international scene on technical manpower. The section on Human Resource in Science and Technology dealt with the various terms associated with studies on scientific and technical manpower. Through this section one also gets to appreciate the phenomenon in India that though there is no shortage of technically qualified graduates, there exists a severe shortage of personnel engaged in scientific or innovative activity in S&T establishments, especially R&D organisations. The stock of graduates in India across disciplines amounts to almost fifty million, including over thirteen million S&T qualified; yet there are less than five million personnel engaged in S&T professions, and there is an acute shortage of R&D manpower with less than 100,000 dealing directly in research activity.

Though the realities seen in HRST as shown in this section may have made this chapter end on a rather solemn note, it serves as a prelude to the discussion on discordances in India's NSI and the research question, further dealt with in the next chapter.

III

Discordances in India's NSI; the Research Question; and Some Preliminary Observations

This chapter is divided into three parts. The first part lends an economic interpretation to the dilemmas in India's technical education system as being an institutional discordance in India's innovation system. It goes on to explain four possible reasons for this discordance to occur, and then expands one of these four possibilities to formulate the fundamental research question of this study, which forms the second major part of this chapter. After a brief discussion of IIT Madras – the institution in consideration as the case study for this dissertation, the chapter goes on to describing the recent trends and process of the placement process in this institute. The chapter in its third part closes with a summary of observations from the department-level survey, thereby also opening the empirical part of this study. The findings from the department-level survey are termed 'preliminary observations' (as given in the title of this chapter) since they serve as a foundation for the student-level survey in the next chapter.

But first we begin by going deeper into the various dilemmas portrayed in the last chapter. This section seeks to base the intricacies illustrated in the chapter on the Technical Education System in India within the theoretical matter in the chapter on the Systems of Innovation.

Discordances in India's System of Innovation

The previous chapter showed that the status of scientific manpower in India is in quite a grave situation – a large supply of HRST-E (many of them unemployed[7]) and yet a low HRST-E presence in the HRST-O. There are scores of unemployed engineers and simultaneously a severe shortage of S&T qualified HRST-O. On the one hand scores of S&T graduates find it hard to seek immediate employment, while on the other hand only half of HRST-O is stocked with personnel who have studied above the higher secondary

[7] About 22% of the undergraduate-unemployed and a staggering 62% of postgraduate-unemployed are science educated (NCAER, 2005).

school. To top it all, the fraction of those in S&T jobs engaged in R&D in particular is very small, and has even been dwindling through the years.

Looked at through a Systems of Innovation perspective, one can say that there is clearly a *discordance* in the institutional structure of India's innovation system. The discordance here is not between two actors, but between one actor – University (in this case the institutions imparting technical education) and the other actors in the system. As discussed in the chapter on Systems of Innovation, University as an actor has a leading role in contributing highly skilled manpower to the other actors like Government and Private Enterprise, besides itself. Though the technical education system in India was set up to cater to the manpower requirements of the other actors in the Indian System of Innovation, in the case of scientific R&D, it does not seem have delivered its role. Such a discordance has the potential of stunting India's innovation capabilities. India's quest to become a knowledge economy will remain only a distant dream until these issues are addressed and resolved. Though these realities have been well acknowledged by media and government, and have occasionally appeared in academic discussions, rarely have they been subjected to research and enquiry in the Systems of Innovation framework. The chapter on Systems of Innovation ended by saying that this particular study aims at going one step ahead in integrating educational systems in systems of innovation. In other words, though there is a vast amount of research on the economics of higher education, there has rarely been an attempt to understand the education system as a leading actor in the innovation system. This direction of research is a much demanded one in the literature on innovation systems (references have already been mentioned in chapter one). This study attempts at studying some facets of the technical education system, treating it ...ded in India's innovation system.

... a number of reasons as to why the R&D manpower, or even Core-... India are so low, and why discordance in our system of innovation has ...

...ng cause as to why the discordance occurs and why R&D manpower ...v is that those who could have filled up the numbers are, in the first place, not in India. This is popularly known, and has been researched into a great deal, as the 'brain drain'. Especially in the premier institutes of engineering and technology, large numbers of students have left the country for either higher studies or on acquiring work in international firms and organisations. It is also commonplace that those who leave the country initially only for higher studies end up staying on outside India even after completion of studies to get absorbed in the labour market the respective foreign country. Though there have been many Non-Resident Indians in the last few years who have returned to India to establish new businesses or to expand their existing establishments, an overall view of the trends in the last few decades has shown distressing signs. It is said that across the last fifty years, around 20% of all IIT graduates have migrated to the United States alone. This has become more critical in recent years, with a record 30% of IIT Madras graduates in the year 1998 going to the US (UNESCO, 2006). Especially in the fields of electronics & telecommunications and computer science engineering, the exodus abroad is of a considerably large magnitude.

Table 1: *Number of Students from India going Abroad*

Field	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Engineering & Architecture	2390	2460	709	792	703	1473	1014	1156
Science	1384	1447	575	340	387	631	789	921
Technology & Industry	121	115	43	141	98	381	325	540
Commerce, Business Administration, Business Management	946	795	341	646	957	1777	2592	2342
Humanities	204	191	130	111	177	235	302	351
Agriculture & Forestry	94	66	12	16	15	80	11	6
Medicine, Pharmacy & Veterinary Science	350	449	85	327	370	907	607	645
Law	26	21	9	18	23	43	55	66
Banking	14	6	9	2	25	38	15	35
Fine Arts	30	69	-	42	39	69	62	46
Others	905	880	371	548	684	792	962	810
Total	**6464**	**6499**	**2284**	**2983**	**3478**	**6426**	**6734**	**6918**

Source: Institute of Applied Manpower Research (2004)

As stated earlier, the case in India is quite different from the case in Korea where those trained abroad duly came back and contributed to Korean business and government.

There is much written about tapping Non-Resident Indian sources for monetary investment, but it is essential to also tap the talent of the Non-Resident Indian scientific manpower.

A look at the general trends in migration of students across various disciplines, as given in Tables 1 and 2, shows that the problem is severest in commerce & business administration, and the engineering sciences. And among the choices of destination, North America, Europe and the Australian continent are among favourites, for obvious reasons.

Table 2: *Destinations of Migrating Students in 1998-99*

Field	America	Europe	Asia	Oceania	Others	Total
Engineering & Architecture	707	160	94	189	6	1156
Science	552	147	22	184	16	921
Technology & Industry	118	73	14	332	3	540
Commerce, Business Administration et al	577	467	64	1208	26	2342
Humanities	193	98	5	49	6	351
Agriculture & Forestry	3	1	-	2	-	6
Medicine, Pharmacy & Veterinary Science	73	37	481	42	12	645
Law	17	43		5	1	66
Banking	9	10	1	14	1	35
Fine Arts	33	2	-	10	1	46
Others	298	121	23	319	49	810
Total	**2580**	**1159**	**704**	**2354**	**64**	**6918**

Source: Institute of Applied Manpower Research (2004)

It may be the case that these engineering-qualified migrants are disillusioned with the functioning of individual actors in India's system of innovation, or with the feeble synergy between these actors. The relatively greater harmony between actors innovation systems in other countries and various monetary and other incentives offered might also be pull-factors leading to out-migration of our best minds. In both cases, the environment in the innovation system seems to be playing a key role. This will be explored into at a later stage in the study. Interestingly, as seen in Table 1 above, there was a low spell of out-migration in the mid-1990s, but it seemed to have picked up to its initial levels by the end of the decade.

Quality of Technical Education

Another leading cause for the occurrence of these discordances in our system of innovation is the quality of the training, or education, imparted to the workforce. This problem plagues the second rung of institutions in the structure of the Indian technical education system – the thousands of government aided and private aided engineering colleges and of course, the polytechnics. Serious shortcomings exist in the system that coaches and gears these personnel may render them not of employable standard, or may even discourage them in taking up S&T as a profession. Infrastructure in most of these institutes is below par and working in such a sub-standard environment discourages students to aim further at core engineering disciplines and professions. Frequency of syllabus revision is done reluctantly and only after overcoming major bureaucratic or procedural impediments. The syllabus is thus in many cases outdated, not having kept up with developments and requirements in industry or even in engineering science.

Pedagogy is also below standard and the cycle of low grade teachers producing low grade students in turn producing lower grade teachers and so on, comes into play. It can be assumed that a majority of the faculty in most second rung institutions have not had sufficient exposure to national or international developments and innovations in science & technology. It follows out of this that innovative teaching methods are rarely experimented. Links with industry are probably minimal if not absent, and students do not get a proper feel as to how the professional environment in their particular discipline is. Most institutes in this rung have rather low-paying campus placements (if at all the campus placement system exists), which offer very little scope for furthering their engineering science skills they have acquired through their course. Taking the advantage of the fact that there is an overwhelming demand for technical education, a number of low quality institutions have sprouted up all over the country (especially owned/managed by private hands and more so in the south of India). Though there are indeed a handful of institutes of excellent quality in the second rung as well, a majority of the others suffer from all these dilemmas, churning out engineers and technicians with below-par skills, rendering them unemployable or on a long term severely underemployed.

So despite all the investment in terms of time and money put in for their training, most individuals in the HRST-E population may end up realising that their training is substandard and is unacceptable for the requirements of the job market.

Demand-Side Inadequacies

Another cause for these discordances occur is found not on the supply side but on the demand side. There is clearly in India, as in the case of many other countries also, a weak system of coordination between R&D organisations and the rest of the production and marketing system in India.

Countries facing similar discordances in their systems of innovation have had their own respective demand side peculiarities. Take for example the case of Russia. After the collapse of the erstwhile Soviet Union, the institutional structure that combined (or rather, controlled) the various actors in its system of innovation completely disappeared. These actors had suddenly lost their common umbrella – the State – and were left to coordinate the system and move between the actors all by themselves. The system that used to herd personnel from University to the other actors was now no more. S&T qualified graduates found it hard to gain employment in line with what they studied, and these highly qualified professionals ended up underemployed. Similarly, many other countries – especially developing economies – face their own individual problems with regard to the demand side.

But there is yet another reason for these discordances to take place: that there exist a number of factors that push students away from R&D and pull them towards other disciplines and professions. Students, especially when highly qualified, may perceive opportunity costs in moving towards R&D related professions and studies, and may consider it a disincentive to work in this line. As far as this study goes, it is this reason that will be in focus.

Research Question

The system of innovation established in India was constructed in a manner that educational institutions, especially the most prominent ones like the IIT and the IISc, catered to the S&T manpower needs of the country. Regardless of the strategy pursued by the state, i.e., whether it is a closed policy of self-sufficiency or an open policy of international cooperation and globalisation, the fact remains that to a great extent any system of innovation will have to generate its own manpower. The low R&D manpower figures and the grave scene of Core-HRST in India lead to the question of where all the manpower, with skills of the highest quality, goes. Given the many constraints (time et al) that define the magnitude of the study, it was decided that the most feasible question for research would be to look at the case of one single institution in India's national system of innovation and understand how and why graduates who were produced to cater to the needs of science and technology are not opting to move towards science and technology, and have increasingly been opting for non-S&T disciplines and careers.

Hence, this study takes the case of one institution (Indian Institute of Technology Madras) and on gathering qualitative information explores as to how and why S&T trained manpower (specifically engineering students at the undergraduate level) from this prominent institution have increasingly opted for non-R&D related and non-Core Engineering professions; in the context of the implications such preferences could have on our national system of innovation.

The study being exploratory and based on qualitative information does not seek to establish any cause-effect relationship between variables, nor does it aim at quantifying preferences. Since no such study has been conducted in the Indian context despite the amount of attention this issue needs, it seeks to be more exploratory than anything else. Students in the highest rung of the technical education system are extremely well qualified and are geared during their course for a career in core-engineering and production, and scientific R&D. Students in the IITs do not suffer from the problems of low-quality education and training (as do most of the students studying in the second rung institutions) and are carved out to become scientists, engineers and technicians contributing to India's system of innovation. But for some reasons, internal and external to the institute environment, they seem to have moved away from scientific R&D or Core-Engineering and production as a profession, the end result being the really low figures that shown in the last chapter. Qualifications and skills gained at IITs are unquestionably of the highest quality India can offer and graduates are *capable* of taking up scientific R&D as a profession, though they are not *opting* so. Though an immediate answer for why this problem exists would be that the many alternative job avenues available pay very attractive salaries, it is suspected that there is much more than just the pull factor of remuneration and other monetary incentives. Before beginning the empirical angle of the study, it is important to look at the trends in placements at IIT Madras in the recent past, to first look at the background scenario in the field under study. But prior to even that, a discussion of the IITs in general and IIT Madras in specific follows.

The Indian Institutes of Technology

The IITs are located strategically, catering to all the major regions of India. The Sarker Committee Report 1946 was instrumental in deciding this geographic positioning (Chandra, 2006). In the north there are the IIT Kanpur and IIT Delhi; in the west there is the IIT Bombay at Powai near Mumbai; IIT Kharagpur near Kolkata caters to the east and IIT Madras in Chennai caters to the south. Besides these five, two institutes in the eastern part of India (Guwahati and Roorkee) were converted into IITs in the 1990s for the benefit of the north-eastern region. The first among these seven to be established was the IIT at Kharagpur, in 1951. This was followed in quick succession by one at Powai in 1958, two, at Chennai and Kanpur, in 1959, and an IIT at Delhi in 1961.

The IITs are funded in three parts – tuition fees, government support and self generation. Though the initial idea was to allow the IITs to fund themselves a few years after their establishment, it is the case even now that three-fourths of funds still come from the State (Chandra, 2006).

It is said that less than one percent of the 200,000 odd applicants and entrance test takers each year succeed at admission into any one of the IITs (UNESCO, 2006). The entrance test for admission to the IITs is of a difficulty level that allows only the most academically brilliant candidates to successfully qualify through; which is followed by an interview testing various other abilities and aptitudes of the short-listed candidates. It requires no explanation, hence, that education centres of the highest quality in the United

States and the rest of the world welcome graduates from IITs. The IITs are centres for teaching and research primarily in technical sciences, but also have departments dealing with high quality teaching and research in the pure sciences and the humanities and social sciences also. Diversity in disciplines is expected to encourage a culture of interdisciplinary research. Also, five Centres of Advanced Study and Research have been set up in Energy Studies (IIT Delhi), Material Science (IIT Kanpur), Cryogenic Engineering (IIT Kharagpur), Ocean Engineering (IIT Madras) and Resource Engineering (IIT Bombay) (DSHE).

