Innovations in an Emerging Software Cluster

Innovations in an Emerging Software Cluster

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

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MPhil Programe in Applied Economics
2009-2011

CENTRE FOR DEVELOPMENT STUDIES
May 2011

I hereby affirm that the work for this Thesis, Innovations in an emerging software cluster, being submitted as part of the requirements for award of the degree of Master of Philosophy 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 study and has not been submitted to any other university for the award of any Degree.

10 May 2011

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Certified that this study is the bona fide work of Mr Arun M, carried out under our supervision at the Centre for Development Studies.

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ABSTRACT OF THE DISSERTATION

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Despite its phenomenal growth, the Indian software industry is not considered as innovative and its services are believed to be of low value. Its growth is solely attributed to the low wage rate in the country. Its sustainability has been questioned in the face of stiff competition from other Asian and East European countries. India's growth in software sector is expected to be stunted if a quantitative growth through expansion in labour supply or increased labour productivity by moving up the value chain is not achieved.

In literature on innovation in Indian software industry, macro indicators like share of software products in India's total software exports are used to assess innovation. Service nature of the industry is looked down upon. Contradictory answers have been given by researchers to questions on the innovativeness of the industry.

This study is undertaken to answer the above questions with micro level(firm level) information. It is done in an emerging software cluster in India — Trivandrum. In the context of software firms in Trivandrum, the study raises the question as to whether they are innovative and if yes, how they innovate. Case study approach is adopted as the inquiry is exploratory in nature and the phenomenon in question is multi dimensional and qualitative. Systems of innovation approach has been used as the analytical framework.

The study found that firms in the cluster are innovative and that they bring out different types of innovation. Nature of innovation depends on the nature of software developed and its knowledge domain. Nature of industry is also shaped by the characteristics of knowledge domain. It was found that knowledge domain and its characteristics are changing, thereby changing the nature of firms and their innovations. The study also provides a systemic view of innovation in the software industry.

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Chapter 1

Introduction

The phenomenal growth of Indian software industry has gained national and international attention. The industry today accounts for a significant portion of India's exports. It has put India in a prominent place among countries that do high-tech exports. The success of Indian software industry and its contribution to the country's economy shows how the emergence of new technology and an industry based on it, may put a developing country on a path of rapid economic growth. Today, India is one of the largest traders of software and related services. It is the fifth largest exporter of Information and Communication Technology(ICT) services in the world and the largest exporter of ICT services in non-OCED countries(UNCTAD, 2009). Going by data on growth in export between 2000 and 2007, India is the most dynamic country in terms of software services export followed by Ireland (UNCTAD, 2009). Total production of Indian software and services industry is estimated by Ministry of Communications and Information Technology, Government of India as 3012 billion rupees in the year 2009-10. It comes to 5.1% of the country's GDP during the same financial year(see section 3.2). Export of software and related services contribute significantly to India's foreign exchange. The gross export revenue is estimated to be 50.1 billion USD which is 26% of India's total export (services and merchandise).

Coming to some of the features of the Indian software industry, the most important one is the two digit growth rate it has been able to maintain for almost two decades(Athreye, 2005). The industry is heavily export oriented with a very small domestic market. This implies that the industry sustained its growth in the face of competition in the international market.

Its nature of operation is similar to that of a services industry where both the producer and the user work together to create a product. This co-production nature of service, creates opportunity for knowledge spillover from the user to the producer. The Indian software industry is regionally concentrated in a few cities like Bangalore, Hyderabad, Pune, etc. Bangalore alone accounts for a significant part of the total software export of the country. Such regional clustering of firms, particularly in high-tech sectors, leads to knowledge spillover and mutual learning. The industry employs a large number of highly skilled knowledge workers like engineers. With international competition providing the impetus for innovation, the service nature as well as the clustering of firms providing the knowledge for innovation and highly skilled labour force providing the capability for innovation, it is expected that the Indian software industry would be highly innovative. Sustained growth rates suggest that it is, indeed, innovative.

Yet a general observation about the Indian software industry is that it is not innovative and it provides only very low value services(D'Costa, 2002; Joseph and Harilal, 2001; Heeks, 1996). Its growth is attributed solely to the low wage rate prevailing in the country. Many authors have raised the question as to whether this growth is sustainable, as competition from other Asian and East European countries can diminish wage rate advantage India has now. To sustain the growth and be internationally competitive, the industry will have to move up the value chain keeping up with the increase in wage rate or it should aim at quantitative growth with increased labour supply which can push down the wage. Without adopting any of these strategies, future growth of the sector can be stunted.

Indicators of Innovation

In research literature, the most important indicator used to argue the lack of innovation in the industry, is the low share of software products[1] in total software and related services exports(Heeks, 1996; Joseph and Harilal, 2001). This weakness is attributed to the export orientation of the industry and the lack of a domestic market for software(D'Costa, 2002; Heeks, 1996). However, there are others who argue that the Indian software industry is moving up the value chain(Arora *et al.*, 2001; Balakrishnan, 2006). Their

[1]Software products are those piece of software which provide generic functionality so that it can be useful to more than one user. Software products are made once and sold many times.

argument is based on anecdotal evidence of software products coming up in India and the enhanced capability of Indian software industry in the form of adoption of new technology and upgradation of software development processes. The emergence of embedded software development is also considered as an indication of Indian firms delivering higher value services. From literature it is not clear why availability of software products and embedded systems software signal greater innovation. Some implicit assumptions are being made about their value in terms of innovativeness of the industry.

In an effort to quantitatively measure innovation in Indian software industry, Joseph and Abraham (2005) came up with an index of technological capability. They classified specialisation of software firms into low, medium and high level based on technological competency required to perform each of the specialization. Based on information on specialisation of each firm and weight assigned to each specialisation, index of technology capability of a firm is computed. They found that Indian software firms are moving up in terms of technological competence. As the authors have noted, the index is limited by the fact that it assigns a competency level for each specialisation of the industry when there is a chance that a firm is providing only low value services in a particular specialisation. The index will be an overestimation of the capabilities of a firm when the area of specialisation is one that requires higher competency but activities of the firm in that specialisation is one which require only low levels of competency. On aggregation, it will overestimate the capability of industry. Athreye (2005) looked at the evolution of dynamic capabilities in Indian software services industry. According to her, increasing wage rate in the software industry in comparison with other industries along with increasing risk of labour attrition have been forcing firms to improve their organisational capabilities.

Moving away from complete denial of innovation, literature on Indian software industry began to recognise its improving capability. Increasing capability in terms of technological skills and improved production processes are all definitely signs of innovation. Researchers seem to have conceived innovation differently and that reflects in their position on innovativeness of Indian software industry. Hence it is important to look at the conception of innovation in software industry[2].

[2]The concept of innovation has been explained in the chapter 2

OECD on Innovation in Software

A recent study by OECD(Organisation for Economic Co-operation and Development), on innovation in software sector(Lippoldt and Stryszowski, 2009) defines software innovation as a process leading to:

- development of a novel aspect, feature or application of an existing software product or process; or
- introduction of a new software product or process or an improvement in the previous generation of the software product or process; and
- entry to the market or use within the production process.

Drawing upon OECD's Oslo Manual, the report says that research and development (R&D) activity is just one element — albeit an important one — in the process of innovation. The report emphasises on the quantitative cross country and inter-firm analysis of R&D in software sector. It adopts a simplistic linear model of innovation starting from R&D, leading to market entry and exit. However, it does describe some of the other features of software sector which show that innovation is much more complex. It says that collaborative and "open" approach to innovation is necessary to bring in external knowledge and capacities for innovation and there by enhance firm's innovation process. This suggests the systemic nature of innovation in the software industry. The three pillars of such an open innovation have been identified as

1. sourcing and integrating external knowledge from customers, suppliers, universities and research organisations, or even competitors,
2. bringing ideas to market (not necessarily finished products); selling, licensing, trading intellectual property as part of strategies to multiply technologies; and
3. working in alliances in order to capitalise on complementarities

One important characteristic feature of software industry that the OECD study identifies, is its pervasive nature. Software production as well as software innovation do not happen within the boundary of a defined 'software industry'. In fact, a substantial part of software production happens in-house, in firms that work in other sectors like media and entertainment

or consumer electronic goods(Genuchten, 2007; Parker and Grimm, 2000). Considering that software finds its application across the industrial sector and leverage on knowledge or innovation that is produced in these other sectors, innovation activity of software cannot be confined to software industry alone. This has been confirmed by the data on R&D expenditure related to software(Lippoldt and Stryszowski, 2009, p. 55).

Evolving business models have been another important source of innovation in software sector. In the 1950s and 60s, software was part of business strategies of hardware firms like IBM to bring value to customers. Software was given free with proprietary hardware(Campbell-Kelly and Garcia-Swartz, 2009). Advances in semiconductor technologies brought down the price of hardware and improved the capabilities of machines dramatically. Increased capability of hardware made software more complex, which in turn made software development an independent specialised activity. Emergence of open hardware architecture led to the creation of independent software firms supplying software directly to users without hardware vendors acting as intermediaries. With the evolution of technology, the business model continued to change. Interaction between business model and technology has been a continuous source of innovation in software sector. Recently, with the emergence of free and open source software[3], a range of new business strategies and licensing software have come up(Lippoldt and Stryszowski, 2009, p. 59).

To conclude, the picture that emerges is that, innovation in software sector is also multidimensional, with a wide range of sources. Therefore, capturing it is also difficult.

Systemic View of Innovation

Measuring innovation is definitely important when one wants to compare across countries or regions or firms to comment about their relative innovativeness. It also helps in monitoring the sector to see if it continues to innovate. From the point of view of public policy formulation, it would be more important to know how innovation happens in the sector. The complex interconnected nature of innovation process and its multidimensionality has led to new approaches in studying innovation. The most important among them is the system of innovation approach. It tries to

[3]For the definition of free and open source software see section 2.1.5

explain innovation in a country or a region or a sector by looking at the actors involved and their interactions for innovation. Difference in innovation is explained through different factors like characteristics of knowledge, institutions that govern interaction, difference in capabilities of actors etc.

Despite growing acceptance of innovation systems approach, not much work has been done to provide a systemic picture of innovation in Indian software industry. Kumar (2001) talks about national system of innovation yet, he only provides a static picture of various actors in an innovation system not the dynamism in the system. Chaminade and Vang (2008) uses regional system of innovation approach to analyse innovation in Bangalore cluster. While there is some effort to develop systemic view of innovation at the national level and regional level, the view at the firm-level is missing. Existing literature does not tell much about what drives firms in Indian software industry to innovate and how they innovate. Understanding this can also help in building an indicator for innovation to monitor progress of the industry in terms of its innovativeness at macro level.

Clustering

Another important feature of the Indian software industry is that it is concentrated in a few cities. In the early 1990s, when the industry was picking up momentum, Bangalore emerged as the most important location for the industry. Bangalore gained from Mumbai, which had been the main centre of Indian software industry in late 70s and 80s. According to data from Software Technological Parks of India, Karnataka, the state in which Bangalore belongs, accounts for 34 percent of total software export from India. As Bangalore commands a lion's share of software exports of Karnataka, this data can be taken as the estimate for total software export from Bangalore. Karnataka is followed by Maharashtra with its two important cities, Pune and Mumbai. Seven cities in India together account for nearly 90 percent of India's total software and related services export. Though every state in India tries to create its own 'Silicon Valley of India', only a few are able to succeed.

From Bangalore in India to Silicon Valley in the United States and Cambridge in the United Kingdom, it has been observed that firms in high-tech industries tend to agglomerate. This agglomeration of firms that come under a specialised industry segment or relate to that segment is

referred as industrial cluster. It has been noticed that firms these clusters exhibit a high level of innovation.

Clustering is expected to bring several advantages to firms within it. Yusuf (2008), points out that co-location of firms leads to crowding of common services such as capital, transportation, etc. required by the firms within the cluster. This in turn leads to substantial gains from localization economies. The second advantage is that the high degree of networking and interconnectedness among firms leads to knowledge spillover. Finally, innovative clusters act as a learning system. They adapt to changing situations. For example, when the principal product of a cluster faces declining demand, the cluster responds by providing a new line of products or services. The Silicon Valley cluster is a very good example of an innovative cluster changing with changing conditions. The cluster which started with semiconductor technology moved to bioinformatics and nano technologies.

In cluster literature, particularly in high-tech sector, it is suggested that geographical concentration arises from localised nature of knowledge flow(Jaffe, 1986; Jaffe *et al.*, 1993; Audretsch and Feldman, 1996, 2004). Proximity of the actors (firms) is supposed to reduce cost of transmission of knowledge. Cost of transmission of knowledge arises out of its property of being tacit and complex. Knowledge flow requires interpersonal contacts and inter-firm mobility of workers. Tacit knowledge can be an important source of innovation. To what extent does the localised nature of knowledge spillover explain clustering of Indian software industry? Looking at how firms access knowledge for their innovation may give us an insight into this.

Research Question

What is evident from discussions so far is that existing literature gives us very little insight as to how firms in Indian software industry innovate. Without evolving a micro level picture of the innovation to complement macro picture, it is very difficult to comprehend innovation as it manifests itself in Indian software industry. The objective of my study is to address this gap in literature. Here, in the context of an emerging software cluster in Trivandrum, I raise the following specific questions

- Are the software firms in the cluster innovative ?
- If yes, how do they innovate ?

Software industry can be considered innovative if the firms within it are innovative. Looking at how firms innovate will also address some of the related issues like role of proximity and the nature of innovation in the industry.

Selection of cluster in Trivandrum for the study is for pragmatic reasons. A micro level study requires that firms participate in the study and share their internal information. It requires some steps to be taken for confidence building with the informants. Social linkages are essential in this process. These factors were available in the context of cluster selected for the study.