Though the State has been the lifeline for the IITs, a mention of the foreign support for technology development in these IITs cannot be ignored. Each IIT credits one particular country among others for technology collaboration. IIT Delhi credits the United Kingdom, IIT Bombay credits the former USSR, IIT Kanpur credits the United States and IIT Madras credits Germany (Chandra, 2006).

An Indo-German agreement signed by the then Prime Minster Jawaharlal Nehru in 1958 in Bonn, West Germany paved the way for the founding of an Indian Institute of Technology at Madras[8]. The institute established was declared one of national importance by Parliament in 1961. The IIT Madras today, spread across 250 acres of land in south Chennai, houses more than 4500 students and scholars, around 460 members of faculty, and around 1300 auxiliary and administrative staff, earning a reputation across the world of being a premier institution for teaching, research, as well as industrial consultancy services.

IIT Madras has fifteen academic departments offering taught and research courses at the undergraduate, postgraduate and doctoral levels, besides a number of centres for advanced research in pure science as well as engineering science. Around a hundred laboratories are also located in the institute, working in coordination with the academic departments and amongst themselves. Under the supervision and training of a distinguished faculty, students are exposed to training and research in fields ranging from aerospace engineering and applied mechanics, to chemistry, mathematics, biotechnology,

[8] The following section on IIT Madras was written based on information derived from the institute's website <www.iitm.ac.in>

ocean engineering, and even humanities and social sciences. Degrees offered include a four year BTech, a five year integrated Dual Degree, two year MTech, MSc, MS and MBA, as well as PhD. Students and faculty are known to win awards frequently for academic as well as non-academic activities, and research.

Students benefit from a Placement and Training Office on campus, which interacts with around eight hundred organisations around the world, more than a hundred of them coming to the institute to hold campus placement interviews every year. The prominent industries that feature in this group include core engineering industries, IT and ITES industries, manufacturing industries, consultancy firms, management organisations and R&D laboratories. Exchange programmes like the German DAAD programme, though not a permanent feature, also aims at benefiting interested students.

IIT Madras works in collaboration with a number of other universities in India and abroad, and has signed several Memoranda of Understanding with them for assignments and projects, with an aim to mutually benefit. Not only does the institute work hand in hand with other academic institutions, but also in partnership with industry. Faculty at IIT Madras offer consultancy services for firms and other organisations in India and abroad, earning IIT Madras the status of being a prominent industry collaborator. There are also sponsored programmes funded by national and international organisations, which engage members of faculty in tasks including project design, testing and evaluation or even training in new areas of industrial development. Most consultancy research is channelled through the Centre for Industrial Consultancy and Sponsored Research (IC&SR) located on campus, the basic aim of which is to foster university-industry collaboration.

IIT Madras was awarded the ISO 9001 certificate in 1999, and has time and again been recertified for not only its academic functioning, library and administration, but also for quality management during its annual technical festival *shaastra*.

Placements at IIT Madras

As a starting point, it is important to take note of the kind of placements for students that have been taking place at IIT Madras in the recent past. The Placement and Training Office (henceforth P&TO) at IIT Madras is an active body that coordinates the placements of the students in firms and organisations that register themselves at this Office. Firms arrive every year in the hundreds to judge (in most cases) by interview the prospective students' skill and aptitude to take up the offered post, more than to assess the academic expertise received during their course at IIT Madras. Needless to say, the latter is highly influential in shaping the former. The P&TO interacts with hundreds of firms, which it classifies by the nature of the job as IT/software related, Management/Finance/Consultancy related, Core-Engineering or R&D laboratories and organisations, Manufacturing Organisations, etc[9]. Information is channelled to the prospective students and faculty by means of printed notices and through the IIT Madras website. Every academic department in IIT Madras has one member who is on the Board of Placement, who is required to be on this Board for a certain period. The members of this Board meet especially during the latter part of the year to discuss various issues in the placement system and to oversee the arrival of companies in the months of December and January. There are also representatives from the student community from across degree levels and across engineering, science and humanities streams. It must be mentioned that student registration at the P&TO is restricted to those in their final year of their respective degrees. Also, on once procuring a placement, a student is barred from appearing for another interview. The P&TO refrains from making suggestions to students as to which profession or specific company to opt for, and to a large extent plays an unbiased role in bringing together firms and prospective students to a common arena.

At an average, around 85% of final year Dual Degree students and almost 100% of final year BTech students enrol themselves at the P&TO, though this may not mean that the same volume of students are actually placed at the end. Table 3 gives the list of departments and the number of students in each department across degree levels that have registered themselves at the P&TO. The maximum number of registered students by department comes from the Mechanical Engineering department, followed by Electrical Engineering and Computer Science and Engineering. But as far as BTech and Dual

[9] There is indeed some overlapping between these criteria, as well as the bunching of professions that are evidently different. But this classification has been done mostly for the convenience of the P&TO in its functioning.

Degree registrations alone go, there are more students from Civil Engineering, Chemical Engineering and Biotechnology departments than Computer Science and Engineering[10].

Table 3: *Number of Students Registered at the P&TO for 2006-07*

Branch	B Tech	Dual	M Tech	MS	PhD	Total
Aerospace Engineering	21	8	7	5	1	**42**
Biotechnology	38	7	-	2	3	**50**
Chemical Engineering	38	10	19	2	11	**80**
Civil Engineering	42	8	37	10	3	**100**
Computer Science	28	7	35	31	-	**101**
Electrical Engineering	69	34	41	19	5	**168**
Engineering Physics	11	-	-	-	-	**11**
Management	-	-	-	2	8	**10**
Mechanical Engineering	84	24	47	18	14	**187**
Metallurgy	31	5	12	5	2	**55**
Naval Architecture	16	3	-	-	-	**19**
Ocean Engineering	-	-	5	3	4	**12**
Total	**378**	**106**	**203**	**97**	**51**	**835**

Source: Placement and &Training Office, Indian Institute of Technology Madras

As can be seen from the above table, the fraction of BTech students among the total is higher than even MTech and Dual Degree combined. In other words, almost half of the registrations at the P&TO are final year BTech students. This is one of the reasons why this study focuses primarily on BTech students (and Dual Degree students) for its survey among students.

Coming to the actual placements, there have been some interesting trends seen in the last few years. First, a look at the total number of students placed in the last three placement sessions. The number of students that have been placed from the P&TO have increased year after year, with around 549 students placed in 2003-04, around 740 students placed in 2004-05 and around 798 students placed in 2005-06. Save for a few tens of students, the large majority of students registered at the P&TO get successfully placed every year.

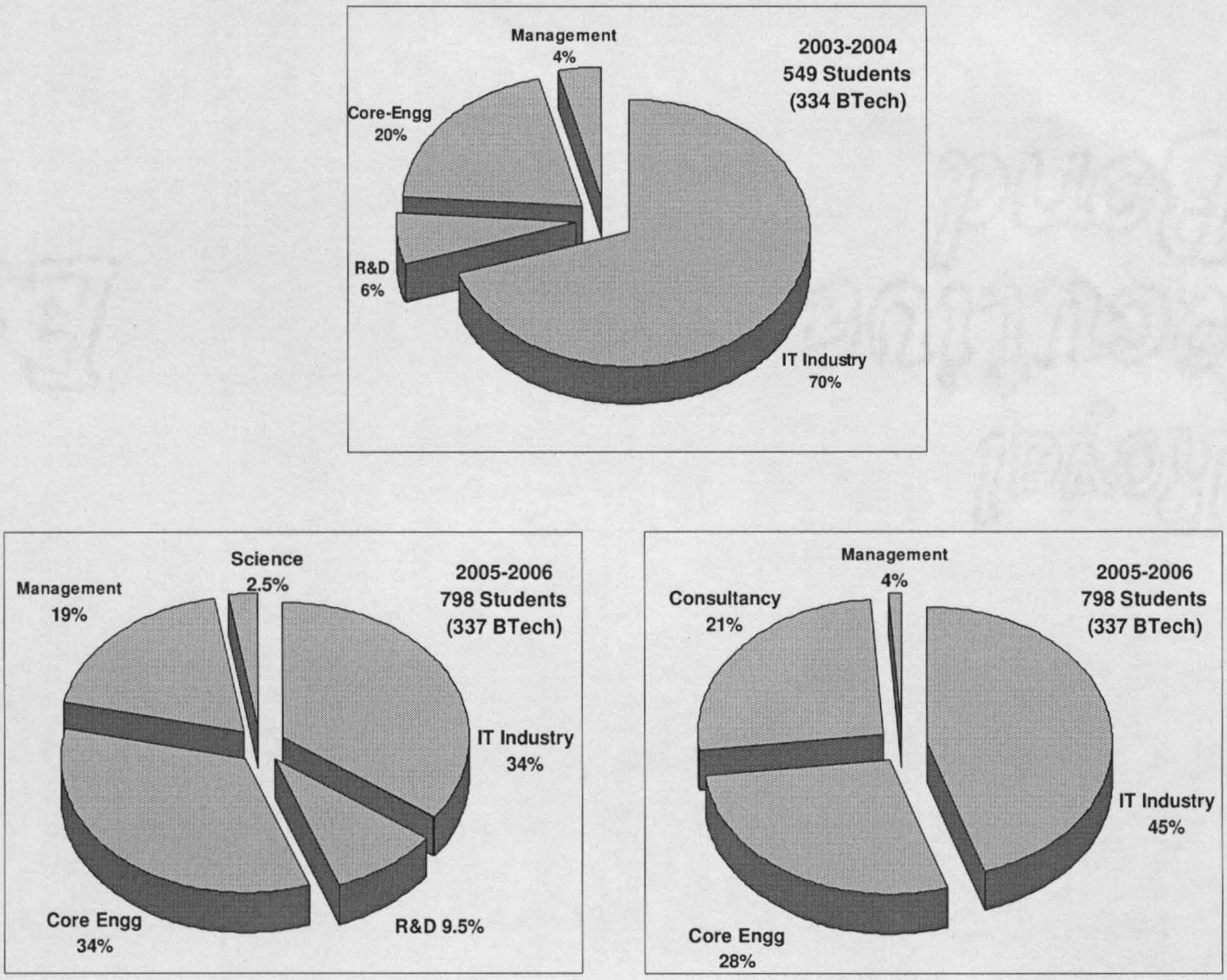
It must be stated at the outset that the classifications used by the P&TO to group incoming firms change year after year and if necessary, more groups are introduced. The

[10] This information was procured in November 2006 and is likely to have altered, as the registrations might have increased in the following months when placement activity would be at is peak. Most of the information that follows in this section and beyond has been procured from the P&TO at IIT Madras.

terms used henceforth for the groups are those nomenclature used by the P&TO. Charts 1, 2 and 3 show these diagrammatically for three years beginning 2003-04.

In the year 2003-04, the classified groups were Core-Engineering, Management, IT Industry and R&D. By Core-Engineering, it is implied that these firms deal with engineering technology and production. Around 70% of the students were placed in IT Industry firms, while 20% were placed in Core-Engineering, 6% in R&D and 4% in Management.

Charts 1, 2 and 3: *Placements 2003-04, 2004-05 and 2005-06*



Source for all three charts: P&TO, IIT Madras

By 2004-05, a few differences are noticeable. Firstly, the grouping has been modified to include an addition – Science. But Science recruited only about 2.5% of the total registered. The IT Industry recruited lesser than the previous year at 34%, while Management seems to have played a major role, recruiting around 19%. In the context of this study, a favourable improvement was seen in Core-Engineering, which increased dramatically to 34% (a 14 percentage point increase) and so did R&D (a 3.5 percentage point increase). Though in absolute terms these last two percentage points may not seem very large, in terms of the increase in the *number* of students placed in these fields it is worthy of mention.

In 2005-06, the grouping was again modified to include Consultancy[11], and R&D and Core-Engineering seem to have been clubbed together as one group. Here too, one can see the separation the P&TO have made between Management and Consultancy. The IT Industry evidently recruited more than the previous year, and the emergence of Consultancy as a recruiter on par with Core-Engineering was very evident. It would have been better for consistency and for precision that R&D were separated from Core-Engineering in this case, but to consider that even their combined total is far lesser than what it was in the previous year is something distressing.

As to find out how and why these trends have happened, as well as to make predictions about trends in the coming years, it is most necessary that a survey be conducted among students to find out what their perceptions are on taking up Core-Engineering and R&D as professions as opposed to the more monetarily attractive IT Industry and Consultancy/Management. Such a survey would reveal the multitude of push and pull factors that have lured students away from R&D and Core-Engineering towards more attractive and 'popular' professions, and would be able to answer the central question of the study, i.e., whether technical education in India (even at the highest level) contributes to R&D manpower.

Perceptions about Core Engineering as a Profession – across the branches

But before undertaking the survey among students, it was found necessary to note the perceptions of the teaching faculty across departments as to why this problem of S&T trained manpower moving towards non-S&T disciplines has occurred increasingly over the last decade or so. The survey at the department level is useful in two respects. Firstly, it allows one to group the departments on the basis of common trends that have occurred and trends that are most probable in the coming years, which in turn assists in drawing a

[11] This includes finance as well.

sample from the total population of students that are to be targeted for survey. As will be discussed in greater detail in the next chapter, it is a little awkward to draw out a sample consisting of a uniform proportion of students from each department, considering the fact that each department may be varying in placement trends. The department level survey helps in grouping those departments that have had common trends in placements, so that one can for the student level survey draw out a meaningful sample from the total population in each of the departments.

Secondly, such a survey across departments would give a wealth of information on this issue from the point of view of the faculty. Valuable insights would come up during the course of interviewing faculty members in each of these departments, which would help in understanding the central issue of the study better, as well as in formulating the interview questions for the students at a later stage.