Methodology

To answer the research questions, I have adopted the case study method(Yin, 2009). I have selected six software firms from the software cluster in Trivandrum for the study. While the share of software cluster in Trivandrum in the total software production of India is very small, it is still one of the fastest growing software clusters in India. It figured as one of the second tier cities for software industry as early as 90s when Software Technology Parks initiative of Government of India was initiated. The software industry in Trivandrum mirrors the Indian software industry in many ways. In both cases, software service firms dominate. Again, the industry of Trivandrum and India consist of a few very large firms and a lot of small firms. There are a couple of firms specialising in embedded systems and software products[4]. Hence, for the study, the software industry in Trivandrum is considered as microcosm of Indian software industry. Despite all the factors that suggest that Trivandrum mirrors India, there is a limit to this comparability which forms the most important limitation of this study. As a few national firms contribute most of the software production in India, it is essential that the innovation of those firms are considered. At the same time, this study should be able to provide a micro level understanding of innovation and contribute to regional policy formulation. Another gap in the study is that it considers only Indian software firms. With multinational firms getting more involved in software production in India, particularly in R&D activities, it is important that we look at their innovation process too.

The most important challenge was in accessing information. Firms, in

[4]For detailed discussion see Section 4.1

general, are not open about their internal operations. This study required someone at the senior management level to provide necessary information. Reaching out to them was a hurdle. It was largely overcome by approaching these officials through contacts in professional organisations like IEEE (Institute of Electrical and Electronic Engineers). Interpersonal relations that existed through these networks were important to gain information. Persons interviewed for this study included founders of the respective firms in most cases and senior managers in charge of R&D in the other cases. Nearly one hour was provided by all of them for the interview. Information from the interview and additional information sourced from the firms' websites have been used to develop the case studies.

Communicating the idea of innovation as adopted in economics was another challenge. Data collected may be limited from my own ability to communicate the idea of innovation to the officials and the limited time they had to make sense of the fuzzy and broad concept of innovation. Multi-case analysis has been adopted to reduce such limitations.

Chapter Scheme

The next chapter, I provide the analytical framework that has been used for this study along with insights from related literature. Chapter 3 provides an overview of Indian software industry. A historic analysis of Indian software industry has been done to show how it changed over time, responding to changing situations. Important characteristics of Indian software industry as discussed in literature have been summarised in the chapter. A background picture of the software industry in Trivandrum and the case studies are presented in Chapter 4. Towards the end of the chapter, a detailed case study analysis has been done with the specific research objectives outlined in Chapter 1. Chapter 5 proposes a knowledge based typology of software firms. Chapter 6 concludes this study, with some important findings that have implications for the Indian software industry.

Chapter 2

Analytical Framework

In this chapter, I introduce different concepts used in this research. In the first and second section, I provide some of the key concepts. In the third, I introduce, the concepts relating to clustering of firms. In the forth section, I introduce system of innovation and two of its specific variants — regional system of innovation and sectoral system of innovation — which will be used as the analytical framework. In the last section, I outline the steps involved in the analysis.

2.1 Understanding Software

Before we go into a deeper analysis of software industry, we need to have a general understanding of software and how it is produced. A computing system has two components—hardware and software. Hardware is the tangible physical part—the machine which consists of various electronic, electrical and mechanical components. It includes the main part of the computing system where computation[1] is done and the peripheral parts that allow the system to interact with users. Software on the contrary, is the intangible part of a computing system. It is a collection of instructions for the hardware/machine to perform a set of desired operations. Hardware can range from large mainframes used by organisations for bulk data processing to mobile phones used by the common man. Hardware these days do not provide any useful function without a software to control it. Software is therefore similar to knowledge in a human brain which enables a

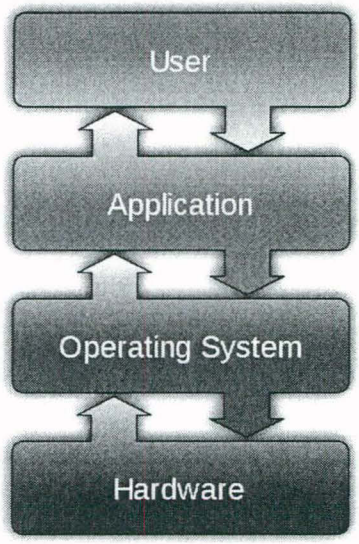
[1]Here I use the word computation in a broad sense. It is not just numeric calculation. See http://en.wikipedia.org/wiki/Computation

human being to process data he/she receives through senses. Software can be considered as a form of codified knowledge, an explicit form of knowledge. It enables machines to do meaningful tasks. These meaningful tasks can vary from complex calculation to drawing a picture.

2.1.1 Layered Structure of Software

A computer system often contains several pieces of software, which function together to provide complex and meaningful functions. Software in a computing system is considered to have a layered structure. A very simple structure is depicted in the figure(Figure 2.1).

Figure 2.1: Layered Structure of Software



Source: Wikipedia

At the lowest level are the operating system and system software. They allow a user to execute other software, control hardware including peripherals connected to the main computer, enable communication between computers and between humans and the machine. Examples of operating systems are Windows, GNU/Linux, Mac OS X. Software like compilers are considered part of system software and belong to the same layer.

Application software functions above this layer. They carry out specific tasks for users. They include word processors, databases and software

development environments (software that makes software development easier). Without application software, a computing system is of no value to users. Application software depends on operating systems to provide various functionalities. Examples include printing a document and communicating over a network to another machine.

Application software can be further categorised based on its primary users. Some application software like word processors, spreadsheets and email clients are of general purpose. Most end-users need them. There are specialised software which are used to develop complex software systems for end-users like database systems and rapid application development suites, etc. Also, there are software for specialised business tasks like movie production, enterprise resource planning and data warehousing.

As can be seen from Figure 2.1, the operating system acts as a generic platform on which various application software can function. Platform software like operating systems are standardised to make application development easier. Platform software suppliers provide instructions for creating application software using their platform software. Platform software provides a lot of functionalities which the makers of application software can take advantage of. Platform software differs in the functionalities it provide to application software.

In more complex computing environments, there can be one more layer of software between operating system and application software. Like operating system, it's main function is to provide additional functionalities to application software that run on it. A very good example of such software is database software, which provides standardised functionality for storing data. These days, a category of software known as middlewares also take the place of this layer. Like operating systems, these software also provide various functionalities to application software. Hence, we can classify operating systems and middleware software as platform software or infrastructure software.

2.1.2 Packaged Vs Custom Software

Software is sometimes categorised as packaged software (software product) or custom software. Packaged software are standardised and generic for users to consume as they are. General purpose software like word proces-

sors and some platform software like database and operating systems are brought to the market as software packages or software products. Custom software on the other hand is tuned to the requirement of a specific user. It is often made as per the demand of the user(made to order).

Of the total software production that happens, custom software accounts for the largest share. As per a study in the US, the share of custom software in total software production comes to 40-50 percent. Of the remaining, 20-40 percent is accounted for by software developed in-house. Packaged software accounts for the rest(Parker and Grimm, 2000).

2.1.3 Software Product Vs Services

Software industry is classified into software products industry and services industry. Software products industry focuses on development of software packages. By developing once and selling many times, it can benefit from economies of scale. Software it develops is licensed to users. Users may use software packages as such or through an application software which uses the package software. Firms in this segment of the industry continuously upgrade their software packages to provide new features which are in demand. They need to create extensive networks for sales and services. Some of the auxiliary activities these firms have to undertake include training on the platform for users and developers, marketing the platform, building a network of solution providers who can benefit from the use of that platform. Some of the notable software product or packaged software companies are Microsoft, Oracle and SAP. In India, Tally has come out as a successful software product company.

Software product can be for a particular business vertical like video editing or more generic like word processor. Some products like enterprise resource planning software, need a lot of customisation before they can be used by end users. Software consulting firms provide this service of customizing software product for specific user needs. They combine custom developed and packaged software to provide "solutions" to users. This is considered to be a very high value activity.

Production of custom software, which accounts for nearly half of the total software production, is undertaken by software services industries. Apart from developing custom software, this segment of industry also un-

dertakes some specific tasks in software production as service activity for clients(See section 2.1.4). It also provide consulting services described above. Its activity requires close interaction with end-users. Modular nature of software enables custom software producing firms to take advantage of economies of scale. Firms will reuse modules of code providing commonly required functionalities.

2.1.4 Software Production Process

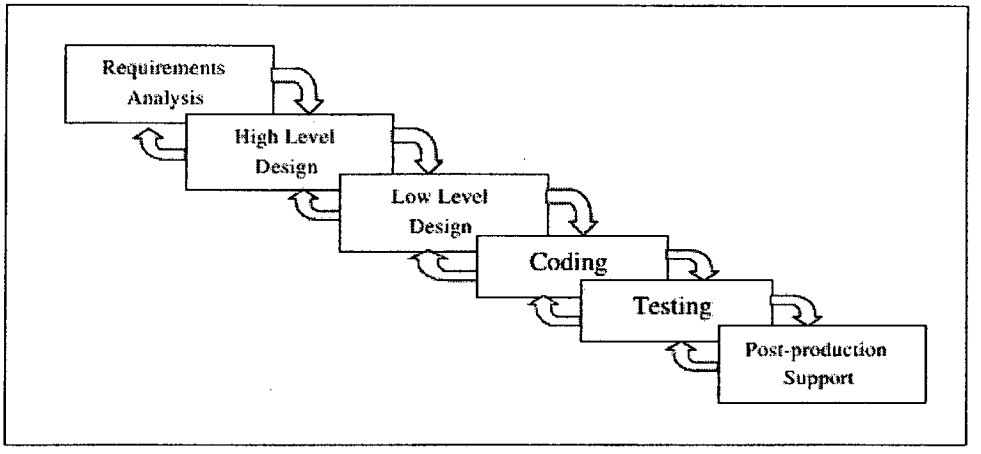
Software development involves several stages, from gathering the needs of the user to final delivery of the software. Software development processes give structure to software development. It is a model to conceive the process of software development as well as an engineering practice to ensure improved productivity and quality. Different models are available and adapted for software development. The simplest and the most popular, is the waterfall model. It is a linear model of software development. This model has been used in most of the economic analysis of software development activities in India(Arora *et al.*, 2001; Chaminade and Vang, 2008)[2].

Figure 2.2 gives a slightly modified form of waterfall model of software development. Unlike strict waterfall model, here the development process is depicted as one that moves back and forth between each consecutive stage. In the first stage user requirement is collected, through close interaction with user. Based on requirement gathered, a high level design of the software system is made. High level design is then broken down further for coding. It is in this stage of coding that software takes birth. Coding is a process, by which software is written in a language legible to humans. The languages in which software are first written are called programming languages. A piece of software written in a programming language is known as source code. Using a specialised software known as compiler, the source code is then converted to object code. Object code is equivalent to source code but it is in a language which machines can understand. Software in the object code form is executed on the hardware and tested to see if it functions as per requirement. If it does not, required changes are made. Fi-

[2]Waterfall model is too simplistic for development any significant piece of software. In practice more complex iterative models are followed. For more information see http://en.wikipedia.org/wiki/Iterative_and_incremental_development

nally the software is deployed. Deployment is followed by support in terms of user training, maintenance etc. Skill requirement and value of work in each stage differs. Low level design and coding are considered to be activities of low value. Many researchers are of the view that Indian software industry is carrying out these low value activities(Arora *et al.*, 2001).

Figure 2.2: Waterfall Model of Software development



Source: Arora et al. (2001)

2.1.5 Free and Open Source Software

Free and Open Source Software(FOSS) is a category of software which is licensed under conditions such that it can be used, copied, modified and distributed by users. It started as model of development and distribution of software, with the launch of GNU project by Richard Stallman. GNU project aimed to develop an operating system similar to Unix but it differs in licensing terms by providing users four freedoms, which include:

- The freedom to run the program, for any purpose
- The freedom to study how the program works, and change it to make it do what you wish. Access to source code is a precondition for this
- The freedom to redistribute copies so you can help your neighbour
- The freedom to distribute copies of your modified versions to others

FOSS is often developed by volunteers from around the world. Some of them are supported by commercial firms in which they work and some by

foundations. A growing number of commercial firms now develop software in FOSS model. While the terms of licensing mentioned above lead to the availability of software 'free' as in gratis to the users, a lot of business models have emerged around FOSS. They adopt strategies like professional services of customization and training, dual licensing where software is made available to commercial users under special licensing terms specific to that user, etc. Firms are experimenting with several new business models around FOSS.

2.2 Innovation, Knowledge and Learning

The word innovation comes from the Latin word, 'innovatus', which means 'to renew or change'. According to Joseph Schumpeter, innovation is what drives economy through a qualitative change at a historical time(Fagerberg, 2005). Change brings the newness that is often associated with innovation. Schumpeter identifies five different types of innovation — (1) introduction of new products (2) new methods of production (3) identification of new sources of supply (4) exploitation of new market (5) new ways to organize business. Despite the recognition of five types of innovation, in economics literature there is an overemphasis on the first two. For example, in OECD's Oslo Manual(OECD, 2005), innovation refers to "implemented technologically-new products and processes and significant technological improvements in products and processes". This emphasis on technology can lead to mistaking invention for innovation. Invention is about the first occurrence of a new product or process. It provides an opportunity to bring about change. Innovation happens when the change (or the newness) has been brought into people's practice. Considering that it is not possible to measure a qualitative phenomenon like 'change', which is what innovation is all about, researchers often resort to measurable inputs for bring about change, like R&D expenditure and human resource employed or measurable outcomes like technological inventions(patents, bibliometric studies) and productivity increase. Use of these measures leads to a very narrow view of innovation. In the context of this study, a broad perspective of innovation as Schumpeter has outlined is adopted. The study looks at whether firms are able to bring in change, within themselves and to the world around.

Based on this conception of innovation, I look at how innovation happens in firms at the core of innovation. Until the late 70s, a linear view of innovation was predominant. This model of innovation gave emphasis to scientific discovery as a source of innovation. A scientific or technological invention provides opportunity for creation of new product or process(change), which in turn gets diffused in society. In the late 70s, Kline and Rosenberg (1986), suggested a new model of innovation — the coupling model. This model conceived innovation as an interaction of two sets of forces — market demand and technological and scientific progress. These forces interact with each other and change is brought in. For any innovator, innovation is an uncertain search. He/she is not sure of finding a solution or bringing about change. He/she has to reach destination before others do. In this context Kline and Rosenberg argues that "Uncertainty reduction is the essence of the innovation process". Uncertainty reduction is achieved through interactive learning involving several actors. These actors can be users, scientific institutions, firms, government etc. This conception of innovation slowly evolved into a systemic view of innovation. I shall discuss this new conception of innovation later.

Learning

The most important resource for innovation is knowledge and the most important process associated with it, is learning. There can be several ways of learning associated with sources of knowledge and nature of knowledge. Malerba (1992) identifies six different types of learnings processes. He finds that technological change is determined by the learning process. Literature on system of innovation, places learning at the centre of innovation. Two different types(modes) of learning are discussed in this context – STI and DUI mode of learning(Åke Lundvall, 2010). Role of scientific and technological advancement in creating innovation has been recognised even in the earliest models of innovation. STI learning refers to learning process associated with scientific and technological knowledge and innovation arising out of it. R&D and other activities that relate to utilisation and access to knowledge are important here. It is associated with exchange of explicit codified knowledge. DUI learning on the other hand, is about learning by doing, using and interacting. It involves organisational learning, employee participation and competency building, participation in industrial

networks, etc(Jensen *et al.*, 2007). Both STI and DUI mode of learning are essential for innovation. While role of STI learning has been recognised traditionally, significance of DUI learning has been emphasised by researchers who work on the system of innovation approach. Particularly in the context of catching up economies, DUI learning is a significant source of knowledge and innovation.

Tacit Knowledge

Tacit and explicit nature of knowledge is another important concept in the context of localised nature of innovative activities(Johnson *et al.*, 2002). Tacit knowledge is part of the knowledge which cannot be articulated. Michael Polanyi, captures the essence of the idea when he says, 'We can know more than we can tell'(Polanyi, 1983). Tacit knowledge is embedded in a person and is context dependent. Explicit knowledge on the contrary, is formalized and can be transferred in a depersonalised manner in the form of technical documentation, diagrams, etc.

Polanyi does not draw strict boundary between tacit and explicit knowledge. It is argued that all knowledge has tacit and explicit dimensions. Tacit knowledge is sticky. It is difficult to codify and transmit it. For transfer of tacit knowledge, the receiver has to interact with the source for a long time. DUI learning process is one that is used for the transfer of tacit knowledge. It is argued that, with the transfer and access to explicit codified knowledge becoming easier these days, tacit knowledge is becoming more important economically as the factor that determines innovation success and failure(Maskell and Malmberg, 1999). This in turn raises the importance of DUI learning.

2.3 Clustering of Industry

Studies on agglomeration of firms suggest that, once an industry is set up in a location, new forces emerge which provide important location advantages. These advantages that emerge facilitate further agglomeration. Three important localization economies arise out of this agglomeration(Breschi and Lissoni, 2001).

Economies of specialisation Concentration of large number of firms attract suppliers of specialised inputs (both goods and services) required for the industry. Economies of scale attained from agglomeration makes location attractive and viable for specialised intermediate input suppliers.

Labour market Localisation of industry attract labourers with necessary skills that location.

Knowledge spillover Knowledge generated within any firm in the cluster flows to other firms through social interactions, enriching knowledge pool available to firms in the cluster.

The success of high-tech industrial clusters like Silicon Valley and Cambridge in UK, and their role in the rapid economic growth of the region as well as their contribution to national economy brought attention to agglomeration or clustering of high-tech industries(Cooke, 2002). These clusters show high degree of innovation and stay at the forefront of scientific and technological development. Clustering of high-tech industries is particularly interesting because their most important activity is production of knowledge which is considered to be easily transferable through fast and low cost communication medium.

Knowledge-centric explanation for clustering of high-tech industries have developed around the idea of 'localised knowledge spillover'. It suggests that economically most valuable knowledge now days is the tacit knowledge which is sticky and can only be transferred through face-to-face interaction. This necessitates geographical proximity of actors. As knowledge is not fully excludable, actors can benefit from mutual learning. Jaffe (1996) defines knowledge spillover as the flow of knowledge from one agent to another without compensation or with a compensation less than the value of the knowledge transferred. Following the work of Jaffe (1989) which looked into knowledge spillover from academic research organisations to commercial innovation in the USA, many empirical research studies have pointed out that localised knowledge spillover exists(See Feldman (1999) for a survey of research). Some of the pitfalls in empirical research on localised knowledge spillover have been discussed in a critical review by Breschi and Lissoni (2001).

2.4 System of Innovation

Firms do not innovate in isolation. Innovation comes out of complex interactive processes involving several actors. These actors include firms like suppliers and non firm organisations like governments, academic institutions, users, etc. They influence and are influenced by each other. The system of innovation approach helps to understand innovation in its complexity. It is considered as a holistic and multidisciplinary approach to innovation(Edquist, 2005). In this approach, innovation is endogenous to system. It is an evolutionary approach that puts learning at the centre of innovation process. There are questions raised as to what extent the system of innovation represents a good theoryEdquist (2005). Lundvall who made pioneering contributions to the development of system of innovation approach argues that, even if the approach is not sufficiently 'theoretical'. it does offer itself as an analytical tool to build general and valid knowledge of causality relating to innovation(Åke Lundvall, 2010). He refers to the system of innovation as an analytical framework. It is this analytical framework that I use for this study. I try to develop a systemic view of how innovation or change is brought about by software firms in Trivandrum cluster, through their interaction with other actors.

Any system consists of a set of components and relations that exist between them. They together constitute a system. According to Edquist (2005), an innovation system is constituted by "all important economic, social, political, organisational, institutional and other factors that influence development, diffusion and use of innovation". A system should also have a boundary based on which it should be possible to discriminate between what is within the system and outside.

Components of a system consist of organisations (actors) like firms, users, academic institutions and other kinds of capability generating institutions. They are formal structures that are consciously created and have explicit purpose(Edquist, 2005). Components are interconnected in varying strength and in their patterns.

In a system, whole is more than sum of parts because of the interconnectedness. Transaction between actors in an innovation system is shaped by institutions. Institutions are a set of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups, and organisations(Edquist, 2005). These

include formal rules like laws and informal arrangements between actors. Some institutions touch upon all the actors in a system, while others, may be between a set of actors. According to the system of innovation, boundaries are not barriers; rather they are permeable routes to interaction with the environment.

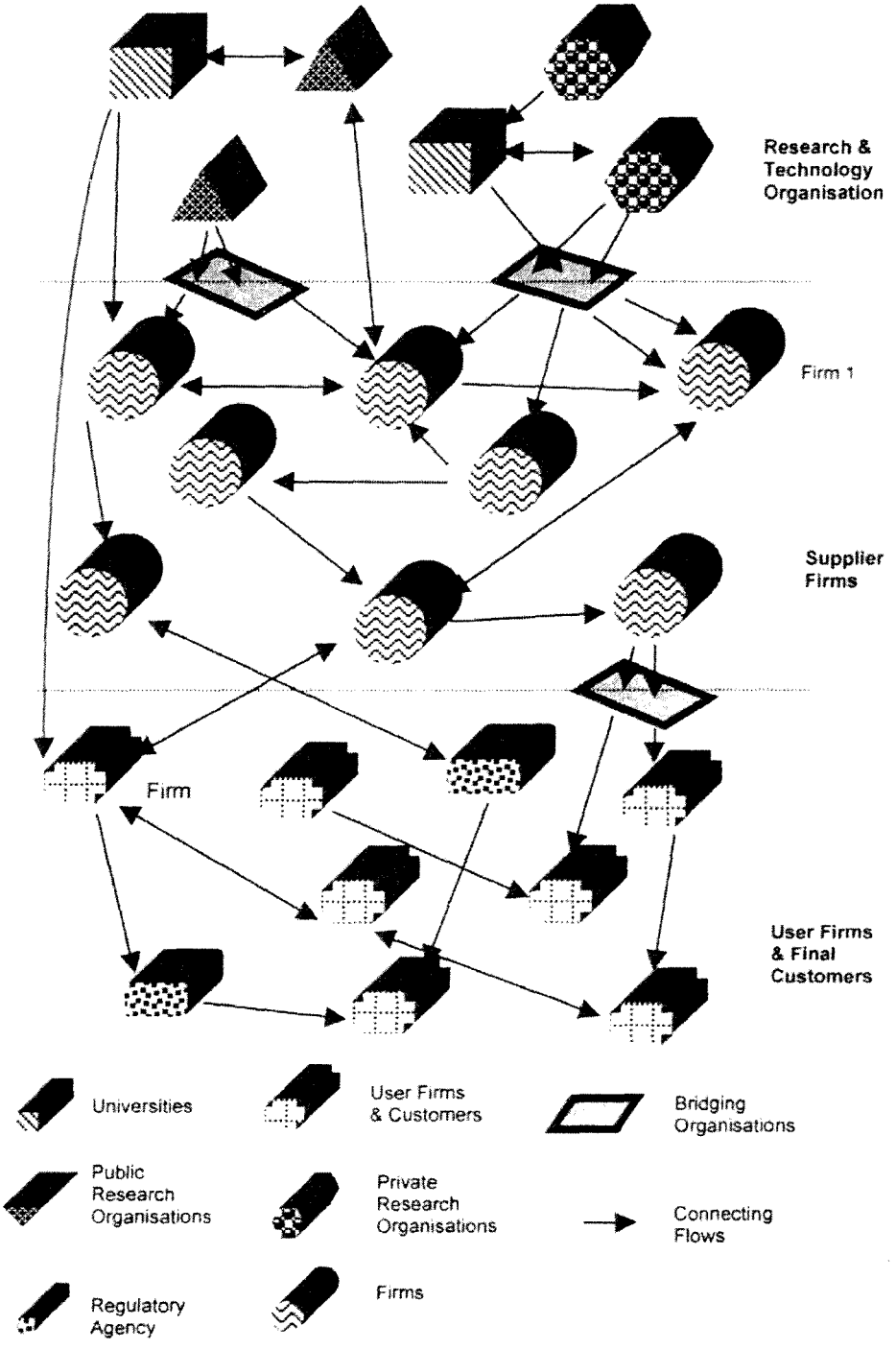
Summarising the rich body of literature in innovation systems Andersen *et al.* (2000) suggests the idea of distributed innovation processes. They consider the system of innovation as a consequence of division of labour in the generation and application of practically useful knowledge. Figure 2.3 such an innovation system with different levels of knowledge generation. Different actors generate different knowledge and stay at different levels of production. Different levels have qualitatively different organisations with appropriate opportunities, incentives, resources and capabilities. Interconnection represents the flow of knowledge. As organisations at different levels are highly specialised, some intermediary must be there to ensure effective communication. Bridge organisations are such intermediaries in this model. Some examples of bridge organisations include engineering consultancies and retail suppliers.

2.4.1 Some Gaps

There are some important gaps in the system of innovation as conceived above. With its components and interconnections, a system does not stay static. Components (organisations) undergo changes, so do the pattern and the strength of interconnections. Many qualities of interconnections like trust are generated over time. The system also undergoes changes when a radically new knowledge appears. How the firms adapt to changing conditions, like market pressure and new knowledge, will depend on the innovation system in which it is embedded and its ability to make use of the system to solve innovation related problems. This process, in turn changes the system also. It is through this dynamic process that system and its components co-evolve over time. It illustrates the significance of historical analysis of innovation system.

Innovation is not just about knowledge and capabilities. Pursuing the activity of learning and knowledge creation itself requires other resources. Innovation depends on other factors like identification and development of markets, supply of finance and skilled human resource and regulatory

Figure 2.3: An Innovation System Schema



Source: Andersen et al. (2000)

systems. A proper innovation system should include all these components along with technological system.

2.4.2 Sectoral and Regional Systems of Innovation

The system of innovation, was developed by considering nation state as its unit of analysis. However, it is not the only possible context of analysis. Sectoral system of innovation and regional system of innovation are two approaches developed around the same idea of system of innovation, but with different boundaries. While sectoral system focuses on a sector of the industry, regional system analyses a region within nation state. For my study, I borrow some ideas from sectoral and regional systems of innovation.

Sectoral System of Innovation

The idea of sectoral system of innovation comes out of the question, why different sectors of industry like chemical, software, machine tools, etc., differ in terms of innovation. Apart from the difference in terms of actors, institutions and interconnections, Malerba, the pioneer of this approach, brings in characteristics of knowledge and technological domain as the key differentiator for innovation in different industrial sectors(Malerba, 2002). The boundary of sectoral system is determined by knowledge and technological domain, which can have national, regional and global dimensions.