What follows is a synopsis of the findings in nine departments whose faculty members teach BTech and Dual Degree engineering students. These departments include Mechanical Engineering, Electrical Engineering, Ocean Engineering, Civil Engineering, Chemical Engineering, Biotechnology, Metallurgy and Materials Engineering, Aerospace Engineering, and Computer Science & Engineering. The P&TO provides a list of the members of the Board of Placements in each of these departments, who were individually briefed about the issue at hand, and were asked one by one to respond to the issue in an open-ended manner. The only closed-ended question asked to each was to list out an order to preferences for professions or higher studies that the students have shown in recent years. In case the respective member of the Board of Placement was unavailable, the Head of the department was interviewed. What follows is a summary of observations based on information related by faculty members in each of the nine departments.

The 'MS-PhD and Settle Abroad' Preference

As mentioned earlier, the 'brain drain' of IIT graduates is famous, this having been quite rampant for the last many decades and still continuing though to a slightly lessened extent. It was a general belief among many in society that the average IITian aspires primarily to go abroad. The initial step to emigrate to a country with a much higher standard of living such as the United States was to undertake higher study there. So an MS or a PhD abroad, though undertaken in many cases also for one's academic furtherance, was also used as a stepping stone to acquiring work overseas. It is understandable that since technical education at the undergraduate level is of the best quality at the IITs, to acquire skills at a postgraduate or doctoral level one needs to look abroad.

Though the interest in postgraduate study followed by doctoral research abroad still remains even to this day, the intensity of this interest has slightly waned through the years, having come about for a variety of reasons. In some pockets of India it might be possible to dwell in high living standards similar to the West. This has various implications for a highly skilled workforce such as the IITians, who now need not aim at the West alone for better living standards. Though unusually high salaries and the emergence of a few tremendously prosperous regions in some parts of urban India is not the sole reason for IITians to reduce interest in settling down abroad, this factor has been highly influential. An indicator of this is the recent trend of a large number of Indian-born emigrants returning to India to establish and expand business and other occupations. Yet, this return of Indians to their homeland is but a trickle compared to the still sizeable population of highly skilled graduates moving abroad. The movement overseas is also highly dependent on the availability of visas and openings for work in countries like the United States, which depend on the fluctuating manpower requirement there every year.

It must be noted at this section on the first preference for IITians to go abroad is quite consistent with the section on discordances in the beginning of this chapter that cited the brain drain as the probable prime reason for the low R&D manpower in India.

To sum up, since undergraduate IITians seek higher learning in institutes that are better than IITs, they would quite naturally have to look outside India. But it must be appreciated that there is a slow but ongoing trend of a large number of people returning to India after foreign study or after working abroad for a certain period of time. Hence, the preference to *study* abroad continues, but the preference to *settle down* there after higher study has slowly begun to wane.

Three Waves

An MS-PhD abroad, according to the department-level survey, is still the most preferred option for most graduates after undergraduate study at IIT Madras. But the preference for seeking employment in India immediately after undergraduate study is also popular. The most preferred field of work after BTech at IIT Madras has changed considerably through the last two decades. If one were to chart out a 'most sought after field of work' by BTech students from the early 1990s onwards, one would easily be able to draw broadly three 'waves' of interest among the students.

In the initial years of the Indian software industry boom during the early- and mid-1990s, there was great demand for highly skilled S&T qualified graduates with basic mathematical and computing skills, to meet the need for manpower in ITES industry firms. IITians seemed to fit the bill since they were by far the best trained in the population of S&T skilled graduates in India. And considering the high wages in this industry, graduates began to herd towards firms in this industry. The initial years were, as everyone witnessed, marked with excitement in discovering that India could benefit greatly from its comparative advantage in IT and ITES manpower. The interesting fact was that even graduates who were not specialised in IT seemed to fit into the profession thanks to the basic mathematical, engineering and computing skills that were considered more than sufficient as qualification for entry[12]. This interest both from the employers' side as well as from the fresh graduates seems to have lasted for a long time until around the early years of this decade. This whole period could therefore be termed as the 'first wave' of interest among undergraduate students at IIT Madras.

The 'second wave' began around five or six years ago, and is still rather prevalent today though the peak period of its popularity is said to be over. Despite its monetary attractions not having declined, the software industry began to lose the initial charm it had on graduates at the beginning of the decade, and there also emerged the widespread layoff of workers in IT and ITES firms in especially the West. The interest towards other occupations hence began to slowly develop. Business and finance related companies began to come forward in a large way at around this time as far as recruitment of engineers went, offering salaries of magnitude similar to IT and ITES. The interest for finance and management related education and professions in the same line came about in a big way, with students even from completely unrelated disciplines like Biotechnology keeping this as their first preference. The interest for professions like consultancy, finance and management is clearly seen in the placement trends at IIT

[12] These skills are acquired by engineers in any branch since it is taught to almost all of them in the initial stages of their undergraduate study. This made an engineer of any discipline eligible for a job in an IT firm.

Madras shown earlier. The preference for work in this field remained strong, and the phenomenon of 'engineers compiling market survey reports' no longer surprises us. Again, this preference is now beginning to diminish, though the diminishment is still in its nascent stages. As will be discussed again later, graduates from IIT Madras from disciplines like Materials Engineering, Ocean Engineering and Chemical Engineering seem to have a high preference for management and finance related professions, the chief reason being the pull factor of very high wages offered by these companies.

What can be termed as a piece of good news for the scientific fraternity in India and others concerned about India's low HRST-O is the new 'third wave' of career preferences emerging at IIT Madras and possibly the other IITs as well. There is, according to those surveyed for the department-level survey, an interest for core-engineering and R&D related professions gradually emerging among students after undergraduate study. There are a variety of interesting reasons for this to occur and to pave the way for its emergence in a large way as a 'third wave'. One of the factors that can be pointed out for the appearance of this 'third wave' is the realisation that firms would, logically, layoff first those who have qualifications that are unrelated to the field of work. In other words: between a Computer Science graduate and a Chemical Engineering graduate in the same IT firm, or between a management trained employee and an engineer in a consultancy firm, the latter in both cases will be the first to be laid-off by the company in times of crisis. Also, it is said that engineering students are found to be more respected as employees when working in firms dealing with core-engineering or R&D, than if working despite a much higher pay for firms dealing with non-S&T jobs or even IT and ITES. These phenomena have been witnessed many a time by both engineering students and teachers and are some of the many reasons for a new and promising 'third wave' to develop.

Interests Begin in Core/R&D, but Eventually Drift Away

There seems to be one universal fact that was mentioned by every faculty member surveyed in each department, it being that when students initially enter IIT Madras for their BTech or Dual Degree courses, they show a great amount of enthusiasm for Core Engineering or even R&D, but this interest fades away in the course of time. It can be assumed from this that if one were to survey students who have newly entered IIT

Madras, they would inevitably express a desire to work in the long run in their own discipline, especially when it comes to Mechanical- or Electrical Engineering. As the course moves on and students travel through the semesters, the interest to work in Core-Engineering or R&D diminishes; and on the day of the placement, remuneration and salary seem to take the upper hand, regardless of the nature of the work.

A cause for this could be the in the internal environment of the institute and the students' experience through course, whether it is at IIT Madras or any other. If this is true, this phenomenon must be prevalent in many institutes besides IIT Madras, and would be more acute in second rung engineering colleges (like the NITs or state-run engineering colleges). Students seem to be not motivated enough to take this up as a career, and as one moves further through the course they might even feel repulse to think of Core-Engineering as a long term plan – an idea that can only be ascertained and delved deeper into through a survey of the students. At this stage, before the student-level survey it could be predicted that there must be some specific points in the course such as the internship most students undergo in Core-Engineering firms that might serve to attract or (as is the case here) discourage in taking up Core-Engineering or R&D as a profession. One can only imagine therefore the consequences the experience of the BTech course has in shaping students' preferences and in eventually filling up the wanted numbers in HRST-O.

As the faculty said, it is the students who will be the best in judging the motivation they receive from the internal environment or the course as such to move towards Core-Engineering. Hence, this point will be taken up in much greater detail in the next chapter and will help formulate a key question asked to the students[13].

An point worthy of note that came up following this was that even if students do land up in Core-Engineering or R&D related work in the beginning, they eventually move on to more attractive professions in the IT and ITES industries, or management. An interesting such 'path' was related by a member of the Placement Board in the Metallurgy & Materials Engineering Department. To narrate it briefly: students specialising in this particular discipline move on to do higher studies (whether in India or

[13] Here is one of the many places in which the department level survey has greatly helped in shaping the questionnaire for the largest part of this study – the student-level survey. This point made by the faculty has formed questions that make up a large part of the second part of the four part questionnaire

abroad) in a branch known as material electronics. This gives them the opportunity to work as specialists in material electronics in firms dealing with electronics and hardware. The experience of working with hardware pays off finally when the student applies for work in a software company. This innovative 'path' from Metallurgy & Materials Engineering to software has been travelled for many yeas now, and is one that students have found to be unfailing if one wishes to move towards IT and ITES industries. This is just one of the many 'paths' that might exist in each discipline to move towards other fields, and which have given many students the confidence that one can move towards more attractive professions, regardless of the non-preferred branch one is saddled with at the BTech level.

'Quick Results' Not Easy and Recognition of Achievement Slower in R&D

Besides the many other grievances they had about the students taking up professions that are not Core-Engineering or R&D, the faculty complained in a few cases that graduates today, unlike their counterparts a few decades ago, are rather 'impatient' in achieving success in their respective field. Though this may seem a rather sweeping statement, there is an element of truth in it: that to innovate, succeed and achieve recognition for one's contribution is quicker in some professions than others. Many faculty were of the opinion that innovations in fields like software and management were easier noticed and lauded than innovations in pure science or even Core-Engineering, which are known to take longer to develop as well as be appreciated. This psychological element in the preference of students to move away from Core-Engineering and R&D is rather strong here, and the effects of peer influence in this regard cannot be discarded.

Besides monetary and other economic incentives that are brought in by the more attractive professions, there is also the inferiority one might feel when working in a profession wherein the delivery of results is slower while one's peers are working in professions wherein the delivery of results in terms of recognitions, promotions, etc., are much faster. Such a mentality plays a vital role in the preference formation process and must be put on par with all the other 'economic' push and pull factors like salary and incentives in the institutional environment.

On interviewing a few employers who have had considerable experience in recruiting fresh engineers for Core-Engineering and R&D work, the similar point was brought up – that students in the present day do not prefer working in Core-Engineering since they are likely to see their counterparts in more attractive professions 'moving ahead' and on this account would feel vexed about their relatively 'slow moving' jobs. The students have seemed to acquire a more or less negative outlook towards Core-Engineering and R&D as they perceive them to be 'slower moving' professions. This actually is a misleading façade that has been constructed on experiences during the coursework and the lack of cultivation of interest in these institutions towards Core-Engineering.

Cases of Two Contrasting Departments

It would be too tedious for the reader if an account of the trends in every single department were to be elaborated here. Yet, it would be worthwhile to glance at two contrasting departments at IIT Madras follows. Given below are outlines of information elicited from interviewing two faculty members in the Civil Engineering and Biotechnology Department respectively. These two departments, as will be seen below, are at quite a contrast in terms of their students' preferences.

- *Civil Engineering*: As a part of the department-level survey the Member of Placement Board in this department was interviewed in the manner explained earlier. It was made clear at the outset that in the context of the issue at hand, this department is certainly an exception in that most students in this department today increasingly prefer work in Core-Engineering. Though it cannot be said that the largest majority of the class opts for this, it has been noticed by this faculty member that the fraction of the class choosing Core-Engineering jobs during the placement sessions has increased over the years. Close to half the class prefers to work in Core Civil Engineering than in IT/ITES or management and consultancy. One of the many reasons for this is that a number of transnational companies have entered India in recent years, which require highly skilled civil engineers for construction and design of office buildings. Civil engineering students at IIT Madras in recent years seem to have taken full advantage of this demand and are moving towards Core-Engineering jobs. Being transnational corporations that generally show a willingness to pay very well for quality work, civil engineers are offered high wages. Besides, entry into the United States is much more difficult now and entry opportunities each year are unpredictable, which is an important factor during preference formulation by students. Of course, attempting the Common Entrance Test (CAT) for management education in India is also quite popular among civil engineering students, but negative feedback from seniors and others who have ventured into non-civil engineering professions in the past have played a part in driving current students to prefer Core-Engineering work. This department had indeed witnessed about a decade ago that most of its students were opting for IT/ITES and other such professions, but the trend has changed a great deal especially over the last few years. This being quite in consonance with the 'third wave' discussed earlier, the continuation of such a trend towards Core-Engineering may ensure that students from this department in the near future may contribute progressively more to Core-Engineering, incrementally filling up the missing numbers in HRST-O.

- *Biotechnology*: On interviewing the Member of Placement Board of this department, it was found out that most students in this department opt for non-Core-Engineering professions, and to add to the dilemma, they even seem to *demand* the P&TO to bring in more non-core opportunities for them. This was at quite a contrast to the assumptions held about preferences in the Biotechnology Department before the department-level survey began. This department (which might appear to one as highly R&D oriented) was established at IIT Madras only four years ago, and the first batch that has graduated out has opted mostly for management, finance and consultancy related professions. The faculty in this department, it was told, take special effort in persuading students to shape their preferences towards jobs in biotechnology research by trying to advertise the attractions of working in this field, but the current batches of students seem to prefer otherwise. The number one factor for such a preference is not so much in disillusionment with biotechnology R&D or with the work environment in biotech firms, but with the pull factor of high wages in 'non-core' companies. Some students do show an interest in biotechnology research, but are willing to join firms undertaking this only on the condition that the wages are at least as much as the starting wages offered by IT/ITES firms or management firms.

It was explained by the interviewee that since innovation in a biotech firm in most cases takes longer to develop than innovation in an IT firm, the former seem quite justified in saying that they can't pay entry level students high wages right at the outset. Comparing with other industries, biotechnology students find themselves in an industry that delivers results slowly. This situation is expected to change since the media and government seem to pay a lot of attention to the biotechnology sector in India, which is actually still in its infancy. Manpower requirement, it is predicted, might be an important element that will come into focus when this sector is sought to be expanded in the future. This would have a bearing on the wages of especially entry level employees as an incentive to join the industry and fill up the manpower requirement. But one has to wait and see.