Discussing the idea of sectoral system of innovation, Malerba highlights two characteristics of knowledge — accessibility and cumulativeness(Malerba, 2002). Accessibility is about opportunities for gaining knowledge external to firms. While being external to the firm, it can be external or internal to the sector. Greater accessibility of knowledge reduces industrial concentration. Particularly, greater internal accessibility leads to increased imitative behaviour and lower appropriability. External accessibility refers to access to scientific and technological opportunity, in terms of its source and level. Sources of technological opportunity for a sector and the easiness with which they can be accessed and transformed into new artefacts will determine innovative entry in the sector. Some examples for these sources of opportunities are major scientific breakthroughs in universities, advances in R&D, equipment and instrumentation and knowledge from users and suppliers.

Second characteristic of knowledge is its cumulativeness. It is the degree to which new knowledge generated, builds on existing knowledge. There are three different sources of cumulativeness.

Cognitive The learning processes and past knowledge constrain current research, but also generate new questions and new knowledge.

The firm and to its organizational capabilities Organisational capabilities are firm-specific and generate knowledge which is highly path-dependent. They implicitly define what a firm learns and what it can hope to achieve in the future.

Feedback from the market, such as in the "success-breeds-success" process. Innovative success yields profits that can be reinvested in R&D, thereby increasing the probability to innovate again.

Regarding the effect of cumulativeness Malerba (2002) says:

> High cumulativeness implies an implicit mechanism leading to high appropriability of innovations. In the case of knowledge spillovers within an industry, however, it is also possible to observe cumulativeness at the sectoral level. Cumulativeness may also be present at the local level. In this case, high cumulativeness within specific locations is more likely to be associated with low appropriability conditions and spatially localised knowledge spillovers. Finally, cumulativeness at the technological and firm levels creates first mover advantages and generates high concentration. Firms that have a head start develop a new knowledge based on the current one and introduce continuous innovations of the incremental type.

In this study, I look at the characteristics of knowledge and technology domain in the software sector and some of its unique actors. Their role in the innovation process is captured through case studies and other secondary sources of information.

Regional System of Innovation

Regional system of innovation brings in geographical dimension to system of innovation. It borrows heavily from cluster literature on geography of

innovation. Literature argues that interactive learning, the most important process in innovation system, is most effective when an innovating firm is co-located with other actors(Lundvall and Borrás, 1999; Maskell and Malmberg, 1999). Tacitness of knowledge discussed earlier, is one reason why proximity is important. Another reason is the role that trust plays in enabling knowledge exchange and mutual learning(Putnam, 1993; Lundvall and Borrás, 1999). Development of institutions that facilitate knowledge exchange like trust, depends on long and close visibility of agents.

2.5 Lundvall's Steps for Analysis

Based on the conceptual framework of System of innovation, Lundvall (2007) proposed a four step process for analysing innovation system. Though discovered ex-post, similar approach has been adopted for this study. Lundvall had written this in the context of national system of innovation.

> First step would be to analyse what takes place inside firms in terms of innovation and competence building.
>
> A second step would be to analyse the interaction among firms including competition, co-operation and networking and how firms interact with knowledge infrastructure.
>
> A third step would be to explain international differences in these respects with a reference to the specificities of national education, labour markets, financial markets, welfare regimes and intellectual property regimes.
>
> As a fourth step firm organisation and network positioning may be used to 'explain' the specialisation and performance of the innovation system.

Chapter 3

Overview of Indian Software Industry

This chapter on Indian software industry provides the context of the study. In the first section, a historic account of Indian software industry is given. This is to provide an evolutionary picture of the industry which is essential in the system of innovation approach. Much of what the Indian software industry today is, can be appreciated only in its historic context. I've tried emphasise on technological change and its role in the evolution of the Indian software industry as most of the literature focuses on policy change and ignores the technology change. The second section provides a quantitative analysis of production in this sector, followed by discussion on the important characteristic features(qualities) attached to Indian software industry as presented in existing literature. These features discussed at the macro level will be re-examined in the micro level case studies undertaken.

3.1 Evolution of Software industry in India

The Indian software industry evolved through a complex interaction of several factors. Most of the economic literature focuses on changes and effects brought about by changing industrial policy from state protectionism to liberalisation. However, existing literature misses the significant technological changes in the global software industry at the time of policy changes in India.

3.1.1 60s and 70s – The Era of Mammoth Machines

Following India's defeat in the Indo-China war of 1962, the Indian government decided to strengthen its capabilities in advanced electronics and computing technologies. The Electronics Committee was set up to advise the government on achieving self sufficiency in those technologies(Grieco, 1982; Tariq and Puja, 2007). The committee recommended that India should absorb the technology already developed in foreign countries rather than trying to develop all of it on its own. The committee observed that the practice of borrowing technology from foreign firms through collaboration had resulted in obsolete technologies reaching the country. While accepting the need for specific collaboration with foreign firms, it argued that within 10 years technology should be made indigenous so that further collaboration is not required. The committee put forward a strategy to develop self sufficiency in the computing industry within 10 years.

IBM, which was in operation in India from 1951, was the largest provider of computing systems. With the new strategy suggested by the Electronics Committee, the government started negotiating with IBM for the latest computing technologies and know-how. The government also set up the Electronics Corporation of India Limited (ECIL) in 1967 to develop indigenous capabilities in electronics. ECIL worked with defence and nuclear establishments in India to provide technological solutions. Computers were part of its agenda. In the period between 1967-72, ECIL provided 13 machines which accounted for 8.5 percent of the total installation base while IBM accounted for nearly 70 percent of the installation base(Grieco, 1982). International Computers Limited (ICL), UK, was another player in the market. Among the manufacturers based abroad, IBM had some advantage as foreign exchange regulation gave it an upper hand in terms of its ability to supply computers. It took advantage of its non-computer export earnings for importing components to manufacture computers.

Computing at that time was largely based on mainframe system or its slightly smaller variant, referred to as mid range systems. These systems were very costly and often customised for individual user needs and manufactured as per order. The users often wrote a major chunk of the software they required. The providers of hardware at most gave compilers for different programming languages in which users could write the software. Sometimes, they also gave the users source codes of software developed by them

or other users. Almost all the software developed during this period was custom software or in-house software. A significant share of the computing cost during this period was that of hardware.

Software development was not considered a high value activity. Software programming was a very complex task which required highly skilled manpower. As the technology for software was in its infancy, even simple programming was a complex task requiring higher cognitive skills than today. Software written during the time was highly machine-specific too.

In India, software development began as a profession in the early 1960s, as a secondary activity of multinational hardware companies like IBM. They created in-house teams of software developers to develop application software to support their Indian customers. Meanwhile, a domestic software industry emerged with Tata Group setting up India's first software services company, Tata Consultancy Services(TCS) in 1968[1]. Tata set up this company to provide computing service primarily to other firms under the same conglomerate, like Tata Steel. Although it bought costly mainframe systems primarily for its own need, it wanted to share the computing facility with users as a commercial service. The commercial services of TCS included software services and bureau services. In 1969, TCS got its first commercial project, the Inter Bank Reconciliation System for Central Bank of India. Its success made other banks to demand the same solution. Thus, software development started becoming an independent commercial service in India.

With mainframe systems, software development activity was mainly to write domain specific code in programming languages like Cobol or Fortran. Software during the period was a relatively simple system with application software being the single most important piece of software in the computing system. Operating systems provided only very basic capability. Software written by user controlled the machine directly. There was not much difference between application software and platform software. Reusable software modules were made available for common tasks like card reading, printing etc. Compilers for various programming languages were also available. Tools to develop software were made by hardware vendors themselves. They ensured that these tools made use of the specific functionalities of the hardware.

[1]Historic account of TCS given here is based on informations from several sources that include,Wikipedia (2011),ICMR (2004) and India (2002)

In 1974, Burroughs, a major US computer maker which wanted to enter the Indian market started collaborating with TCS. Indian software export thus began with TCS providing custom software development services to clients of Burroughs in the US and other countries. A joint venture between Tata and Burroughs, named Tata-Burroughs Ltd., was established in 1977 and it started to export software and printers from India. Burroughs expected this activity to give it foreign exchange required to import its computers to India and help it capture the Indian mainframe market from IBM. In the process, Tata gained inroads into the large market of software services in the US(See Grieco (1982) for a vivid account of power plays and negotiations during the period). Tata's services cost much less than those available in the US market. However, it was not just the cost that contributed to the acceptance of TCS in the US market. The quality of work done by TCS did matter. Given the critical nature of systems being deployed during the time, a low quality software would have been unacceptable to customers even if its cost was low. TCS was thus able to create confidence among customers in the capabilities of Indian software programmers. Software industry at that point consisted of only TCS.

3.1.2 Late 70s to Early 80s – Time of Minis and Micros.

In 1975, the Indian government set up Santa Cruz Electronics Export Processing Zone (SEEPZ) near Mumbai to attract foreign investment in software production in India. The success of TCS attracted other foreign firms like Data Basic Corporation to set up export oriented software development centres in India. In the early 80s, new software firms like Infosys also emerged. Like TCS, Infosys also partnered with an American firm, Database Corporation, to provide custom software solutions to its clients in the US(Rediff.com, 2006). The software service model during the period was largely based on onsite service delivery[2]. Infrastructure limitations of firms may have been an important reason for this bias. Communication facility between the two countries were also poor. Infosys relied on fax to

[2]Onsite service delivery is one in which service firms do most of the production at the client site. This involves movement of human resource to client location. It is assumed that workers who thus move to client site work under the direction of client. They will provide their labour force to client without much value addition

transfer code between its development centre in India and the US. Infosys worked without hardware for the first two years.

The domestic demand for computing service also expanded during this period, with most of it coming from the public sector. The computerisation of the banking sector, Air India, Indian Railways, etc., provided opportunity for domestic software firms. The domestic demand for software provided a wide range of learning experience for Indian software firms. However, the growth of this sector was limited by the high cost of computer hardware and restrictions on import.

In 1978, IBM put an end to its love-hate relationship with the Indian government. It decided to leave the country protesting over the new import regulations that were introduced by the government. The exit of IBM left a pool of its former computing professionals free to pursue new ventures. Some of them joined IBM centres outside the country and some started small software houses in India.

IBM's exit from India coincided with rapid changes in the computing industry. Mass production of cheaper, microprocessors like Intel 8088 and developments in peripherals made development of computer systems easy and low cost. By the late 70s, microprocessor based cost effective mini and micro computers reached the western market[3]. The computer peripherals sector also saw radical changes with the introduction of new technologies like floppy disk by IBM. All these facilitated the entry of new firms into computing industry both domestic and international. Microcomputers were made available as 'Do It Yourself' kits.

Several indigenous firms emerged providing lower range computing hardware in collaboration with foreign partners. Minicomputer systems like PDP system from Digital Equipment Corporation, entered the Indian market around this time in partnership with Hindriton. ECIL came out with its own minicomputer. Firms like HCL and Nelco brought out microcomputers, which sometimes masqueraded as business calculators to bypass policy restrictions. Semiconductor revolution started slowly changing the computing industry[4].

[3]Minicomputers or midrange computers are a class of computers with computational capabilities lower than mainframes and higher than personal computers. They also cost less than mainframes. Microcomputers were even less powerful than minicomputers but targeted home or small business users

[4]This part of the discussion, on Indian hardware industry, borrows heavily from Dataquest (2002)

Despite the policy restricting the number of computer manufacturers (which existed till late 70s), rapid growth in this sector was facilitated by developments in the microprocessor industry and the semiconductor industry in general. The sudden surge in the number of Indian computer manufacturers did not imply that technology relating to computer hardware was being increasingly transferred. Domestic firms just assembled computers with screwdrivers and software was often copied from the west. Value addition by Indian firms was very low. In terms of market, the government was the chief buyer. However, with the arrival of micro and minicomputer technology, there was a great diffusion of computing in the country.

With increased adoption of small computers, demand for software also started growing. Newly emerged computer manufacturers wrote their own system software or sometimes even copied them from firms in foreign countries. Most of the software developed during the period continued to be custom software for the various business needs of clients. With the emergence of local hardware manufacturers, Indian software industry also began to demonstrate capabilities in developing platform software like operating systems and compilers. The design and development of BASIC programming language for ECIL computer by the founder of Infosys, Mr Narayana Murthy, is an example. However, the export market was almost exclusively for custom software for specific user needs.

3.1.3 Mid 80s to Early 90s- from Hardware to Software.

During the time of mainframes and minicomputer systems, technological limitations prevented firms from tapping the possibilities of software development. Capabilities of a computing system was largely determined by the hardware used. Software was often bundled with hardware at zero cost. Its code was printed and given along with the hardware in such a way that anyone could use it for his/her need. Users continued to share source code for different tasks among themselves. At this point of time, no one believed that software could be an economic good. All these factors made software more open than hardware in the early days.

Advances in silicon chip technologies such as improved processing capabilities and larger and faster memory slowly improved possibilities for

software development. Increasing capabilities in hardware meant that it was possible to create more complex software. Mini and microcomputers started gaining computing capabilities comparable to mainframes at a much lower price. Cheap and powerful microcomputers made computing more popular. Introduction of microcomputers like IBM PC and Apple Macintosh were important milestones in the computing history of the early 80s. From mainframe, computing moved to high-end computers with microprocessors and Unix operating system. Unix became a standard platform for software across different hardware. It was possible to develop software for Unix operating system which could run across different hardware that supported Unix operating system. This helped early packaged software vendors like Oracle to develop their products for multiple hardware users without depending on hardware vendors.

Development of microcomputers also led to the development of generic software market, as there were many users with the same kind of mass produced hardware. IBM PC became a standard for personal computers with many hardware vendors providing computers compatible with IBM PC. Packaged software vendors like Microsoft grew dramatically due to the fact that their software could run on computers from different vendors. IBM PC and DOS operating system became a kind of standard for low end computers for personal and small business applications whereas mainframe and Unix based server systems, were used by the corporate sector. The mass market for software was created on IBM PC-DOS combination, which later became Intel-Windows combination, when hardware manufacturing became more standardised.

This period is also marked by a shift in the cost of computing system from hardware to software in the world market. In the 60s, hardware accounted for 70 percent of the cost of a computing system employed in a business or professional environment. By the 90s, this was reversed, with software costing 70 percent of the total.(Lakha, 1990).

In 1984, Government of India announced its New Computer Policy, which aimed at intensive computerisation. This initiative led to greater domestic demand for hardware. The same year, Microcomp, an Indian manufacturer announced the launch of IBM PC compatible in India, close on the heels of its launch in the US. Intense competition in the private domestic market started and the price of computers dropped from Rs 1 lakh

to Rs 29,000, within a few years. The new policy gave several incentives for Indian software exporters including very low import duty on hardware.

In 1986, Government of India announced another policy that recognised the independent existence of software industry. Policy changes favouring software and the availability of low cost computers happened at a time when migration from mainframe to Unix based client server model was speeding up in the developed countries(Athreye, 2005). This migration led to increased demand for software services in the form of converting software written in mainframe to Unix based systems. In the same period, Rangarajan Committee for bank computerisation in India announced that banks will standardise on Unix operating system and Motorola 68020 microprocessor. This generated interest in domestic manufacturers to come out with Unix based hardware. As early as 1984, HCL had brought out an indigenously designed minicomputer with Unix operating system. In the late 1980s, it came out with its own Unix software. Wipro, another hardware manufacturer, also came out with its version of Unix on a PC platform.

From mainframe, India slowly began opening up to Unix technology in the high end computing segment. There was also a greater penetration of computers in the lower segment through low cost PCs. Availability of hardware, low cost human resource, better communication systems and the routine nature of tasks like migration, enabled greater offshoring[5] of software services.

Demand for domestic software also started increasing with the availability of low priced hardware. As per some estimates, the install base of computers in India grew from 3,500 to 26,560 between 1983 and 1987(Lakha, 1994). Domestic firms like Sonata, Wipro and Mastek tried to introduce software products in the domestic market. Unfortunately, they could not succeed economically as unauthorised copying was rampant in the country. In addition to that, they also faced competition from foreign firms which provided generic software with the same functionality. The export software market for custom software was a relatively safer route for software firms. Domestic software product market almost collapsed, except for minor successes like Tally and some Indian language software packages.

[5]Contrary to onsite, offshore is a service model in which software development is moved from the client site to location of service provider, i.e to India

With the introduction of Software Technology Parks of India (STPI) initiative and the economic liberalization of 1991, a lot of new firms tried to enter the software export market. Data communication facilities provided to firms through STPIs gave a boost to production in India(Desai, 2003). Software could be transferred to export destination through Internet. As a result, offshore model of software development gained greater momentum.

3.1.4 From Mid 90s to Present - The Time of Internet

The 1990s marked the growth of Internet which improved communication between India and its export destinations. Internet also brought in new demand, particularly with the development of e-commerce. Between 1995-2000, a lot of firms came up to provide new services on Internet using mainly World Wide Web (WWW). Indian software exporters gained in the process through outsourcing and offshoring of such work. The firms began to learn and respond to the new opportunities brought in by the Internet. Unlike in the older paradigm of developing software on largely proprietary technologies (like Windows), the software for Internet, largely depended on open technologies. Java came up as an important technology for development of software for WWW along with other tools like Apache, Perl, GNU/Linux operating systems. All of them were freely accessible and open. At the same time, Y2K bug fixing also gave a lot of work to Indian software firms. By 2000, the window of opportunity for Y2K related projects was closed. Dot-com bubble[6] also came to an end. However, the Indian software industry was not much affected and it continued to show strong growth.

By the late 90s, most of India's software industry, including export industry, was focused on developing software solution for enterprise business needs. The efforts from indigenous computer manufacturers for platform software came to a close. Most industry leaders like Infosys and TCS, developed custom software solutions for business specific needs. A few firms like Wipro and Mindtree offered R&D services along with custom software development services(Parthasarathy and Aoyama, 2006). There were exceptions like Sasken, specialising in telecommunications and providing exclusively R&D services,.The same period also saw the arrival in India

[6]Dot-com bubble refers to speculative growth shown by Internet related firms between 1995-2000. For more information see http://en.wikipedia.org/wiki/Dot-com_bubble

of all major international software companies providing consultancy, custom software service and software package development. Many of them set up R&D centres in India, indicating superior technological capability possessed by Indian software professionals(Giarratana *et al.*, 2004).

The 1990s and 2000s also saw various regional governments trying to attract international and domestic software firms to their respective states. Each region tried to provide its own incentive to attract firms. Special Economic Zones (SEZ) became the new mantra of software industry.

Table 3.1: Brief Overview of Evolution of Indian Software Industry

	Technology	Domestic Hardware Industry	Beyond Application Software[7]	Source of Opportunities	Source of Knowledge	Global Data Connectivity
60s and 70s	Mainframe computers, Software specific to hardware	MNC led		Improvement in hardware	Hardware manufacturers	
Late 70s to early 80s	Microprocessor; Mass production of hardware	Attempt to indigenise the technology	Beginning of platform software for domestic market	Improvement in hardware	Hardware manufacturers	Fax
Mid 80s to early 90s	Platform software dominates	mini and microcomputer from domestic manufacturers	Platform software surges and collapses	Developments in platform software	Platform software providers	Satellite based Internet/STPI
Mid 90s to present	Open Internet technologies	Opening up of manufacturing sector and collapse of local hardware manufacturing industry	R&D services emerge	Improvement in Internet/Web technologies	Open Internet tools and standards becoming more important	Public Internet

Source: Own compilation

[7]From the beginning, the focus of Indian software industry was on application software for businesses, that too mostly as custom software solution.

3.2 Indian Software and Services Industry – Some Facts and Figures

Table 3.2: Software production in India(in Rs Billion)

Year	Domestic Sale	Export	Total Output	Export as % of Total
1999-00	72.00	171.50	243.50	70
2000-01	94.00	283.50	377.50	75
2001-02	108.74	365.00	473.74	77
2002-03	134.00	461.00	595.00	77
2003-04	162.50	582.40	744.90	78
2004-05	217.40	801.80	1019.20	79
2005-06	296.00	1041.00	1337.00	78
2006-07	370.00	1410.00	1780.00	79
2007-08	470.10	1644.00	2114.10	78
2008-09	590.00	2161.90	2751.90	79
2009-10	662.00	2350.80	3012.80	78

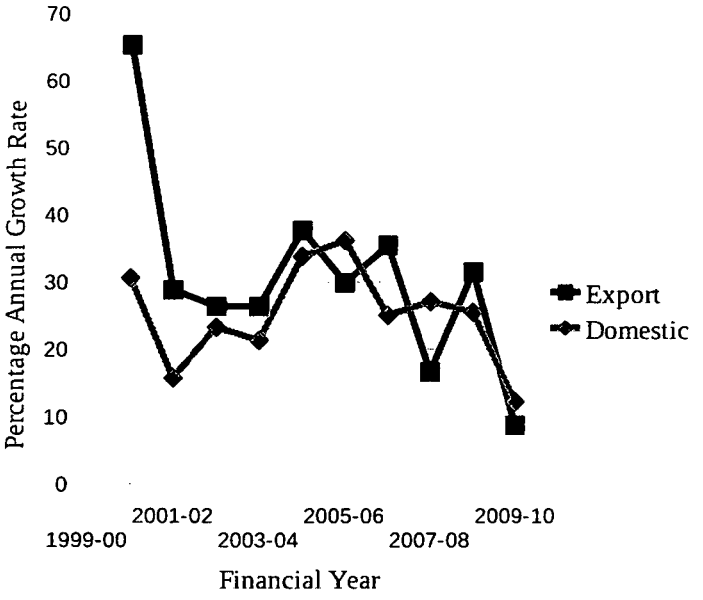
Source: Various issues of annual report, Ministry of Communications and Information Technology, Govt. of India

In literature, the term software has been used to refer to a broad category of services which include software and related services and non software services like Information Technology Enabled Services (ITeS). The Ministry of Communications and Information Technology has also adopted this definition in its data.

After the gestation period from the mid 60s to mid 80s, the Indian software industry never looked back. In 1999-2000, the total output of software services industry stood at Rs. 243.5 billion. In a matter of 10 years, it grew more than 10 times to reach Rs. 3012.8 billion (See Table 3.2). Nearly 80 percent of the total output was in export. Export intensity did not show any change in trend. Export showed an average annual growth rate of 31 percent. This growth rate is noted to be unparalleled in Indian economy(Balakrishnan, 2006).

The growth rate dropped soon after 2000, with the bursting of dot-com bubble and the end of Y2K related work (Figure 3.1). The industry picked up soon after, only to see a significant drop after 2008. This drop is largely due to global economic recession and reduction in demand. The growth of the sector and the sheer magnitude it achieved is largely due to its export orientation. At the same time, this export orientation makes it vulnerable to global changes.

Figure 3.1: Indian Software Production Annual Growth



Based on Table 3.2.
Source: Annual reports of Department of IT, Ministry of Communications and Information Technology, Govt. of India

IT and IT enabled Services (ITeS)[8] sector accounted for 48 percent of world trade in 2007(UNCTAD, 2009). In this sector of trade, worth 1600 billion USD, India accounted for just four percent. For the US, the largest exporter, the share was 16 percent. India is at fifth position, very close to Ireland at fourth position with 4.6 percent of the world market. Between 2000 and 2007, India gained 2.66 percent world market share— the largest gain— followed by Ireland and China with 2.37 and 1.43 percent respectively. The US was the largest loser with 3.11 percent market loss followed by Japan at 1.16 percent. At the very first stroke of success, the industry transformed the image of India from a land of snake charmers to a land of high-tech industry.

3.2.1 Contribution to Indian Economy

Until recently, the only source of disaggregated data on Indian software and services industry had been the industrial association, NASSCOM. In 2010, the Central Statistics Office(CSO) in the Ministry of Statistics &

[8]Definition is equivalent to the definition of software and service sector used by Ministry of Communications and Information Technology, Government of India

Table 3.3: World IT/ITeS Trade in 2007 (USD Billion)

		% of world
World	1635	100.00
USA	270	16.50
Israel	13	0.79
Germany	111	6.78
Ireland	75	4.58
United Kingdom	205	12.55
India	69	4.22

Source: UNCTAD. See UNCTAD (2009, annex table III.4)

Program Implementation(MOSPI), Government of India, brought out a report which provided information at a disaggregated level (CSO, 2010). It provide information on production and employment in computer and related services (IT Services) including software[9].

Table 3.4: Contribution of computer software and related service to India's economic growth

Year	GDP at factor cost (in Rs Billion)	GVA of the Sector (in Rs Billion)	Share of the sector to GDP (in %)	GDP Growth (in %)	Sectoral Growth (in %)	Contribution to GDP Growth (in %)
2000-01	19250	269	1.40			
2001-02	20977	339	1.62	8.97	26.02	4.69
2002-03	22614	414	1.83	7.80	22.12	5.19
2003-04	25382	546	2.15	12.24	31.88	5.60
2004-05	28777	708	2.46	13.38	29.67	5.46
2005-06	32824	918	2.80	14.06	29.66	5.90
2006-07	37794	1178	3.12	15.14	28.32	5.83
2007-08	43209	1452	3.36	14.33	23.26	5.46

Source: Own compilation based on data from Central Statistics Office. See CSO (2010)

Based on new data made available by CSO, the share of computer related services has been increasing consistently, in the GDP of the country (Table 3.4). Sectoral growth has been nearly consistent with the two digit annual growth rate. From 2002-03 onwards, the contribution to the growth in GDP has been more than 5 percent.

[9]In many data sources like Reserve Bank, the term software and services is used to refer to a broader industrial sector which includes software, related services and ITeS activities like Business Process Outsourcing. In this new data set, ITeS is excluded by definition

Table 3.5: IT & ITeS exports in India's exports (in Rs billion)

Year	Merchandise Export	Services Export	Total Export	Software Export	Software Import	Software Export as % of Services Export	Software Export as % of Total Export
1999-00	1627.53	681.37	2308.90	174.12	16.00	26	8
2000-01	2078.52	745.55	2824.07	290.13	27.05	39	10
2001-02	2133.45	817.39	2950.84	360.38	32.02	44	12
2002-03	2600.79	1004.19	3604.98	464.24	35.65	46	13
2003-04	3039.15	1231.75	4270.90	587.81	21.75	48	14
2004-05	3817.85	1937.11	5754.96	794.04	35.79	41	14
2005-06	4657.48	2556.68	7214.16	1046.32	59.54	41	15
2006-07	5828.71	3330.93	9159.64	1413.56	102.12	42	15
2007-08	6680.08	3630.42	10310.50	1620.20	134.94	45	16
2008-09	8579.60	4880.10	13459.70	2122.42	127.01	43	16
2009-10	8623.33	4532.46	13155.79	2351.61	69.92	52	18

Source: Database of Indian Economy, Reserve Bank of India

The share of software and services exports in India's total exports continued to increase from 1999-2000. Despite the reduction in growth rate, its share in service exports and total exports is on the rise. Despite significant decline in growth rate, software and services sector managed to raise its share in the total services export above 50 percent mark in 2009-10. Its share in total exports was continuously on the rise and in 2009-10, it reached 18 percent. Import of software and services sector is less than 10 percent of the export.

Software and services exports also account for a large portion of foreign exchange earned by India. Nearly 50 percent of Net Invisible in India's balance of payment is accounted for by this sector. India would have faced a serious crisis with the current account deficits, had the software and services sector not performed as it does now.