An alarming statement made in both the department-level as well as the student-level survey was that the large investment made in establishing and running this department can be considered almost entirely pointless since it might scarce produce biotechnology manpower, assuming that manpower creation is the primary goal of the investment in this department.

It was therefore seen through this chapter that the research problem is essentially an institutional one; clearly a case of discordance between the technical education institutes and the other actors in the system of innovation in India. What was more distressing was that institutes of even the highest rung like IIT Madras where students are tailored for R&D or Core-Engineering work are not opting to do so because of the various push- and pull-factors that affect their preferences, ultimately resulting in the missing numbers in scientific manpower stock. The department-level survey showed that the problem is indeed a crucial one as far as India's R&D manpower goes. But there is hope for the future, and since the 'third wave' has supposedly begun, one can now hope for its full emergence as a popular preference, favourable for the future of R&D in India. But one can neither make suggestions for policy nor fully appreciate the nuances of the situation unless the students themselves are interviewed.

The department-level survey has indeed helped in gaining an understanding of the complexities of preference patterns of students and has served as a beneficial prelude to the student-level survey, which is the most important part of this piece of research.

IV

Analysing the Process of Preference Formation

This chapter deals with the largest part of this study and seeks to explore at ground level, one of the many causes for India's low R&D manpower and its low Core-HRST stock – the phenomenon of S&T-trained manpower moving out of the innovation system into other professions. As explained in the previous chapter, this study takes the case of one institution, IIT Madras, as a prominent actor in the system of innovation in India and explores why engineering qualified students at the undergraduate level have increasingly been inclined towards non-S&T professions. A look at the placement trends only confirms this, and it would be imperative to interview the students themselves to explore first hand as to why they have been displaying such preference patterns. Not only would an exploration such as this gather information as to what the push- and pull-factors are, but would also, on aggregation of collected information, show the mechanism by which such preferences are shaped, and how they ultimately have a bearing on India's Core-HRST stock.

This chapter pursues the following path. It first addresses the importance of this student-level survey in the context of this study and then demonstrates the method by which a stratified random sample was drawn out of the population of over five hundred students. After a brief section on the questionnaire, an analysis of findings from the interviews is then presented in detail, this being the largest part of the chapter. These findings would not by themselves explain the preference shaping process and the reason for low Core-HRST. Hence, the chapter at the end uses these factors to sketch out a mechanism by which a majority of respondents in the sample (and also the students in general) choose the placement they have opted for. At a broader level this chapter ultimately shows at the ground level how economic, non-economic, and institutional factors shape preference patterns that ultimately have far reaching consequences for R&D manpower and Core-HRST stock.

The Student-Level Survey

In the previous chapter it was mentioned that the P&TO is a relatively unbiased agency which, as a part of its policy, does not play any role in prompting or influencing the students to opt one profession or the other and plays the role of merely bringing together the prospective firm and the student. As to which particular firm's interview to attend or which placement offer to accept is a decision made by the students themselves – a decision shaped by a multitude of factors. These factors, some within and some outside the realm of mainstream economics, are extremely important to list out and assess, since it is the interaction between all these factors that ultimately decides whether the S&T trained manpower has incentive to move towards R&D or Core-Engineering related work or not. It is important to understand the working of an interaction mechanism that shapes placement preference, it being complex. This can be understood only by actually discussing with the students at an individual level and collecting information as to what factors in and around IIT have made them move towards a certain placement offer. The respondents would not be able to spell out the exact manner in which their preferences are shaped, but the information collected through these interviews, when processed and arranged, would clearly help in evolving the interaction mechanism at the end.

The detailed methodology of the student-level survey is what follows, beginning first with the sampling procedure and then a brief description of the various sections of the questionnaire with the intended information sought to be elicited from each section.

Sampling Procedure

The Population of Students

The student body at IIT Madras consists of over 4880 students and scholars, distributed across fifteen departments, undergoing BTech, MTech, MS, Dual Degree, MBA, MSc, MA, or PhD programmes. Table 1 gives a brief overview of the spread of student population across year of study and across programme. The largest section of students naturally falls into the BTech and Dual Degree category, together constituting about 46% of the total student population. For this particular study, as mentioned earlier, the only categories of students considered were BTech and Dual Degree students, and in addition only those in their final year of study and only those who have acquired placement offers through the P&TO. Though this might at first seem too small a subset of the population to take as sample, in reality it is not, since a substantial 23% of all BTech and Dual Degree students were in their final year; and almost all of them had already acquired placement offers by the time these interviews began.

Table 1: *Population of Students across Programme and Year of Study at IIT Madras*

Year	B Tech	Dual Degree	M Tech	MBA	MSc	MA	PhD	MS	PC
I (2006)	328	196	370	61	92	29	-	-	-
II (2005)	340	186	329	64	92	0	-	-	-
III (2004)	368	177	8	1	2	0	-	-	-
IV (2003)	382	121	8	0	0	0	-	-	-
V (2002)	30	111	3	0	0	0	-	-	-
<2001	12	10	0	0	0	0	-	-	-
Total	**1460**	**801**	**718**	**126**	**186**	**29**	**1081**	**466**	**14**

Source: Office of the Registrar, IIT Madras
Note that for MS and PC students as well as for PhD scholars, the year-wise break-up was not available.

A Few Considerations before Sampling

The population was to be first stratified on the basis of the various branches offered for the BTech and Dual Degree. Of the eleven branches in total, this study selected nine, since in two branches (Engineering Physics and Engineering Design) the population was considered to be too minute to draw a sample from and to aggregate preferences. The other nine branches were considered to have a substantial population enough to draw a sample from for study and to subsequently make aggregations and generalisations. There were a few considerations to be made before drawing the appropriate sample, given below.

- First: keeping in mind the constraints of time et al, it was considered feasible to take around ten percent (around fifty students) of the population of nearly five hundred final year BTech and Dual Degree students as a sample. Hence, the sample to be studied was to have a total of fifty final-year BTech and Dual Degree students across nine branches, who have acquired placement offers.

- Second: it was considered rather improper to draw a uniform ten percent of each branch's student population while stratification, since this would result in more populous branches being over represented in the sample and less populous branches being under represented. Here is where the department-level survey came to great assistance. On close analysis of the findings of the department-level survey, it was seen that a number of departments reported similar past trends in the placement choices of their students. One set of departments reported that most of their students in the past had always opted for R&D or Core-Engineering jobs and that the research problem of this study was not of very critical concern in their particular department. Aerospace Engineering, Civil Engineering, and Computer Science & Engineering came under this category. These three departments were clubbed as Category II. Six other departments reported that the research problem at hand was very relevant to be studied in their respective departments, that they did face a severe problem of engineering-trained students moving towards management and finance, or even doing MS-PhD abroad, never to return. These six departments were clubbed as Category I.

- Third: it was seen that Category I held 75% of the total population while Category II held 25% of the total population. Drawing from the argument above, if only 25% of the sample of fifty students was to come from Category II, this category of branches would end up under-represented in the sample and one would find it difficult at the end to make aggregations and generalisations. It was thus decided that due to the already small population of students in the three branches *not* facing the research problem, the weightage given to Category II in the sample would be a little greater than 25% of total sample; and due to the already large population of students in the six branches facing the research problem, the weightage to Category I would be a little lesser than 75% of total sample. Hence, a little more than 10% of total students from each branch belonging to Category II, and a little less than 10% of total students in each branch belonging to Category I, would be drawn for the sample.

Stratification

Keeping the above considerations in mind, it was finally decided for practicability of study and feasibility of aggregation of preferences that *the sample, stratified by branch, would consist of fifty final-year BTech and Dual Degree students who have been offered placement through the P&TO; the sample stratified in the manner that 60% would come from six branches facing the research problem (Category I) and 40% would come from three branches not facing the research problem (Category II).*

Table 2 gives the stratification of the population and intended sample size to be drawn from each branch.

Table 2: *Stratification of Population and Sample in each Categorised Department/Branch*

	Branch	Population	Sample		
Category I Branches wherein the research problem has been reported to exist	Electrical Engineering	109	9	*(8.2)*	*Population: 371 Sample: 30*
	Mechanical Engineering	110	7	*(6.3)*	
	Chemical Engineering	49	4	*(8.1)*	
	Biotechnology	47	5	*(10.6)*	
	Metallurgy and Materials Engineering	36	3	*(8.3)*	
	Naval Architecture & Ocean Engineering	20	2	*(10.0)*	
Category II research problem was reported not to exist	Civil Engineering	53	10	*(18.8)*	*Population: 121 Sample: 20*
	Computer Science & Engineering	39	4	*(10.2)*	
	Aerospace Engineering	29	6	*(20.6)*	
	Total	**492**	**50**	***(10.1)***	

Figures in parenthesis indicate percentage of the sample in the corresponding population.
For example, for Electric Engineering, the figure 8.2% was computed as (9/109)*100.

Generating a Stratified Random Sample

In accordance with the principle of random sampling, each member of the population of students in each branch had an equal probability of being selected for interview. From the list of students in each branch, listed in roll call order, the table of random numbers[14] was used to pick students for the sample. For example, for the Electrical Engineering department, the first nine two-digit numbers listed in the table of random numbers were referred to and the students with corresponding roll numbers were picked for interview. In this manner, the requisite sample was derived from every one of the nine branches in consideration. Each branch had a 'student representative' at the P&TO, and the students picked from the random sample were contacted and brought for interview by these representatives.

A point to note is that though each respondent was interviewed individually and responses were recorded on an individual basis, the entire sample from each branch was made to assemble for interview and each respondent was given an opportunity to listen to the other respondents' interviews. From the preliminary student-level survey it was

[14] A table of 7500 random numbers was obtained from Fisher and Yates (1963).

discovered that respondents were more informative and responsive when interviewed in the midst of their peers than when interviewed individually. It was assumed that the synergy flowing between the respondents when assembling in a group gave each respondent impetus to answer more elaborately.

Questionnaire

The questions were categorised into four sections, with the idea of constructing four categories of information that would help understand the issue at hand and finally answer, step by step, the research question as to why S&T trained graduates move out of the system of innovation.

- *Background of the Respondent:* it was considered important to know the background the respondent comes from, in terms of the parent's educational qualification and the education of other siblings. Also, it was considered necessary to know the location in India (or outside) where the respondent has had most of one's education. Both these details provide a small foundation as to understand the family environment, and the urban or semi-urban environment respondent has had. These factors, if not highly significant, provide a basic grounding for the kind of future the average IITian plans.
- *The IIT Experience so Far:* it was considered important to document the experience the respondent has had through the years spent at IIT. This section elicited information about which part of the course the respondent found most interesting and whether it inspired him/her to consider R&D or Core-Engineering as a profession, keeping in mind that there was a possibility of the lack of motivation from the side of the course to take up this line of work.

  The students at IITs do not really 'choose' their branches of study in the true sense of the term, as this is decided by the performance in the Joint Entrance Examination (JEE). It might be the case that a student wishes to change one's branch for reasons pertaining to future job options. This was also noted. Another part of this section was to make note of the internship experience. Internships are a mandatory part of the course and almost all students undergo the internship in organisations that carry out Core-Engineering work or R&D. A good motivating internship might make an intern seriously consider R&D as a long term option; a de-motivating one could even push the student away from this line of work.

- *Placement:* this section not only noted the category of firm (Core/R&D, IT/ITES, management/consultancy/finance) the respondent was offered placement in, but also the circumstance under which the student chose this (i.e., whether this was a choice at all). It was asked whether the current placement offer was satisfactory to the respondent's liking or whether there was any inclination to change to any other profession or further study within the next one year, and if yes, why. Importantly, it was asked whether a student has written the GRE or CAT and is serious about either, keeping in mind the MS-PhD and Management Education preference discussed in the previous chapter.
- *Perceptions on R&D and Core-Engineering:* this was the last and most open-ended part of the questionnaire, wherein the respondent was asked to narrate his/her views on why they think most of their peers (even if initially offered placement in R&D and Core-Engineering firms) wish in the long run to move away towards non-S&T professions. Push factors if any were noted, and the respondents were also asked to suggest any incentives that might attract them towards R&D or Core-Engineering. Keeping in mind the issue brought out in the department-level survey of interest in engineering weaning away through the course's time-span, it was asked whether or not one had an interest in Core/R&D at any point in the course (initially, throughout, progressively, etc.). Importantly, it was also asked as to whether there was a prestige issue involved and whether respondents might consider their investment in the IIT experience as unfruitful if they took up R&D or Core-Engineering.

Most of this interview questionnaire, especially with regard to structuring its various sections, was constructed on the basis of combining information elicited from both the department-level survey and the preliminary student-level interviews. The questions were asked, in almost all cases, in an open-ended manner. Only very few questions were closed-ended, since this study was meant to explore afresh as to what the students' preferences/opinions are. The structuring of the questionnaire in the order given above corresponds to the stages by which the research question needs to be addressed in the context of this case study. The questionnaire that was used for interview is supplied as an appendix to this chapter.

Analysis of Findings

On aggregating the responses collected through the interviews of fifty students, a number of general trends began to emerge. What follows is an analysis of the various findings of the student-level survey. These findings are the building blocks of the interaction mechanism that shapes preferences. In the larger context, this information helps one to understand why the Core-HRST in India is low despite the existence of highly skilled S&T manpower in the system of innovation.

The points correspond with the questions in the four parts of the questionnaire as discussed earlier, and in turn are consistent with the four stages by which the research question has been addressed.

Background of Respondent

The first step required is to note the background of the respondents in terms of family environment and geographic location where the respondents have had most of their educational experience. This would be the foundation upon which to understand the rest of the information.

- *Education of Parents*: it was found that more than half the respondents (56%) came from families where the parents had a relatively high level of education – the postgraduate level at minimum. Only around a third (34%) of them hailed from families where parents were educated until the undergraduate level or even below. Interestingly, around 10% of the respondents had at least one parent who was an IITian. One can naturally assume that relatively well educated parents have a good amount of influence in encouraging their wards to join IIT.

- *Education of Siblings:* in terms of education of siblings, it was found out that around two thirds of the respondents had siblings currently undergoing, or have had, technical and professional education (which includes BTech, BE, MBBS, MBA, and the like). Only about one-third of the respondents reported to have had siblings who were not undergoing or have not undergone professional education. The respondent's family's educational background, therefore, seems to understandably have had an impact on the respondent's choice to come to IIT.

- *Area of Education:* it was noted that an overwhelming 50% of the respondents reported to have had a large part of school education in state capitals or other large cities in India, mostly South India. Since many respondents mentioned the district name rather than, the name of the specific town or village they had been educated in, it was hard to assess whether the respondent spent most of one's schooling years in rural or semi-urban areas, the border between these two being rather blurry. Only one student out of the sample of fifty admitted to have been educated in a rural environment, though there may definitely be a few more in the sample. But save for the exception of this miniscule number of respondents, it can be said that a majority of the respondents were educated and brought up in mostly urban/semi-urban settings – an environment highly influential in preparing the groundwork for successful admission into IIT.

The IIT Experience so far

Now that the background of the respondents has been recorded, it is important to know another important feature that would shape their preference for placement – the experience they have had at IIT Madras. Through this section, we will see that there have been indeed a number of factors through their course experience at IIT Madras which have had a significant impact in shaping their preference for placement.

Interestingly, only a quarter of the respondents (26%) stated that academic work was the most stimulating part of their four or five years at IIT. A majority were of the opinion that the most stimulating part of the experience at IIT was extra-curricular activity or peer interaction. Though this fact does not play a very significant role in determining placement preference, it can be mentioned in passing.

- *The Course in Specific:* one of the questions asked to the respondents intended to find out for how long or for what period the BTech or Dual Degree course held the respondent's interest, suspecting it would have a say in placement preference. Besides a small minority of respondents (8%) who felt that the course was not interesting at all and another marginal number (8%) who found the course progressively getting interesting, almost half the respondents (46%) claim to have found interest only at the very end of the course. This could be due to greater interdisciplinary interaction and more intense involvement of engineering skills in towards the end of the course. A good number of respondents (26%) also claimed that the BTech or Dual Degree programme was interesting throughout – right from the basic engineering and mathematical skills in the initial semesters to the more advanced level training in the final semesters. This question regarding specifically the course is important in that the course in engineering and technology has a direct influence of the students' interest in engineering and technology related work; an interest that might later manifest itself in a choice of placement offers. It can be hypothesised that those who claimed the entire course to be interesting are more likely to opt for R&D/Core-Engineering than most others.

- *Change of Branch:* branches be it Electrical Engineering or Civil Engineering are not chosen by the students themselves, rather are decided by the performance in the JEE. A better performance will result in a more 'prestigious' branch being offered and vice versa. It was asked to the respondents as to whether, after four years of rigorous experience and exposure within their respective branch, they would like to change their branch given an option. It was hypothesised before the interviews were conducted that most respondents belonging especially to 'less prestigious' branches would wish to change to a 'more prestigious' branch, keeping in mind above all the attractiveness of placement offers in the latter. But on interviewing, it was found out that around 70% of the respondents did not mind remaining in their own branch, despite admitting that there are other branches with more 'attractive' placement offers. Of the 30% who wished they were in another branch, most quoted the un-attractiveness of placement offers in their current branch as the prime push factor. The hypothesised response to this question, though, was not fully realised. This might be because there are a number of attractive placement offers that have no restriction on the branch, which gives equal opportunity for students of any branch to apply for such placements, hence making the branch immaterial at placement stage.

- *Internship:* as explained earlier, the internship is part and participle of the course programme and is usually undertaken in a Core-Engineering or R&D organisation. This internship was assumed to play a leading role in influencing students' decisions with regard to choice of placements. The exposure to work environment in R&D/Core-Engineering, the scope of expanding one's potential, the long-term prospect, and so on, were important experiences within the internship that would definitely play a significant role in the shaping preferences for placement. It was found that less than half the sample (46%) found the internship a motivating experience in terms of the stimulus it gave to students to consider R&D/Core-Engineering for placement. Whereas there were only about 12% who were actually demotivated by the internship experience (most of these respondents said that due to the internship experience, whatever little hope they had to consider R&D as a career was diminished to naught), about 42% of the sample admitted that the internship had no effect or influence on their future decisions at all. They stated to have undergone the internship only because it was a part of procedure, and did not use the experience to shape their preferences. So, though a little less than half the sample did experience a sense of motivation after the internship, almost an equal number of respondents seemed to be indifferent to it.

  But the positive side of this is that almost two-thirds of the respondents acknowledged to have used, during the internship, the engineering (or even analytical or computing) skills they acquired through the course, even if it were minimal. Interestingly, another 20% of the respondents stated that their course-based engineering skills were not developed upon during the internship as much as other skills such as professionalism, developing public relations etc. This fraction of the sample seemed to be the most pleased with the internship since the work environment in the internship allowed them to develop professionalism et al vis-à-vis technical expertise, as well as acquire an exposure to the industry environment. But contrary to expectation, almost half the respondents within this 20% claimed that though the internship was helpful in developing a variety of skills, it was not influential at all in terms of shaping future plans. A mention must also be made about the 16% of respondents who said that the internship did not use or develop any skills, and was a mundane ordeal done for its own sake. Though 16% is in relative terms the smallest fraction among the others, in absolute terms it is indeed a troubling figure if this opinion is extendable to the population of students at large.

It is understood, based on the responses, that the internship in most cases has had very little direct impact as far as placement preference goes. But the fact is that the internship helped give a good amount of experience in skill building of various kinds, as well as a reasonable amount of exposure to what the Core-Engineering and R&D work atmosphere is like. This would make one suspect that the internship experience did have its *indirect impact* on preference for placement, and would probably turn out to be a very important factor as far as understanding the research problem goes.

Placement

After understanding that the background of the respondent, to a small extent, and the IIT experience in terms of the course and internship, to a large extent, are factors to explain placement preference, one can now come closer to understanding the actual process of making a choice for placement; and in turn more directly addressing the issue of S&T trained manpower moving to non-S&T disciplines.

- *The Placement Offer:* despite the indifference of a large number of respondents to the internship experience and a lukewarm opinion on the course experience, almost half the number of respondents in the sample reported to have acquired placement offers in R&D/Core-Engineering firms. Around one third (34%) reported to have acquired placement offers in firms dealing with management/consultancy/finance and the rest 16% reported to have acquired placement offers in IT/ITES firms. On the face of it, it would seem like the 'third wave' discussed in the last section of the previous chapter has appeared on the horizon. But on going deeper, one can see how this is not as simple as it seems and the figures can actually be quite misleading.

  It is very important to note that though the placement has been *offered*, the student need not at a final stage actually accept the offer. Though this is not applicable in most cases, there have been many instances whereby students have not accepted the placement offer on getting hold of an attractive opportunity to study further.

- *Motivation to take up the Offer:* here is a claim that needs very close inspection – the claim by 64% of the respondents that they have made the choice of placement using their 'own discretion'. Leaving aside the small minority of 4% who admitted to have taken up the offer due to pressure from family and peers, one can say that the majority of students who have opted for their respective placement have made the decision not truly out of one's 'own choice', but out of circumstance. To elucidate further, a large majority of students at IIT who are keen on acquiring placement are not, on the placement day, driven purely by their interests in any particular field. Firms that arrive on the first day are highly sought after (regardless of field of work) due to the highly attractive remunerations they offer and by virtue of the fact that they are 'day one companies'. It was suspected that even though 64% of respondents in the sample claimed to have made their 'own choice', a large number within this 64% have in truth merely, out circumstances on placement day, *consented to the first placement offers they have received*, this to them appearing as their 'own choice'.

  Around 32% of the sample admitted to have picked any opening that comes in their way, rather than actually choosing the line of work they are interested in. There may be many cases within those who claimed to have made their 'own choice' who might actually add to this 32% category. So, though the 64% respondents have claimed to have made their own choice, a lot of other information gained through the interview seems to suggest that even within this category there are many who have merely consented to the first placement they have been offered, rather than truly choosing among alternatives keeping their interest in mind. Hence, this study is of the opinion that the large majority of 'placed' students within this sample have accepted placement offers by consenting to circumstance, rather than by 'own independent choice' as they have claimed.

  This is very important since we come to understand that even highly skilled S&T manpower may ultimately be consenting to circumstance rather than making an own choice per se as far as placement goes.

- *A Change in Job:* it was considered necessary to ask the students whether they are satisfied with this placement and are not keen on moving out of this placement in the near future, i.e., within the next one year. Around 64% of the respondents seem to be quite pleased with the current placement offer, and wish to continue in this line of work for at least one year. Yet, the remaining 36%, consisting of respondents who wish to change into a different line of work (or even higher study) within the next one year, is not a small fraction of the sample. Out of these 36% who wish to change soon, around 70% want to change to management/consultancy/finance related work and the rest wish to pursue higher studies abroad.

The good side is, that of those who have been placed in R&D/Core-Engineering firms, around 70% have no intention of moving out of R&D/Core-Engineering work at least for the next one year.

- *The GRE and CAT:* as mentioned in the previous point, only about 30% of those offered placement in R&D/Core-Engineering firms wish to move out of their current placement offer. Students need not leave their current placement offer only in search of another placement; they could do so even to pursue higher studies in India or abroad, in S&T related fields or otherwise. Corresponding to the discussion on the MS-PhD preference in the previous chapter, it was considered important to find out how many within the sample have attempted the GRE and how many out of these are actually serious about it. It was found out that within the sample there were only about 56% who had written the GRE and only a quarter of these were actually keen on going abroad to pursue an MS-PhD. Within those who had acquired placement offers in R&D/Core-Engineering, 60% had written the GRE, but again only about 32% of these were keen on going abroad.

  It is well known that a number of engineering graduates, whether from IIT or otherwise, are keen on pursuing a management degree after an engineering degree for the attractive placement offers that come by after this sequence of education. Corresponding to the 'second wave' discussed in the previous chapter, attempting the CAT and consequently aiming at the Indian Institutes of Management (IIMs) has become a favourite trend among IITians, reflected in the fact that over 66% of respondents have attempted the test. But only about 20% of those who have written the CAT within the sample were keen on actually pursuing management education. Similarly, among those offered placement in R&D/Core-Engineering, though 60% had attempted the CAT, only around 16% were actually serious about management education. Yet, one cannot conclude using these figures alone whether the 'second wave' is coming to a close. The CAT and GRE therefore seem to be tests that respondents within the sample, probably even IITians in general, attempt as a part of routine rather than being actually keen on them.

Perceptions on R&D/Core-Engineering

After understanding the respondents' background, the course experience, the internship and the placement preference, we have now come to the last step in understanding the issue at hand. This section describes the various perceptions that students at IIT Madras have in general about taking up R&D/Core-Engineering as a profession. Each respondent was asked to give one's own opinion as well as to what their peers in general believe about R&D/Core-Engineering.

- *Remuneration, Employment Opportunity and Conditions of Work:* the wages that are offered for R&D jobs and Core-Engineering work are low comparative to the more attractive wages that are offered in management- or finance-related professions. This was assumed, even before the empirical part of the study began, to be a prime cause for students preferring non-S&T work rather than R&D/Core-Engineering. This could easily be ranked as the number one push factor that repels prospective S&T trained students from S&T professions, and was quoted by almost all respondents to be so.

  It was stated by a large number of respondents that there they perceive, in some branches of engineering and technology, no opportunities for employment whereas they see a great amount of scope for non-S&T professions in India. The respondents said that even if there is opportunity, in the case of especially government labs there exist severe impediments like bureaucracy and red-tape and in most cases, sub-standard infrastructure. Some respondents complained that in their particular branch of engineering, there was no cutting edge research undertaken in India, with more of over-designing obsolete technology than undertaking radical innovation using the potential of the existing highly skilled manpower. This, according to the respondents, killed the initiative for creativity, and was a major factor pushing students away from R&D. Whether these opinions are made based on complete information or based on assumptions or incomplete information about the industry will be examined shortly.

- *The Temporal Element:* the time-factor while considering a career in Core-Engineering and especially R&D is very significant since it plays a leading role before and even after gaining employment. It was mentioned by the respondents that the initial post offered to them during placement within an R&D organisation is much lower[15] than the initial post offered to them during placement within a non-R&D/Core-Engineering firm after BTech or Dual Degree. An initial high post in an R&D firm would require at least a PhD, which only means a number of years of further study, considered an expensive investment by many. Putting it briefly, there is a long time period involved before gaining a high first post in an R&D organisation that is relatively equal to the high initial post in say, an IT/ITES or a consultancy firm.

  But what is a greater disincentive is not so much the time period *before* gaining employment but the time period *after*. In other words, many respondents were of the opinion that to achieve 'success' and recognition in the field of S&T research takes much longer time than the period required to be recognised for an innovation or a contribution in non-S&T work. Also, the point mentioned earlier that the initial post in an R&D firm after BTech is lower than the initial post in a non-R&D firm accentuates the time required to climb the hierarchy in the organisation post-employment. This double 'waiting period', before and after beginning one's first job, becomes an even greater disincentive when looked at in comparison to one's peers in non-S&T professions, who have achieved recognition and 'success' in a much shorter period of time. 'Quick results' in shorter time periods are one of the most significant features of non-S&T professions, which easily attract highly qualified S&T graduates.

- *Interest in R&D through the Course:* while most respondents were quite satisfied with the teaching and the motivation from faculty to consider R&D/Core-Engineering, it was mentioned many a time that the course itself is a de-motivating factor, and probably the first among all de-motivations. Many respondents were of the opinion that the way the coursework was taught dampened interest in the subject matter, ultimately influencing the choice of placement offer. To quote a respondent: 'we do not want to do text-bookish matter for the rest of our lives'.