IT services account for more than 6 lakh workers which comes to 19.43 percent of ICT sector employment (Table 3.6). Out of this, software sector alone employs more than 5 lakh people, who account for nearly 83 percent of gross value added in the sector. Labour productivity in the software sector comes to nearly Rs.90,000 per worker. This very high labour productivity is one important feature of software sector.

According to the latest report of NASSCOM, the revenue from software services industry was expected to reach 63.7 billion USD by the financial

Table 3.6: Gross Value Add. Employment and Labour Productivity in ICT sector 2006-07

ICT Activity Description	GVA		Employment		Labour Productivity(GAV per worker)
	Rs. million	% of Total	In numbers	% of Total	Rs. million
Telecommunications	96658	15.77	2521847	79.91	0.04
Software publishing	18074	2.95	19830	0.63	0.91
Computer programming activities	489441	79.83	518435	16.43	0.94
Computer consultancy and computer facilities management activities	1383	0.23	3090	0.1	0.45
Other information technology and computer service activities	2814	0.46	51617	1.64	0.05
Data processing, hosting and related activities	1345	0.22	20546	0.65	0.07
Web portals	169	0.03	2913	0.09	0.06
Repair of computers and peripheral equipment	3182	0.52	17439	0.55	0.18
Total	613066	100	3155717	100	0.19

Source: Own compilation based on data from CSO. See CSO (2010)

year 2009-10[10](NASSCOM, 2010). During this period, direct employment in IT and IT enabled services was expected to reach nearly 2.3 million. Indirect job creation was estimated at 8.2 million. IT and IT enabled Services together accounted for 1.2 percent of GDP in the year 1997-98 and this was expected to reach 6.1 percent in 2009-10.

3.2.2 Supply Side Structure

Indian software and related services (ITeS not included) export is led by Indian firms. They account for nearly 70 percent of the exports, whereas MNCs account for the remaining 30 percent. There are more than 3000 firms but the top five account for 46 percent of total exports as per data for 2004-05.

3.2.3 Knowledge Base of Indian Software Firms

Production of new knowledge depends on the knowledge stock and the capability to build new knowledge using existing stock. In the case of

[10]Annual Report of Ministry of Communications and Information Technology for the year 2009-10 indicates that it has not

Table 3.7: Top 10 Software Exporters from India (2004-05)

Rank	Firm	Export (in USD Million)
1	Tata Consultancy Services Ltd	1644
2	Infosys Technologies Ltd	1502
3	Wipro Technologies	1198
4	Satyam Computer Services	745
5	HCL Technologies Ltd	588
6	Patni Computer Systems	342
7	I-flex Solutions Ltd	245
8	Mahendra British Telecom	202
9	Polaris Software Lab Ltd	154
10	Perot Systems TSI(India) Ltd	145

Source: NASSCOM (2006)

software, this stock is all about computer and software related knowledge. Computer related patents including software should be a broad indicator of stock of technological knowledge a firm/industry/country has[11]. A limitation of this indicator is the fact that patenting depends on the explicit decision of the inventor to patent the invention. He/she will be using patent or other mechanisms of exclusion depending on nature of knowledge and model of business adopted. Particularly in the context of information goods like software, a wide variety of business models have been adopted, many of which do not depend on patents. Moreover, patentability of software invention per se is an issue of intense debate. Another related challenge is that software patents are spread across different classifications. An alternative and better approach would be a bibliographic study.

For the purpose of this study, patents under USPTO class 700-726 are considered as computer related patents including software. Patents under these classes have been manually verified and classified. Table 3.8 provides the patent portfolio of seven firms that hold more than three patents. Two of them work exclusively in the area of embedded systems software. Infosys leads with 12 patents followed by Ittiam Systems and TCS with 11 patents each. Only two firms, Satyam Computer Services and Wipro have business process related patents. Ramco Systems has seven patents in software development process. What is most striking about the patent portfolio of Indian software firms is that even in the area of embedded systems,

[11]Whether patents can be an indicator of innovation in software sector is an issue of intense debate. For a discussion on use of software patent as indicator of innovation see (Arora, 2008). Some of the issues are relevant in the context of my use of the indicator.

Table 3.8: Computer related patents issued to Indian software firms

Firm	Patent category				
	Embedded	Technology	Business	Software Development process	Total
Infosys	1	8		3	12
Ittiam Systems	11				11
Ramco Systems		1		7	8
Sasken	7				7
Satyam Computers		5	4		9
TCS		9		2	11
Wipro	1	2	3		6

Source: Own compilation from USPTO database as of January 2011

patenting by Indian firms is negligible and concentrated in two firms.

Industry leaders in R&D services and embedded systems like HCL, TATA Elexi, Mindtree etc., do not appear on the list. This can be due to two reasons. One, Indian firms are not inventive in the area of ICT including software technology. Two, as per service contract, the ownership of knowledge created goes to the client firm. In the latter case, the domestic firms' ability to benefit from innovation is severely hampered.

Lack of technological knowledge within the country is a concern not just from the point of view of making use of the technology, which can be addressed through licensing. The tacit nature of knowledge will limit ability of domestic firms to take advantage of technological knowledge for innovation. The picture that emerges of the Indian software industry, is one of limited technological knowledge base. Situation does not change even if we include Indian non-firm organisations.

When we bring in MNCs operating from India, the picture completely changes(Table 3.9). MNC firms are inventing and increasing their knowledge stock through their Indian operations.

Table 3.9: Patent filing by firms operating in India

Company	2004-05		2005-06	
	Filed	Granted	Filed	Granted
Microsoft	40	-	70	-
Symantec	47	43	57	16
ST Micro	62	32	37	14
Adobe	10	-	32	-
Freescale	10	-	16	4
Flextronics	2	1	4	1
Cadence	1	5	–	-
Texas Instruments	35	10	-	-

Source: Arora (2008)

3.3 Nature of Software Industry in India

The most striking feature of India's software industry is its high export intensity. It has been argued that this outward looking nature has forced the industry to depend heavily on low-skill jobs in the sector, though the economic benefits of this was high(Heeks, 1996; D'Costa, 2002). In this section, I will be looking at some of the features of Indian software industry discussed in the literature on innovation in Indian Software Industry.

According to Correa (1996), the software industry in a developing country progresses through three stages. The first stage is that of export of labour. A developing country sends human resource to a developed country. It will bring back knowledge required for the growth of the industry. The second stage is export of services. Here, relatively low value activities of production process like programming is brought down to a developing country. Other low value activities like data entry for computing systems can also move to the developing country during this stage. In the last stage, the developing country is able to take advantage of the entire production process and start exporting software products. This model underlies most of the discussion on qualitative growth of Indian software industry. I keep this model in mind throughout the discussion and raise the question as to what extent this is true.

3.3.1 From Export of Labour to Service - Offshore Vs Onsite

Share of onsite work to offshore is considered as an indicator of the extent to which the industry has been able to move from export of labour to export of services. High level of onsite work means industry is in export of labour stage and increasing share of offshore means increased services export. According to survey estimates provided by Heeks (1996), in 1988, 75 percent of India's software export happened overseas, ie onsite. He also identified that offshore activities were increasing in Indian subsidiaries of multinational firms. According to him, the situation remained the same even in the mid 90s.

According to NASSCOM report, Strategic review 2006, offshore revenue has been continuously increasing in India's total IT and ITeS exports. As per its estimates, offshore revenue increased from 43 percent in 1999-00 to 70 percent in 2004-05. If software sector alone is considered, this change is from 33 percent to 58 percent.

Onsite work has been part of Indian software exports from 1974, with TCS providing service to Burghas(Grieco, 1982). As we saw earlier, Infosys depended on fax to send code between their offshore and onsite teams. Sometimes, development work was done in parallel, thus duplicating efforts, to avoid delay. Difference in hardware between client site and development facility in India meant that code had to be modified onsite to suit the hardware.

Another source of high share of onsite activity comes from maintenance services. From the late 70s, TCS has been taking over mainframe systems in the western market. Considering the lack of technology for remote administration during the period, the movement of human resource to onsite facility where the hardware is housed was necessary.

Definitely, offshoring of software related activities to India involved a lot of organisational learning for Indian software firms. However, it is not clear to what extent these firms learned how to produce software from the market. TCS and Infosys had shown their capability in complex software development before they got foreign clients. Improvements in data communication technologies, the entry of low cost mini and microcomputers, standardisation of hardware and platform software, all had significant ef-

fect on offshoring. The important question is, what is the knowledge that firms bring from the export market to home country ? Literature does not answer this question. It simply accepts the macro indicator and the model.

3.3.2 From Services to Product

Having moved from labour to services export, the next stage expected is, emergence of software products. India's entry into software exports was through service model. TCS, through its partnership with Burroughs, provided custom software solutions to mainframe users in the US an UK. It was also able to take over system maintenance contract for large financial institutions in the US. Other major entrants in the software market followed the same model. Later, these maintenance service activities helped the country to enter Y2K bug fixing business which in turn helped the industry to expand rapidly.

Table 3.10: Indian Software Services and Product Exports (USD Billion)

Service Categories	2003-04	2004-05	2005-06
Project oriented engagements			
Custom application development	3.71	4.98	6.6
IT Consulating	0.13	0.25	0.33
Systems integration	0.15	0.2	0.26
Network consulting and integration	0.05	0.15	0.2
Outsourcing Engagements			
Application management	2.27	2.69	3.56
IS outsourcing	0.3	0.6	0.79
Support and Training	0.64	1.1	1.45
Sub Total	**7.25**	**9.97**	**13.19**
R&D and Product Development	**2.5**	**3.1**	**3.9**
R&D and Product as share of total output	25.64	23.72	22.82
Employment (nos)			
Software services	215000	297000	398000
R&D and Product	81000	93000	115000
Productivity (Exports per employee)			
Service	0.03	0.03	0.03
Product	0.03	0.03	0.03

Source: Based on data from NASSCOM (2006)

Indian software and services industry is classified into two groups by NASSCOM - - IT Services and Engineering, R&D and Software Products.

The high value sector of R&D and software product consists of software product by Indian companies, outsourced work done for foreign product firms and R&D and engineering services provided. As per the data for 2004-05, each of these account for 11 percent, 18 percent and 71 percent of the total production of the sub sector respectively. Together, they come to nearly a quarter of the total production of Indian software and service industry with a declining trend from 2003-04 to 2005-06. Looking at productivity in terms of export value per worker, the two subsectors do not show any difference. If the data is correct, moving from software services to product has not brought an increase in value. One reason for this counter-intuitive result may be the large volume of low value engineering services being accounted as R&D services.

Whether or not the Indian software industry moved through the stages in the model that Correa proposed, software service has been an integral part of India's software export industry. Existing literature suggests that Indian software industry provides software services which are of low value in software production cycle. A quick empirical investigation done above casts doubt on supposed difference in value.

TCS, the first and largest software exporter from India, entered software production by developing software for the financial sector. Though it was a custom software which is classified under software service, TCS must have undertaken the entire cycle in software production process. It clearly indicates the firm's capability in software production. Other Indian firms also came out with operating systems and other platform software .

In the 80s, Wipro had introduced a software product in the domestic market for project management. In partnership with a US firm started by an expatriate Indian, it introduced another project management tool, InstaPlan, in the US. According to the President of InstaPlan joint venture, the product was successful. He says of the model: "We design the software; Wipro programmers make it work; and then we sell it. It'd be easier if we could do everything here, but it's more cost-effective to develop in India, and you can develop even complex applications there. FAX communications have dramatically improved within the last six months." (Harding, 1989). However, the project could not survive the competition from monopoly firms in software product market(SiliconIndia, 2001). Wipro abandoned product export and moved on to service.

The history of large Indian software firms indicates that they had all skills required for the production of software products (at least software for businesses). Platform software products emerged in the industry with the growth of domestic hardware segment and then collapsed when that segment failed to take off. Large monopolies were a challenge to generic software product firms, as suggested by the story of InstaPlan. Generic software product market continues to be monopolistic.

If firms had the capability to produce software products for long, what does it mean to move from services to products? Does the emergence of software products like Flexube indicate the improved capability of firms as many researchers suggest? Or is it because of changing market conditions? Is there really a move from software service to product?

3.3.3 Service Capabilities

Since the Indian software industry does not focus on development of new technology, its innovation comes from improved service capabilities. Historical analysis shows that Indian software industry has been responding effectively to technological changes. From mainframe it moved to Unix and PC platforms. During the dot com boom of 1995, it entered web technologies, while catering to the Y2K market simultaneously. The good performance shown by the industry even after the end of Y2K demand and dot com boom, shows that the industry is effective in responding to changing market conditions.

Besides learning technology, firms have been improving software development process to achieve higher quality and productivity. From the 1990s, Indian software firms have been trying to get their processes certified as per ISO 9001 standard and Capability Maturity Model (CMM). Wipro technologies became the world's first firm to obtain CMMi (Capability Maturity Model Integration) Level 5 complaint. While firms went for certification mostly as a way to differentiate themselves in the market, they also gained in the process, managerial and organisational capabilities required to handle complex projects. India today accounts for the largest number of CMM Level 5 certified firms.

Arora *et al.* (2001) says that firm investment in R&D is very low. According to them, this confirms the notion that Indian software industry is

only providing programming services which require no new technological development. The discussion on software patents in this chapter also points to the same situation. They also note that R&D spending has been mainly by firms that create semiconductor intellectual property and a few large firms like TCS. Firms like Sasken (formerly Silicon Automation Systems) and EnThink (subsidiary of Wipro), have started investing in the development of new technology in the field of communication, mostly the new mobile communication segment. For these firms, business model centres around licensing of technology and contract R&D.