[15] Respondents used the terms 'lower' and 'higher' mainly in the context of remuneration offered at the initial post

Similar statements by many respondents give the impression that the course environment is rather significant in framing a mindset as to how a R&D/Core-Engineering profession works. Through the coursework a perception is built that engineering & technology at the workplace is similar to engineering & technology in the classroom; a perception realised to be erroneous when the students are exposed to the internship or any other exposure to industry, ultimately discouraging the students heavily.

Some respondents argued that such opinions given by their fellow respondents are founded on incomplete or even false information about industry environment in R&D. It was suggested by these respondents that one of the ways in which such perceptions arising out of course environment can be avoided is to make the course more industry-relevant and to have much more exposure to industry conditions during the course. The students in some branches of engineering are exposed as a part of the course to the industry in the form of visits to firms, but following these visits the students seem to see the vast difference between the classroom and the workplace. This can serve as an advantage in that they can observe the functioning of an R&D firm first hand; but it can also serve as a detriment in that the students believe that a vast difference between the course content and industry environment might render their classroom training unsuitable and incompetent for R&D work.

- *Pre-Placement Talk:* here is a factor closely linked to the point made earlier on incomplete information about industry. Almost every firm that wishes to conduct placement tests and interviews gives a short talk or presentation on the work conditions, work environment, potential for creativity as well as scope of further growth in that particular firm or industry. The prospective students depend on this as their source of information on the industry or the firm and consequently mould their preferences. The fallout of this is that those firms giving more extensive and well-enunciated information are able to convince students about the growth potential more easily; while those firms delivering ineffective pre-placement presentations give the impression that there is no potential for growth and development in that particular industry – with the result that students get incomplete information on the industry environment. The respondents stated that most non-S&T firms' placement talks fell in the former category while most R&D firms' placement talks fell in the latter category. This results in information imbalance between industry conditions in S&T and information on non-S&T industry conditions, which has its consequence in shaping placement preferences. In fact, around 40% of the respondents admitted to have thought that R&D related work after an IIT experience would seriously undermine their potential. To quote a statement made by a number of respondents: 'I can do much more than just that (i.e., R&D) with my IIT experience'.

Many respondents who were aware of such an information imbalance due to the pre-placement talk, suggested for better pre-placement talks in especially R&D firms to convince the students that there *is* potential for growth and development of skills in R&D work and that it is not as mundane as most assume it to be. Reducing this information gap would not be very expensive since bettering the quality of pre-placement presentations may not be out of reach in terms of cost for the R&D firm. Information imbalance, therefore, is as significant a factor in pushing students away from R&D as remuneration or course-based de-motivation.

- *Reputation of Firms, Prestige and Role Models:* it was found out that the reputation of the firm matters as much as other aspects like remuneration, etc. Students seem to prefer highly reputed firms even if they offer low wages, than those that pay high wages but do not have an influential brand name. The reputation of the firm (or even the industry as a whole) plays a leading role in shaping preferences – the majority of the management or finance related companies coming to the P&TO having a much more influential brand name than the majority of the R&D companies coming there to recruit students. A prestige issue would naturally arise as a consequence of this (50% of respondents having mentioned about R&D jobs being perceived as 'less prestigious'). All this is closely linked to a factor that may seem beyond the realm of mainstream economics – the presence of role models. Though it is not a very highly significant factor, it is connected to the point on the firms' reputation and does play a role in shaping preferences. A few respondents made the comment that the kind of role-models that the well educated in society look up to today are more in the line of entrepreneurial or managerial success stories than those in concerning engineering science and technological innovation. This is a factor not to be excluded in this study, since it is closely linked to other factors like the reputation of firm.

A Few Points to Consider

- It was mentioned specifically that most of the questions were open-ended, this being an exploratory study. But all through the detailed discussion prior, many aggregations regarding respondents' preferences and opinions have been given in percentage terms which might give the impression that the questions had discreet closed-ended choices (since closed-ended choices allow for easier aggregation in qualitative interviews). As the interviews went on many answers were found to be common and it was possible at the end of the interviewing to actually club common answers and see what percentage of the sample gave a particular common answer. To give an example: in the section on the internship experience, the respondents were asked merely to state what the work and the work environment were like, and not specifically whether engineering or other skills were used in the internship. Most respondents answered this question mainly by relating the type of skills they used (of which there are only a finite small number) hence allowing for aggregating the percentage of the sample that experienced engineering skills, the percentage that developed other skills, and so on. Most of the questionnaire was answered likewise, allowing for easy aggregation of qualitative information. Only in the last part of the questionnaire on 'Perceptions on R&D/Core-Engineering' was it not possible to aggregate preferences, since the responses to this were too heterogeneous, required explanation, and every respondent had given a large number of opinions to each question, which did not allow for aggregation.

- It was considered more appropriate and meaningful to conduct the interviews *after* the students had been offered placement. The placement process at IIT Madras is concentrated in the months of December and January. If the students were asked *before* being offered placement to respond to questions especially in the third part of the questionnaire on 'Placement', one would only be able to record what a respondent *wishes* to pursue, which would seem pointless. It would be more meaningful to record what a respondent *has* opted for, and why. Since respondents were to be interviewed for the preference they have *already* made out of various placement options, rather than for preferences they would *like* to make in the future for placement, the month of January, after a good part of the placement process is over, was decided as an appropriate time for interviewing the sample.

- It is necessary, after discussion of the student-level survey, to reiterate the argument in an earlier section of this chapter on stratification of the population. Though the department-level survey resulted in stratifying the population which in turn assisted in drawing a sample for the student-level survey, it was realised only after this latter survey was completed that there is a clear contrast in most cases between what the departments said the students preferred in the past and what the respondents in the sample actually preferred. Referring to Table 2, it was seen in the department-level survey that three branches came under Category II (where the research problem *did not* exist critically) and the other six came under Category I (where the research problem *did* exist critically). Yet, the student-level survey showed that in five out of nine branches the respondents did not follow the department-level survey categorisation. Table 3 describes this more easily. However, this should not disturb construction of the interaction mechanism, since the study is not at the department-level.

Table 3: *Contrast between Categorisation in Department-Level Survey and Student-Level Survey*

Branch	Total Interviewed	Number *Opting* for Core/R&D	Number *not Opting* for Core/R&D	Category in Dept. Level Survey	Category in Student Survey
Electrical Engineering	9	5	4	I	II
Mechanical Engineering	8	6	2	I	II
Chemical Engineering	4	2	2	I	II
Biotechnology	5	0	5	I	I
Metallurgy and Materials Engineering	4	1	3	I	I
Naval Architecture & Ocean Engineering	2	0	2	I	I
Civil Engineering	10	4	6	II	I
Computer Science & Engineering	5	5	0	II	II
Aerospace Engineering	3	1	2	II	I
Total	**50**	**24**	**26**		

An Interaction Mechanism Shaping the Placement Preference

The Possibility of Econometric Analysis

The student-level survey is an exploration of influential factors, which on interaction shape the placement preference of a student. It would be worthwhile to actually list out the important factors (such as internship, course motivation, pre-placement talk, remuneration, etc.) and to find out how significant and to what magnitude each of these significantly influences placement preference. The factors listed below are probably the most influential among the many others that were brought out through the student-level survey. To find out which of these factors are truly significant in shaping placement preference and in turn which of these significant ones are the most influential, regression analysis can be considered – the dependent variable being Placement Preference and independent variables being those listed below. Within parentheses are the terms that could be used for each variable if a regression analysis is indeed feasible.

- Remuneration and other monetary incentives (REM)
- Course environment and motivation (CEM)
- The desire to pursue higher education instead of accepting a placement offer (HIGHEDU)
- Ease of climbing the hierarchies in each line of work (CLIMB)
- Gestation period required before and after employment (GESTBEF, and GESTAFT)
- The internship experience
    - usage of engineering skills (INTERNUSE)
    - motivation (INTERNMOTIV)
- Correctness of information on employment opportunities (INFO)
- Pre-placement talk (PRETALK),
- The issue of prestige in society (PREST)
- Reputation of the firm in industry (REPUTE)

However, before attempting to model such a regression equation, it is important to understand the various obstacles that might surface while attempting such an analysis

Only after such an understanding is made can one decide even on the feasibility of this regression analysis.

- *Quantifying Variables*: this is the first consideration that needs to be made. Looking at the various factors listed above, only two (REM and GESTBEF) can be made readily available in quantitative terms. In some cases such as INFO, quantification would be an almost impossible task. Some others such as INTERUSE or PREST or even the dependent variable 'Placement Preference' (PLACEPREF) could be represented using dummy variables; and there are yet others like CEM that would require proxy variables. It might require an entire study to evolve proxies for variables like CEM, INFO or PRETALK. The difficulty in exploring feasible proxies for these variables must be noted, since an inappropriate proxy variable would result in incorrect analysis and one would end up drawing biased conclusions. Hence, one can say at this juncture that the evolution of proxy variables for many of the above factors is rather tricky and probably even out of bounds in the case of some variables. Quantifying such qualitative variables is thus the first obstacle to be faced before attempting to construct an econometric model or conducting regression analysis.

- *Correlation between some Independent Variables:* a number of independent variables highly correlate with one another. For example, INTERNUSE and INTERNMOTIV would correlate with INFO, since it is partly based on their internship experience that students acquire information on the work environment and so on. Again, INFO, PRETALK and REPUTE go hand in hand. In some professions, though not in all, GESTAFT and CLIMB is one and the same thing. A remedial suggestion to solve for such correlations is to drop related variables. But considering the fact that each of these related variables has its own independent influence on PLACEPREF, dropping important variables would result in committing specification bias. This is probably more critical an obstacle than quantifying and representation of variables.

- *Missing Variables and Model Inadequacy:* since the student-level survey has been rather humble in the sense that the sample size was small and the study as a whole was restricted only to one institution, it might be so that this study has not discovered a number of factors that may be highly influential on PLACEPREF. Many more influential factors might have been discovered if the sample size were larger, or even if the same sample size would have been tested in various other institutions of the same calibre. Omission of important variables is rather critical in that it could result in model inadequacy. This is another consideration to be made before attempting any regression analysis.

Hence, there are a few important considerations one cannot avoid before quantitatively analysing which the most influential factors are inducing an S&T trained student to take up a placement offer – a set of factors that ultimately have a say in the Core-HRST stock in a country. A regression analysis would therefore first require solving these obstacles; a task not impossible but which may be out of bounds for this study. This study would instead try and understand the interaction mechanism itself, than try to estimate the most influential factors.

Diagrammatically Representing an Interaction Mechanism

Since an econometric analysis is out of bounds for this study considering the various problems that one has to first overcome, this study restricts itself to representing the interaction mechanism – showing the various factors in deciding a placement preference, and showing the interactions between these that lead to the placement preference at the end. This interaction mechanism is the culmination of all important findings elicited through the student-level survey. It helps to understand the intricacies that work independently and on interaction with each other to shape placement preferences. Figure 1 is a diagrammatic representation of this interaction mechanism. At the centre is Placement Preference, which is influenced by the various important factors surrounding it. Each of these factors has been discussed in the section on the findings of the student-level survey.

There are first those factors that independently influence placement preference, for example the possibility of higher education (whether in India or abroad), the work environment and remuneration offered during the placement process, and the environment the student faces during coursework. But what is of interest are not only these independent factors themselves – each of which have an individual bearing on the placement preference – but the interplay between these factors which on summation would have a large influence on placement preference. A few of these interactions are explained as follows.

- The internship experience, as seen in the discussion earlier, is rather important in solidifying impressions about the kind of work environment one would face if one took up R&D or Core-Engineering work. That is, though the internship experience may have had its own direct influence in making a placement preference, it also works its way through other factors that otherwise have independent effects also. Through the internship the student comes to perceive R&D work as something with limited scope for growth and one where innovating and achieving recognition for the innovation takes a great deal of time. Hence the dotted arrow in Figure 1 between the Internship Experience circle and the Quick Results et al circle. So it can be seen that not only do the internship experience and the knowledge of 'quick results' influence placement preference independently, but also the interplay between them.

- Apart from other information sources, it is also through the internship experience that students realise the long waiting period especially after employment to achieve laurels in R&D work. They also seem to realise that an undergraduate degree without higher studies will result in the student doing work similar to the internship – one which taps very little of the student's potential and with very little scope for 'growth'. Hence, the internship experience *indirectly* communicates to the student that an R&D job would require long waiting periods before and after employment. Yet, the temporal element also has its independent effect. Hence, we see the internship experience and time period factor by themselves influencing the placement preference, as well as these two factors reinforcing each other.

- Though the internship has to some extent its influence on determining the kind of information or impression the student has on R&D work, it is the pre-placement presentation, as well as the reputation of the firm in the market and industry that has greater influence in determining the information the students have on R&D work. Not only does the pre-placement talk have its indirect influence on the information about R&D work an industry conditions in general, but also has its direct say in the placement preference.

- Knowledge about the time period before and especially after beginning employment has not only its own independent influence on the placement preference, but also is highly influential in giving information about whether or not 'quick results' are possible and the ease of climbing the hierarchies in that particular line of work, which by itself has a say in deciding the placement preference.

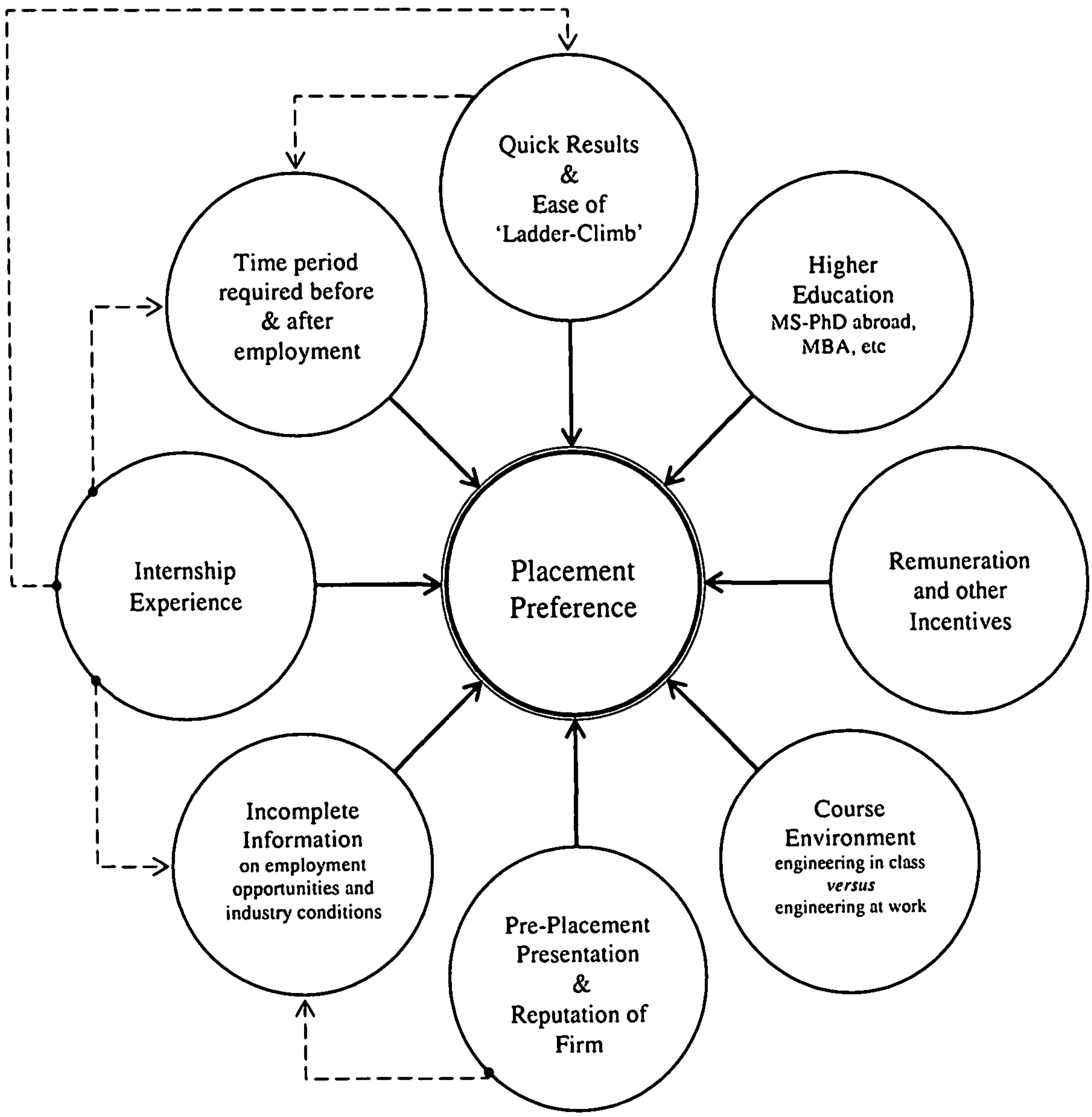
It can slowly be seen that there are actually a few broad categories of factors that can subsume many of the other factors. For example, one could club the 'time period' factor and the 'quick results et al' factor into one category pertaining to the temporal element in the decision-making process, the 'pre-placement et al' factor and the 'incomplete information' into another category pertaining to the quality of information, and so on. Figure 2 was hence evolved by modifying Figure 1 and is a more consolidated version of the latter, showing the broad categories under which the various factors and their sub-factors can be put together.

Each of these broad categories is a function of various sub-factors. While the larger double-lined circles in Figure 2 denote the broad categories or 'main factors' or 'independent variables', the smaller dotted-line circles connected to the main factors show the respective sub-factors, which the main factors are a function of. For example, the 'temporal element' category can be seen as a function of time period before and after employment, the ease of climbing hierarchies, and the possibility of 'quick results'. The 'information' category is a function of the quality of the pre-placement presentation, the reputation of the firm, and so on. Figure 2 might even make quantitative analysis of this interaction incrementally easier, in that there are lesser correlations among independent variables[16], and lesser independent variables themselves.

Figures 1 and 2 have been displayed in the following pages.

[16] But of course, there would still be a few correlations between these independent variables, as seen in the dotted arrow, in Figure 2, between Internship and the Temporal Element, and Internship and Information.

Figure 1: *Preference Formation as the Effect of Interactions between Various Push and Pull Factors*



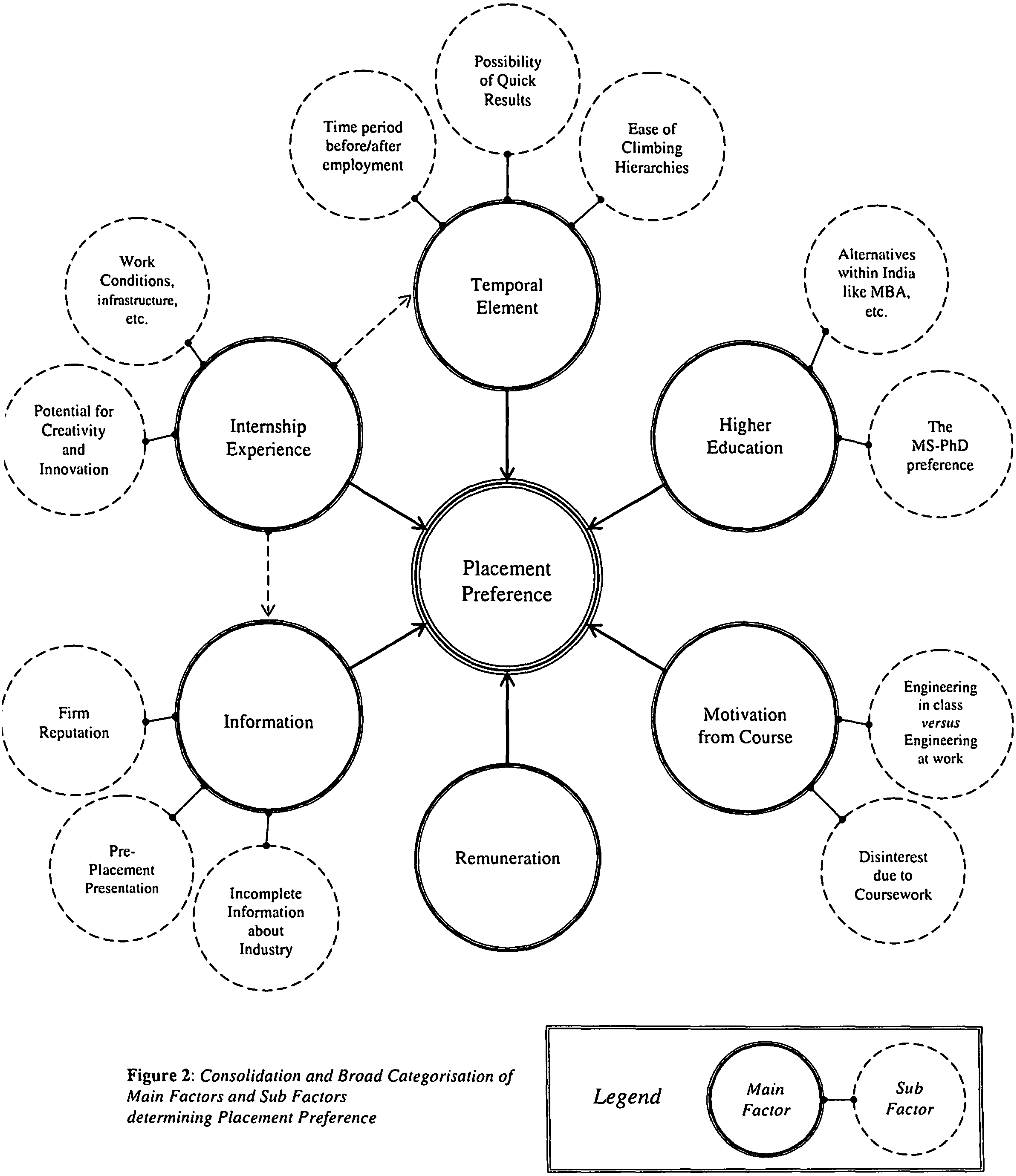


Figure 2: *Consolidation and Broad Categorisation of Main Factors and Sub Factors determining Placement Preference*

Summing Up

This interaction mechanism is but a step in understanding the various processes that occur within an innovation system; processes that decide whether S&T trained manpower moves between the actors within the system of innovation, as it theoretically should, or whether it is pushed or pulled out of the system. There exists in India a situation of low Core-HRST stock despite no deficiency of high quality S&T manpower. To analyse this paradox of sufficient S&T manpower supply vis-à-vis low Core-HRST, a case study of one prominent technical educational institution was taken up. Preceded by a department-level survey, a survey of students was conducted to find out the various push- and pull-factors by which many students increasingly are not preferring to stay in R&D or Core-Engineering jobs – a preference pattern that has heavily influenced the Core-HRST stock in India. Though in this particular sample around fifty percent of the respondents seem to have opted for R&D/Core-Engineering placements, the general opinion seems to suggest repulsion against this line of work. The reasons for aversion towards Core-Engineering or R&D work include a number of factors that influence, not just individually but also on interaction with each other, the preference for placements.

To get first hand knowledge of these push- and pull-factors from the students themselves, a questionnaire for qualitative interview was developed by which information on the various facets of the IIT experience and placement preference was elicited. After drawing a random sample from the stratified population of students, the interviews were conducted over a short period or time, and push- and pull-factors documented. Interesting in themselves, these factors were but building blocks to construct the interaction mechanism by which students make preferences for placements among various choices before them. These factors, with the backdrop of the respondents' backgrounds and experiences at IIT, were at first discussed in detail in this chapter and then brought together to construct a interaction mechanism that shapes preferences. This being an exploratory study rather than one attempting to establish econometrically a cause-effect relationship, it was considered appropriate at this preliminary stage to display this interaction mechanism and its various intricacies.

This study is a first step in the direction of further enquiry in similarly prominent institutes and surveying parallel samples in these institutes. With just one institute as a case study and a sample of only fifty undergraduate students, it may not be fitting to conduct a quantitative analysis and to draw from it sufficient conclusions as to which of the many main factors is most significant in inducing S&T trained manpower moving out of the innovation system.

The interaction mechanism in this study is not a last word on the matter, but is only a step in understanding how even prominent technical educational institutions can, in an innovation system, deliver their roles insufficiently. Many of the push- and pull-factors are indeed out of the reach of University as an innovation system actor to rectify, yet at the same time many are well within its scope. What is important to understand is that, seen through a Systems of Innovation approach, Core-HRST in India is low mainly due to a discordance between technical education institutions and the other actors in the system of innovation; this discordance resulting in a phenomenon where although there is no deficiency of highly-skilled S&T-trained manpower at even the highest rung of the technical education system, even those best qualified and well capable of taking up scientific R&D and Core-Engineering work are increasingly not opting to do so. Through this case study, we have seen the reasons for such a phenomenon happening in India, and have understood – at a preliminary stage – that there are a number or interplaying factors, major and minor, that shape the preference of S&T trained graduates as far as placement goes.

To briefly trace a path – many factors within and outside the technical education institution push students away from considering R&D and Core-Engineering as a line of work for the long term, which are manifested in the preference for non-R&D and non-Core-Engineering placement offers, a preference that leads to discordance in the system of innovation and ultimately a low Core-HRST stock in India.

V

Conclusion

The Systems of Innovation framework understands the process of innovation as a 'systemic' process, i.e., where the creation and diffusion of new technologies and processes is undertaken through a network of interconnected institutions. The central elements in an innovation system are institutions, which includes educational institutions – especially those undertaking research and teaching in science and technology – that are created to provide manpower to the other actors in the innovation system. India has a large network of technical education institutions, with thousands of S&T qualified graduates being produced year after year. It should ideally follow that there is no scarcity of S&T-manpower supply and the manpower requirements of India's innovation system are sufficiently met. Though the former can be agreed with to some extent, the latter is highly contestable, evident from the low figures of Core-HRST stock and disparagingly low ratio of just 87.5 R&D manpower to 10,000 labour force. This paradox – of the presence of a system of high quality technical education institutions and an adequate supply of well trained S&T graduates existing simultaneously with a low R&D manpower and low Core-HRST stock – plagues the future of India's innovative capability and its quest for becoming a knowledge economy. This dilemma can be understood more effectively if positioned within a Systems of Innovation framework.

Clearly, there is discordance among institutions in India's innovation system, i.e., between technical education institutions and the other actors within the system. Given the fact that there has been very little research in this area in the Indian context, this study attempted to make an exploration of this discordance. The Indian innovation system has come a long way through the decades in building up an outstanding set of institutes like the IITs. Yet, especially in recent years, graduates have increasingly been choosing placement offers or higher studies in disciplines that have very little to do with the S&T training they have received at the undergraduate level and are increasingly moving away from S&T related work. Over time and at an aggregate scale, this translates into the fact that India is losing its best scientific manpower – a fact rather worrisome for India's innovation system and future scientific and technological capabilities.

What this study set out to do

This dissertation set out broadly to analyse the contribution of India's technical education system in its role as an actor in the Indian innovation system, with specific focus on the problem of S&T trained manpower moving to non-S&T professions in the long term. The study first attempted to understand the technical education scenario in India, looking at trends in growth and development of institutes as well as the status of manpower in S&T, across regions and across disciplines. With this as a backdrop, the study went on to show how the situation is rather disappointing as far as India's standing in Core-HRST stock goes, despite existence of a vast and growing network of institutions and despite a voluminous supply of engineering qualified manpower. The future of India's innovative capability is bleak, owing to the seeming shortage of R&D manpower and a low Core-HRST stock.

One of the various reasons for this, as mentioned earlier, is phenomenon of even the best quality manpower preferring to move out of the innovation system by choosing professions or higher studies that are unrelated to engineering and technology. It has been well accepted that many of the best trained graduates opt for professions that pay better, since non-R&D or non-Core-Engineering professions are far more rewarding and 'attractive' in terms of remuneration and in many other ways. But it was suspected that there is much more than just the issue of remuneration that pushes graduates or potential scientific manpower out of the innovation system. It was doubted whether remuneration could be the only, or even the most important, reason for this phenomenon; and there must exist a variety of economic, non-economic and institutional factors at play.