3.3.4 Moving Up the Value Chain

India is now a significant player in international software trade. In terms of quality, a mixed picture emerges. Concerns are being raised particularly about its export orientation and its impact on quality(Heeks, 1996; D'Costa, 2002). It is being argued that a lucrative export market is leading to a situation where firms work in low value routine activities which provide few learning opportunities. Considering the limited pool of human resources available, sustainable growth of Indian software industry could be hampered by its export orientation.

India's comparative advantage in software exports, comes from low wage rate. It has been noted that China and East European countries can challenge India's advantage in cost. Technology development is also in its infancy. To the question of how the industry can face the new challenge (Arora *et al.*, 2001) suggests the following :

> Developing tools is one way of reducing cost. A complementary strategy is to try to "move up the value chain", by providing services beyond simple programming services, intensive in industry specific business knowledge and technical capability. Together, these enable the software supplier to provide "solutions" to business problems, rather than simply programming services to implement solutions that the customer or firms such as Anderson Consulting and Oracle provide.

The view has been echoed by Balakrishnan (2006).

Arora *et al.* (2001), has further identified four strategies being adopted by Indian firms for this purpose.

> (a) developing mature software development processes to take on larger, more complex, and higher paying projects and effectively do more value added work; (b) understanding business needs of the customer and proactively developing business and technical solutions to existing problems; (c) developing products from the services provided earlier ("productized" services) and (d) entering emerging technologies and businesses such as multimedia and e-commerce.

While accepting that implementing these strategies is not easy, scholars like Arora *et al.* (2001), express optimism in the ability of Indian industries to do so. They say:

> We think that in the shadow of the much more prominent software services firms, we are finding firms developing a variety of new software products, components and technologies.
>
> ...
>
> A large number of software firms are de novo start-ups, indicating that the supply of entrepreneurial talent appears to be forthcoming when the opportunity arises, even in new and technology intensive sectors. These software firms are relatively flat organisations, with young management teams, informal but professional management styles, and with an emphasis on efficiency, punctuality and other virtues that an export orientation brings.

This observation is compatible with NASSCOM's comment on newly emerging software product companies(NASSCOM, 2007). According to NASSCOM, the Indian software industry is entering the third stage of its growth. The first stage of export growth was from factor arbitrage, the second stage was driven by domain expertise and quality of services delivery and the current stage by innovation and high value services.

To conclude, the final picture that emerges is that of an Indian software industry that has grown in quality and quantity. Its service capabilities have improved. Challenges and opportunities that have been identified for the growth of Indian software are primarily technology development and productisation. Innovation also comes out as an important issue. In the

coming chapters I will put these notions to the test based on micro level picture of innovation in firms.

Chapter 4

Innovation in Software Clusters - Case Study of Trivandrum

This chapter provides an account of the micro level investigation of innovation in software firms in Trivandrum. It is divided into three sections. The first section gives an overview of software industry in Trivandrum. The second section contains six case studies. The third, draws conclusions from the case analysis.

4.1 Software Cluster in Trivandrum

The origin of software industry in Trivandrum is closely linked to the origin of electronics industry in the region. In 1973, the Government of Kerala set up Keltron, a public sector electronics company in Trivandrum to accelerate industrialisation of the state. Keltron, under the leadership of the famous technocrat, K P P Nambiar, attracted the best talents in the area of electronics from the country. In 1980, Keltron set up a research and development centre with the support of Government of India under the name, Electronics Research and Development Centre of India (ER&DCI). The centre was headed by Dr Vijay P. Bhatkar, who is renowned for developing supercomputing in India with PARAM supercomputer series. Research and development activities of the centre enabled Keltron to come out with microcomputers in the early 1980s. Like all computer manufacturers of the

time, Keltron also had to develop software to run its computers.

Trivandrum is home to several other institutions dedicated to the advancement of technology. Two important institutions among them are Vikram Sarabhai Space Centre (VSSC), a space research and development organisation and College of Engineering, one of the oldest technology training institutions in the country. These institutions ensured availability of human resource in the area of software. While the latter produced human resource, the former attracted and held human resource in the region. The presence of these technology related institutions may have prompted the Government of India to locate one of the proposed nine software technology parks in Trivandrum.

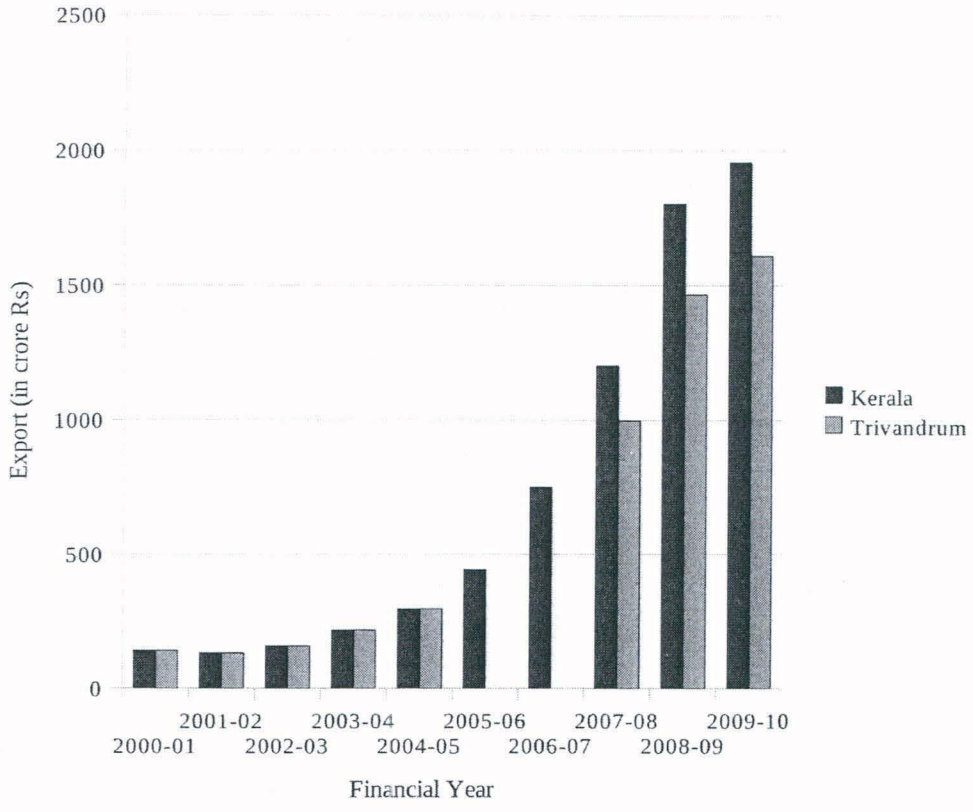
As early as 1990, the Government of Kerala had decided to set up a technology park in Trivandrum following a visit by the then Chief Minister, E K Nayanar, Industries minister, Gowriamma and K P P Nambiar to Silicon Valley. The ministerial delegation concluded that an electronic technology park would facilitate the development of electronics industry in the state. The technology park would provide an isolated and conducive environment for the growth of electronics industry in Kerala. The park became operational in 1995, providing all modern amenities for a high-tech industry. The park provided high quality redundant data communication facilities through satellite, fibre and copper links. It also provided modern facilities like convention centre, open air auditorium, conference rooms with multilingual translation support, cafeteria and hotels. The lush green environment was an added attraction of the park. There were not many electronic firms to operate out of Technopark. The software industry, on the other hand, found Technopark an attractive location. Technopark also provides incubation facility to foster the growth of new firms. The park is completely controlled by the state government. After a period of sluggish growth for the first five to six years, the park grew beyond its planned capacity to house around 200 firms and 30,000 employees. From 125 acres, the campus was expanded to 300 acres with 4 million sq. ft. of built-up space.

Information on export oriented software firms in Trivandrum is available from Software Technology Parks of India (STPI) and Technopark. Not much is known about the domestic software firms in Trivandrum other than Keltron and SunTec. SunTec is a domestic software firm started by

K Nanda Kumar who was an engineer at Keltron. A software developed by Nanda Kumar for telecom billing was implemented by the Department of Telecom for landline telephones in India. Its success created demand for the solution from outside the country and SunTec became one of the most important software exporting firms of Kerala.

4.1.1 Growth of Industry

Figure 4.1: Software Export from Trivnadrum

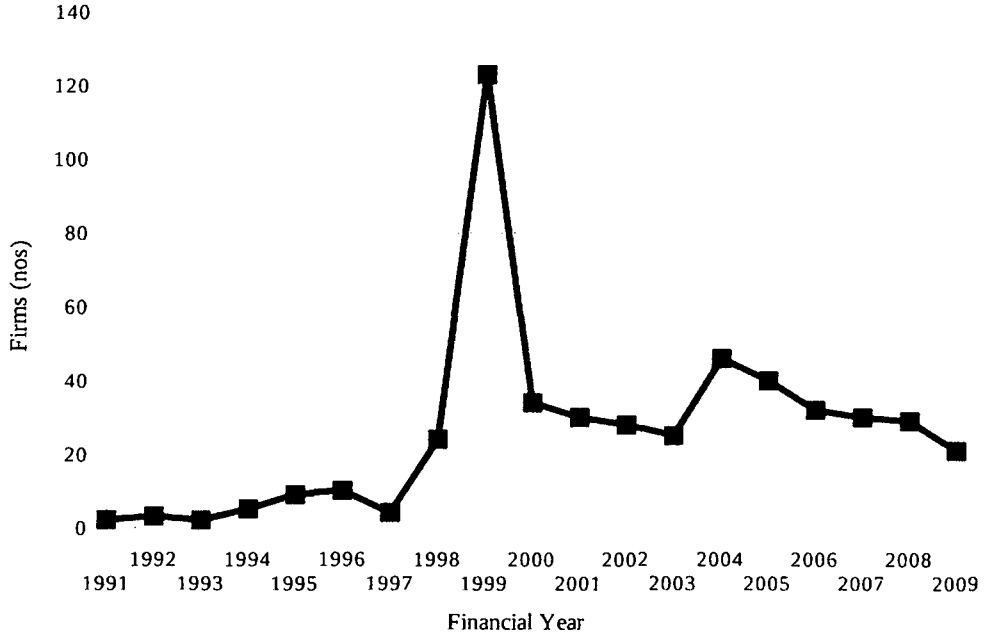


Source: Software Technology Parks of India, Trivandrum

Until 2004-05, the software industry of Kerala was largely concentrated in Trivandrum. Therefore, the total software exports of Kerala for that period can be considered as representative of the total exports from Trivandrum. Segregated data is available for total exports from 2007-08 onwards. As per the data, software exports from Trivandrum alone was more than 80 percent of the total exports from Kerala. Data from 2005-06 onwards shows more than 50 percent growth in exports from Trivandrum. A significant drop was seen in 2009-10 with a lowered growth rate of 8.5 percent.

Still, it is above the national figure.

Figure 4.2: Emergence of Software firms in Trivandrum



Source: Software Technology Parks of India, Trivandrum

In terms of registration of firms in a year, there was a sudden jump in 1999-2000. 123 firms registered with STPI during that period. After that, registration of new firms dropped to less than 40 firms a year. The figure again peaked in 2004-05, but declined later. 2009-10 recorded the lowest registration since 1998-99. This decline in export growth and firm registrations is attributed to the global economic recession.

While there is no specific data on firms that have wound up business, the data for the first five years of STPI operations shows that out of the 21 firms that had registered, only five survived. Two of them are software service providers- Network Systems & Technologies Pvt Ltd (NEST) and IVL India Pvt Ltd. Both of them focus on specialised software services in Embedded Systems and Enterprise Resources Planning respectively. Other surviving firms also work in specialised domains of IT enabled Services.

4.1.2 Overview of Firms in Technopark

Almost all the software exporting firms in Trivandrum operate out of Technopark either fully or partly. These firms operate in diverse fields such as software services, software product development, animation and

engineering services. As of November 2010, Technopark hosted 164 fully operational firms. They accounted for nearly 30,000 employees. Out of these, 110 are software firms and 52 are ITeS firms (2 are unknown). The analysis that follows is based on data compiled from multiple sources that include officials of Technopark and the firms and their websites (See Appendix A).

Table 4.1: Size and age of the firms in Technopark

	Mean	Standard Deviation	Min	1 Quartile	Median	3 Quartile	Max	n
Size								
Software	209.32	868.05	8	8	33	67	6000	98
ITeS	122.25	273.67	8	8	41	106	1754	47
Age								
Software	7.16	4.64	0	3	6	10	20	66
ITeS	6.22	4.41	0	3	5	9	19	37

Source: Technopark, Trivandrum. See Appendix A

Two software firms, UST Global and IBS Software Services, together account for nearly 40 percent of the total employment (6000 numbers each). Both firms were started by entrepreneurs from Kerala who were working abroad. They started operations in Kerala and expanded to other Indian cities. Based on data available for 147 firms, share of ITeS firms in total employment is 22 percent and that of software firms is 33 percent.

In terms of size, the industry is positively skewed. 26 percent of software firms and 31 percent of ITeS firms are in the incubation stage with 10 or less number of employees. Four firms in software sector and two firms in ITeS sector have more than 500 employees . The large software firms are IBS, UST Global, NeST and Infosys.

Table 4.2: Ownership of software firms in Technopark

	Nos	%
Foreign	28	31
Mixed[a]	6	7
Indian	57	63
Total	91	100

[a]Owned by foreign and Indian nationals. No data available on who is the majority owner

Source: Based on Appendix A

More than 60 percent of firms were started and are owned by Indian

entrepreneurs. Except for the two Indian IT majors, Infosys and Tata Elexi, all other firms were started in Technopark by entrepreneurs from Kerala. 31 percent of the firms are foreign-owned. There are no important multinational firms in the foreign firm category. What is noticeable is the presence of a large number of small firms from Europe in this group. Except for a few, all the entrepreneurs from Kerala had earlier worked in the IT sector in the US or Europe.