To unearth these factors, one institute – the IIT Madras – was chosen for case study, for its institutional prominence in the Indian innovation system and for its laudable contribution to Indian scientific and technological progress. Using the primary survey method, this study first understood the problem from the point of view of the faculty across engineering and technology departments. Based on the findings of this, a survey questionnaire was constructed and the survey undertaken among a sample of fifty BTech and Dual Degree students drawn from the population of undergraduate students, who have been offered placement.

What this study found

It was found that there were, as suspected, a large number of factors simultaneously at play, within and outside the institution.

The department-level survey discovered some broad trends among students through the years. It was acknowledged by all departments that the issue at hand required immediate attention, lest it have long term repercussions for India's innovative capability. The age-old phenomenon of IITians moving out of the country on a permanent basis was reported to have reduced considerably (given the recently elevated standards of living in some pockets of the country), though it has not ceased altogether. So while the preference to study abroad continues, the preference to permanently settle down outside India after higher study has waned.

It was found out that there was, until the beginning of the current decade, a wave of preference for ITES related jobs, as a result of the phenomenal growth of the Indian ITES sector in the mid and late 1990s. By the early part of the present decade, the preference for ITES related work diminished. As this wave was diminishing, another wave emerged – a preference for management-, consultancy- or finance-related work. This wave, as indicated in the department-level survey, has also begun to slowly diminish but has not reached its trough yet. The next wave predicted is a preference for R&D and Core-Engineering related professions; a wave that is said to have appeared on the horizon. This may improve the condition of India's Core-HRST stock and might bring a lot of hope for India's innovation system, yet it was indicated that the coming of this wave would not be easy, given the intrinsic nature of the profession and given the number of factors at play in the minds of graduates. These factors were unearthed in the student-level survey.

The student-level survey, based on the findings of the department-level survey, uncovered a whole host of economic, non-economic and institutional factors at play. These factors cannot be studied in isolation and have to be understood in terms of the combined effect they have. That is, one has to understand the interaction mechanism that is at play between the various factors unearthed in the student-level survey.

Factors range from the more familiar economic factors like remuneration and industry conditions in R&D; to institutional factors like coursework related de-motivation and the existence of intimidating hierarchies and bureaucracy in especially government funded R&D organisations; to other factors like the reputation of firm, quality of pre-placement presentation, potential for creativity in Indian R&D firms and time period required for recognition of achievement in R&D related professions versus other professions. It was noted through the findings of the student-level survey that the repulsion towards R&D and Core-Engineering as a profession begins right from the classroom through the coursework. Students get the impression that engineering in the classroom does not prepare them for engineering in the workplace. Alternatives are readily available to them in the form of non-S&T placement offers as well as higher education in non-S&T fields. The internship is the arena where graduates are exposed first hand to industry conditions. Students expose themselves through the internships to the stifling work conditions and low quality infrastructure in especially government-run R&D organisations in India. Besides, the long time period required before and after gaining employment becomes a major disincentive. Many students mentioned that such an environment depresses one's potential for technological creativity and innovation. The impressions students gain about industry conditions in R&D or Core-Engineering are based also on what is portrayed during the pre-placement presentations offered to them – an area where especially government-run R&D firms lose heavily. The reputation of the firm also seems to play a major role.

As mentioned, these factors are not to be analysed in isolation, but are to be treated as highly interconnected; the sum of interaction between them creating disincentive to take up R&D and Core-Engineering related work.

The interaction mechanism was discovered to be nothing but the incentive structure at ground level, which gives students the incentive to join, or in most cases leave, the innovation system. There may be many other such factors and many other such incentive structures operating within the innovation system that have led India's Core-HRST to its present state.

What remains to be done

There has been no prominent study so far on India's Core-HRST dilemma, except for the seminal India Science Report. Also, across literature on the Systems of Innovation framework, a need for embedding education systems within innovation systems has been highlighted. This dissertation takes an incremental step in both directions. That is, it explores at ground-level, taking the special case of one institution, one of the many reasons for Core-HRST being low; and at the same time addresses the issue at hand by positioning the institute under study as a part of India's innovation system and interpreting the research problem as a discordance within this system. This dissertation is only an incremental step in understanding the full picture of India's Core-HRST stock. Much remains to be done.

This study has uncovered some of the factors that lead S&T trained manpower to move towards non-S&T professions, and has also pointed out the interactions between them. But there may be many more such factors at play, which can be unearthed only through a study on a broader scale. For instance, it may be worthwhile to carry out the same study in all IITs and other equally prominent institutions to uncover more such factors. Once all the possible factors are listed out, it might be worthwhile to even quantify them, fine-tune the problem of collinearity between them, and using econometric analysis find out which of the factors are more significant or influential than others, and if possible whether there is at all a 'root cause' for the entire problem.

It would take us a long way in our understanding of the manpower problems within India's innovation system if both the demand as well as the supply side of Core-HRST were analysed on a parallel, to fully understand the interplay between them and to grasp the situation better. For especially policy purposes, this would be fruitful.

This study is therefore an attempt or a step towards the much more substantial amount of research required not only regarding the state of affairs of India's Core-HRST, but also on understanding technical education institutions in India as actors within the Indian innovation system. This case study has endeavoured to illustrate one of the many ground realities in India's S&T manpower, which could have long term repercussions for India's future innovative capabilities. Given the ambition to become a knowledge economy, the need of the hour is to consider the issues raised across this dissertation while formulating policy regarding technical education and innovation, and conduct much more research on the many concealed issues in India's innovation system – like the dilemmas facing India's scientific manpower, and the contribution that the vast network of technical education institutions actually makes towards building our stock of human resource in science and technology.

References

Adiseshiah, Malcolm (1985) Engineers in the Indian Economy, in *International Cooperation in Higher Education in Science and Technology*, Jubilee International Seminar, IIT Bombay, Oxford & IBH Publishing, Bombay

All India Council for Technical Education, AICTE (2006) *Hand Book for Approval Process*, AICTE, New Delhi

Chandra, N., and Krishna, V.V. (2006) Knowledge Production and Transfer at IITs, unedited conference draft of paper presented at Globelics 2006, Trivandrum, India

Christensen, Jesper Lindgaard (1992) The Role of Finance in National Systems of Innovation, in Jan Fagerberg et al (ed.), *The Oxford Handbook of Innovation*, Oxford University Press, UK

Coriat, Benjamin, and Weinstein, Olivier (2002) Organisations, Firms and Institutions in the Generation of Innovation, *Research Policy*, 31(2), 273–90

Dalum, B., Johnson, B., and Lundvall, B-Å (1992) Public Policy in the Learning Society, in Lundvall (ed.) *National Systems of Innovation: Towards a New Theory of Innovation and Interactive Learning*, Pinter, London and New York

Department of Science and Technology, DST (2002) *Research and Development Statistics 2000-01*, Ministry of Science and Technology, Government of India

Edquist, Charles (ed.) (1997) *Systems of Innovation: Technologies, Institutions and Organisations*, Pinter, London

Edquist, Charles (2005) Systems of Innovation: Perspectives and Challenges, in Jan Fagerberg et al (ed.), *The Oxford Handbook of Innovation*, Oxford University Press, UK

Edquist, Charles, and Johnson, Björn (1997) Institutions and Organisations in Systems of Innovation, in Edquist (ed.) *Systems of Innovation: Technologies, Institutions and Organisations*, Pinter, London

Fisher, Sir Ronald A., and Yates, Frank (1963) *Statistical Tables for Biological, Agricultural and Medical Research*, Oliver and Boyd, Edinburgh Tweeddale Court

Forbes, Naushad (2003) Higher Education and Scientific Research for Industry: Reflections on Priorities for India, the Fourth Annual Conference on India's Economic Reforms, Stanford University, 5–7th June 2003

Gregersen, Birgitte (1992) The Public Sector as a Pacer in National Systems of Innovation, in Jan Fagerberg et al (ed.), *The Oxford Handbook of Innovation*, Oxford University Press, UK

Institute of Applied Manpower Research, IAMR (2004) *Manpower Profile India*, Concept Publishing Company, New Delhi

Jan Fagerberg et al (ed.), *The Oxford Handbook of Innovation*, Oxford University Press, UK

Johnson, Björn (1992) Institutional Learning, in Lundvall (ed.) *National Systems of Innovation: Towards a New Theory of Innovation and Interactive Learning*, Pinter, London and New York

Johnson, Björn (1997) Systems of Innovation: Overview and Basic Concepts, in Edquist (ed.) *Systems of Innovation: Technologies, Institutions and Organisations*, Pinter, London

Kim, Linsu (1993) National System of Industrial Innovation: Dynamics of Capability Building in Korea, in Nelson, Richard R (ed.) (1993) *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York

Lundvall, Bengt-Åke (ed.) (1992) *National Systems of Innovation: Towards a New Theory of Innovation and Interactive Learning*, Pinter, London and New York

Mani, Sunil (2002) *Government, Innovation and Technology Policy: An International Comparative Analysis*, Edward Elgar, Cheltenham, UK and Northampton, Mass., United States

Metcalfe, S (1994) Evolutionary Economics and Technology Policy, *The Economic Journal*, vol.104, no.425 (July), pp.931-944

Metcalfe, S (1995) The economic foundations of technology policy: equilibrium and evolutionary perspectives, in Stoneman, P. (ed.), *Handbook of the Economics of Innovations and Technological Change*, Blackwell, Oxford

Ministry of Human Resource Development, HRD (2005) *Annual Report 2004-05*, Ministry of HRD, Government of India

Ministry of HRD (1998) *Higher Education in India: Vision and Action*, Country Paper, UNESCO World Conference on Higher Education in the Twenty-First Century, October 5^{th} – 9^{th}, Paris

Mowery, D.C., and Sampat, B.N. (2005) Universities in National Innovation Systems, in Jan Fagerberg et al (ed.), *The Oxford Handbook of Innovation*, Oxford University Press, UK

National Council of Applied Economic Research, NCAER (2005) *India Science Report: Science Education, Human Resources and Public Attitude towards Science and Technology*, NCAER, Delhi

Nelson, Richard R (ed.) (1993) *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York

Nelson, R.R., and Rosenberg, N. (1993) Technical Innovation and National Systems, in Nelson (ed.) (1993) *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York

Sharif, Naubahar (2006) Emergence and Development of the National Innovation Systems Concept, *Research Policy*, 35, 745-766

Smith, Keith (1997) Economic Infrastructures and Innovation Systems, in Edquist (ed.) *Systems of Innovation: Technologies, Institutions and Organisations*, Pinter, London

UNESCO (2005a) *Towards Knowledge Societies*, United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Report, Paris

UNESCO (2005b) *UNESCO Science Report*, United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Report, Paris

Wengraf, Tom (2001) *Qualitative Research Interviewing: Biographical-Narrative and Semi-Structured Methods*, Sage Publications, London

World Bank (2000) *Scientific and Technical Manpower Development in India*, WB Report No.20416-IN, Education Sector Unit, South Asia Region, World Bank

Zuwaylif, Fadil H. (1970) *General Applied Statistics*, Addison-Wesley Publishing Company, California

Electronic Sources

Central Intelligence Agency (CIA), United States of America
<http://www.cia.gov/cia/publications/factbook/index.html>
(accessed on 27th September 2006)

Department of Science and Technology (DST), Ministry of Science and Technology, Government of India
<www.dst.org>
(accessed on 20th September 2006)

Department of Secondary and Higher Education (DSHE),
Ministry of Human Resource Development, Government of India
<www.education.nic.in>
(accessed on 7th May 2006)

Indian Institute of Technology (IIT), Madras
<www.iitm.ac.in>
(accessed on 24th August 2006)

Indiastat
<www.indiastat.com>
(accessed on 30th July 2006)

Analysing the Contribution of Technical Education to India's Core-HRST: A Case Study of IIT Madras

MPhil Dissertation at Centre for Development Studies (CDS), Trivandrum under
Jawaharlal Nehru University (JNU), New Delhi

Survey Questions for Qualitative Interviews of (placed) BTech and Dual Degree Students at IIT Madras during January 2006

I. General and Background Information

- Name of Student
- Place of Education; Native place
- Parents' Education and Income
- Siblings' Education and Income

II. The IIT experience thus far

1. Which to you has probably been the best part of the entire IIT experience (academic/non-curricular experience/peer interaction)?
2. Specifically which part of your BTech course did you find most interesting?
3. Specialisation
   a. Given a choice would you like to change your specialisation?
   b. If yes, why?
4. Internship
   a. Where did you do your internship?
   b. What were the work and the work environment like?
   c. Did this internship play a role in motivating or discouraging you to take up Core/R&D?
5. Pedagogy
   a. Do your teachers inspire you in the form of 'role models' or so?
   b. What is your opinion on their teaching, i.e., on the methods they use to teach and the interest they cultivate in you?

III. Future Plan

1. Placement:
   a. Where have you been placed?
   b. Has this choice been your own, or has it been shaped by peer/family/seniors' trends and the circumstances on the placement day?
   c. Are you satisfied with what you have got, or are you going to apply for another job soon (especially not in Core/R&D)?
   d. Why do you want this other job?
2. The MS-PhD Abroad Preference:
   a. Are you writing the GRE (despite your placement) and are you serious about it, or are you doing it because it is just another option many others are doing?
   b. Are you intending to come back to India?

3. Management Education/Career: Are you writing the CAT (despite your placement)?
   a. Are you writing the CAT (despite your placement)
   b. Are you serious about it, or are you doing it because it is just another option many others are doing?

IV. Perceptions on Core/R&D as an Option

1. Have you ever considered (through your course or after acquiring your placement) a career in Core/R&D in India, especially in your field of study?

2. Push Away from Core/R&D: What is it about Core/R&D in India that pushes you (or generally, most people) away from it?

3. Do you think you wouldn't reap all the returns of an IIT experience if you took up R&D in India?
   a. Would it undermine your potential, or underutilise your earned capabilities if you?
   b. Is there a prestige issue in India about taking up jobs in areas like consultancy, banking, core...how much does that influence your choices?

4. What changes/improvements would make Core/R&D more attractive to you (or in general, most other people)?