Table 4.3: Nature of activity by software firms in Technopark

	Nos	%
General Software[a]	67	61
Software Product[b]	14	13
Specialised Software[c]	9	8
Embedded Systems[d]	8	7
SAP[d]	6	5
Geographical Information System[d]	3	3
Web Portal[e]	3	3
	110	100

[a]Software service firms without any specialisation
[b]Software firms that sell software products
[c]Software firms providing solution in particular business vertical
[d]Software firms with particular technology specialisation
[e]Firms that manage web portal and develop software for that portal

Source: Based on Appendix A

Only around 40 percent of firms in the cluster show some specialisation in terms of technology or business vertical in which they work. All others are generic software service providers. There are 14 firms that focus on software products and six on ERP segment. Generic software service providers mostly work with web technologies. This enables them to enter the mobile applications market. A few innovative startups emerged from the state —SuryaKiran, a bio informatics firm and ArtinDynamics[1], an energy management product firm. Two important technological specialisations within the cluster are embedded technologies and ERP solution around SAP. In 1991, NeST introduced embedded systems and IVL introduced SAP to the cluster.

Even among firms offering IT enabled services, there are a few innovative firms like Alamy, a world leader in stock photography. 16 firms specialise in media. Two firms-one foreign and the other local- are into

[1]Firm has brought out an intelligent device to reduce the power consumption

clinical research and they network with bio-medical research agencies in the region. These innovative ITeS firms are not major employers. Employment in ITeS mostly comes from sixteen BPO/KPO firms. One of them, Accentia Technology, has grown rapidly and has branches across India and USA.

4.1.3 Firms Under Study

Six firms promoted by entrepreneurs from Kerala were selected for this study. Except for one firm, PIT Solutions, all the others are fully owned by entrepreneurs from Kerala.

Table 4.4: Summary of firms selected for case study

Firm	No of Employees	Year of Establishment	Domain
NeST	1000	1991	Embedded Systems
SunTec	400	1990	Software Product
QBurst	300	2004	Software Service
PIT Solutions	128	2000	Software Service
InApp	100	1996	Software Service
Ospyn	25	2008	Software Service

Source: Based on Appendix A

Firms were selected in such a way that their diversity (age, size and area of work) is captured in a reasonable manner. In terms of size, NeST is one of the largest in the cluster with more than 1000 employees. Ospyn on the other hand, represents small sized, emerging firms.

In terms of age, SunTec and NeST are two of the earliest software firms in the cluster. Ospyn and QBurst represent two of the new comers in the field. PIT Solutions and InApp emerged in the early days of Technopark, riding on the dotcom boom. QBurst is a recent entrant with high growth rates in terms of employment.

In terms of area of operation, SunTec is one of the few product firms in the cluster. NeST provides specialised service in embedded systems and R&D Services. All the other firms represent generic software service firms. They form the majority of software firms in Technopark.

Three important gaps in the selection of firms are 1. Non representation of the two large software firms that account for nearly 40 percent of work force 2. Non representation of firms that focus on specific technology like

SAP or GIS 3. All the firms except Ospyn, belong to the upper 25 percent of firms in terms of employment size. Although I invited the participation of more firms, many of them did not volunteer. However, these gaps will not affect this study significantly as it does not aim at statistical generalisation. Evidence from these case studies are used to validate and analyse macro level observations made in literature.

4.1.4 Case Study Structure

The individual case studies given below do not follow a strict structure. The structure has been made flexible to capture diversity of the firms. It addresses the following questions. 1. What is the nature of innovation in each firm ? 2. How does a firm innovate and what are the important sources of innovation ? 3. Is there localised knowledge spillover ? 4. How does the clustering add value to a firm ?

Keeping the above questions and theoretical framework in mind, a broad outline has been given for case studies.

1. Innovation in the firm and nature of innovation
2. Source of innovation
3. Learning process
   (a) Role of R&D (Science and Technology learning — STI learning)
   (b) Interactive learning(DUI learning) and Non Disclosure Agreements(NDAs)
4. Localised knowledge spillover and channels of spillover
   (a) Inter-firm linkages
   (b) Worker movement
   (c) Other organisational linkages
5. Contribution of Technopark and the local region to innovation
6. Constraints to innovation
   (a) Funding
   (b) Human resources

4.2 Individual Case Studies

4.2.1 Network Systems and Technologies Pvt Ltd

Network Systems and Technologies Pvt Ltd (NeST), is one of the oldest software export firm in Trivandrum. It started operations from Software Technologies Park of India, Trivandrum in 1995 and later moved to Technopark. It was the brain child of Dr. Javad K. Hassan, a technocrat who has more than 20 years of experience in IBM. The firm, today employs more than 1200 workers in its software services division and is one of the largest firms in Technopark.

NeST is unique in many aspects. It is one of the few firms in Trivandrum which provides technical service in the area of Embedded Systems. Another feature of NeST is its market focus. Unlike most other software firms whose primary market is USA, for NeST it is Japan.

NeST provides high-tech engineering services involving software and hardware. It works with the R&D wings of client firms which develop new products in areas like automotive engineering, health care and avionics. Often, the client firms are not able to define their product specification. NeST takes advantage of its experience and knowledge in the product domain (functional area of the product) and provides input required to complete product specification. In this manner, the firm directly participates in the innovation process of clients.

Nature of Innovation

NeST is a firm that has an exclusive R&D division which became operational two years ago. Today, it has 15 research staff. Some of them are on leave from public - held academic institutions. The R&D team works in areas like image processing. Its area of research is influenced by the focus area of clients. Its interest in image processing comes from its collaboration with medical imaging equipment firms.

The R&D division has published several papers. While most of its innovations are linked to very specific equipment and requirements of client firms, it also develops generic solutions based on its experience in certain domains like medical imaging equipments. Work is also in progress for patenting some innovations.

Another innovation introduced in the firm during the last two years is the induction of fresh graduates. In the area of Embedded Systems, technological options are many. Clients come with different choices and a firm has to have expertise in many technologies to be competitive. The fresh graduates recruited by NeST, usually do not have the expertise that allow them to be productive. This increases the pressure on experienced employees who has to address the client needs and at same time train the new recruits. NeST has now developed a new induction programme wherein, new recruits are given focused rather than a general training on Embedded Systems. Training is on specific technologies being used by clients with whom NeST has a long term relationship. Manpower requirements are planned with the clients. The new process has the benefit of faster adoption of new recruits in production process and reduction of dependency on senior employees.

Knowledge Spillover from Client

Spillover from client is an important knowledge source for NeST. Manufacturers of hardware products for medical imaging, automotive, etc., approach NeST for software. For NeST to develop software for them, like a device driver[2], the client has to disclose a lot of information on the hardware internals. This knowledge is often highly proprietary in nature and protected by patents making it very difficult to access otherwise. Increased capability of the firm from these knowledge spillovers is evident from the fact that clients have started entrusting NeST with complete product development including hardware and software.

Other Knowledge sources

Another important source of knowledge for NeST is online forums like Linux kernel mailing list. It considered much more important as a source of knowledge than experienced professionals in the cluster. In these forums, a lot of experience-based sharing of knowledge happens. As a query raised in these forums is likely to be seen by more people than one can imagine, chances of getting an appropriate answer is high. Extent of knowledge

[2]Piece of software which enables users to directly control the hardware or the electronic unit. Development of device drivers are considered a high value service

sharing is also very high in free software forums like Linux Kernel mailing group. A lot of tacit knowledge flows through these forums.

Increased adoption of free software in Embedded Systems has been of benefit to NeST. Client firms are also demanding free software more as it brings financial advantages to them. Nearly 50 percent of NeST's projects are based on Linux or related free software platforms.

NDA and Learning

Generally, client firms try to limit service firms from taking advantage of knowledge spillover through NDAs. NeST and its employees agree to NDAs that limit the movement of employees from one client's project to another for a stipulated period of time, within and outside the firm. NeST weighs the risks in restricting workers against potential benefits. The benefits include direct financial gains and indirect gain of knowledge from the client.

Inter-firm Linkages

Inter-firm linkage within the cluster was non-existent until very recently. In recent times, web and Internet technologies are integrated with Embedded Systems, particularly in consumer electronics segment. While NeST does not focus on web technologies, many firms in the cluster do so. This has made it possible for NeST to take advantage of expertise in web technology that is available within the cluster for its product development. Similarly, software testing is an activity that NeST would like to outsource to firms in the cluster. The challenge for NeST is to grow mature enough to clearly state its requirements so that testing can be done almost mechanically following instructions. It experimented with a potential partner and the outcome was positive. More testing activities will be outsourced in the coming days.

Worker Movement

According to a senior manager of NeST who had been working in Bangalore until recently, attrition rate is very low (7-8%) in Trivandrum compared to Bangalore. It is the young employees who often move in search of better options to usually larger clusters like Bangalore.

Increased employment option in Trivandrum cluster is attracting experienced professionals who are originally from Kerala. This has helped NeST to obtain highly skilled human resource in certain areas. There is hardly any movement of experts from other states to Trivandrum.

Being in Trivandum

The founders of NeST decided to set up their firm in Trivandrum because they were natives of Kerala. When it started operations in Trivandrum, NeST required experienced electronics and software engineers. Many of the team members came from public institutions like Vikram Sarabhai Space Center, Keltron (a public sector company in electronics industry) and Center for Development in Advanced Computing (CDAC, earlier known as Electronics Research and Development Center). If not for these organisations, it would have been difficult for NeST to obtain professionals. It has also established relations with CDAC to avail its expertise in certain areas and to jointly explore business options. According to a senior manager in charge of research, NeST will have to depend on research organisations like CDAC and academic institutions to access specialised knowledge in future.

Other location advantages include low operation cost and low attrition rate peculiar to a small city. It has its disadvantages too. Most importantly, it is very difficult to find specialised human resources in the cluster. It is also difficult to attract such resources from other parts of the country as the city offers very little advantage to them. NeST has the risk of losing potential clients as they may explore partnership with firms in larger cluster.

Technopark has helped the firm to grow by providing some form of isolation from social unrest and good quality infrastructure. Its brand value helps firms to attract human resources. Without this facility, NeST would have found it difficult to operate in the region.

Challenges to innovation

NeST does not see many constrains to innovation based on its plans for future. Its budget for R&D is very small compared to that of product firms. Manpower has not been a challenge for its R&D plans as it is looking only for a very small number of personnel. It is able to attract human resources

from academic institutions in the region. The only challenge is, orienting them in target based approach of commercial organisations.

4.2.2 QBurst

QBurst is a medium sized software services company that specialises in web and mobile applications. It was founded in 2005 by three friends who hd been working in software industry. QBurst grew rapidly in a span of five years from three to nearly 300 employees, in what may be one of the fastest growth recorded in the history of Technopark.

Nature of Innovation

According to one of the founders, the company owes its success to the emphasis on technological capabilities over management structure and processes. He rejects processes like CMM and calls for more flexible(agile) methodology. The founders have ensured that the management system does not constrain technological innovation. The individual developer is given substantial freedom. This does create some new challenges for the firm — workers should be skilled enough to manage projects on their own as there is only a weak system to provide checks and balances. Alternative systems are put in place, like frequent release and interaction with client following agile methodology of software development which provides some control.

Though there is no exclusive R&D division or R&D budget, resource and time of employees are spent on absorbing new technologies. This enables QBurst to be on the cutting edge of web and mobile technologies, cloud computing, Software as a Service (SaaS) model, Smart Phone applications development etc. As soon as Google came up with its technology for SaaS, the firm was among the first to adopt it. Today its entire internal operations are managed by an application hosted in cloud using Google technology. It has 19 employees working on iPhone/Android smart phones. More than 50 iPhone applications and around 10 Android applications have been developed by the firm. It is to be noted that even firms that are far more experienced than QBurst find it difficult to enter the iPhone market as they are not able to retain professionals trained in these technologies.

Learning Strategies

Unlike many other firms which depend on the lead entrepreneur for implementing innovation, QBurst looks up to its employees for innovation. Many new technologies were brought to the firm by employees. QBurst is successful in creating an atmosphere in which employees are free to experiment and innovate. Employees are often trusted when they come up with new ideas. The firm takes some risks in this process but is able to be on the cutting edge of technology. Most of its clients are also innovative service or product start ups. Client firms look for support on latest technologies from QBurst. This also requires and motivates the firm to be at the frontier of technological knowledge. A fertile climate for learning and experimentation is what differentiates QBurst from other firms.

Knowledge Spillover from Client

Knowledge spillover from client firms is very high. Many of them are aggressive product companies that demand a lot of learning and experimentation from QBurst. Knowledge spillover is mostly related to user needs. In some projects, client firms directly manage the team in QBurst.

QBurst provides technical know-how to other firms in the cluster. While it does not focus on any particular domain, local firms which avail its services are focused on some business domains. All of them demand technical expertise of QBurst.

Worker Movement

Employee attrition rate in QBurst is around 30 percent in the first 6-9 months. At the end of induction period, attrition drops to 3-5 percent. QBurst also started a center in Kochi to address the needs of professionals from North Kerala who want to be closer to their home.

QBurst's emphasis on technology is helping it attract experienced professionals. In most firms, an employee has to take up project management responsibilities instead of technical work, as he/she gains experience. Otherwise it would limit their career growth within the firm. This discourages professionals who are more keen on technical work. QBurst is able to attract professionals looking for technology oriented work, even from large

firms. This may also explain why QBurst is able to grow rapidly in terms of number of people employed.

Challenges to Innovation

QBurst's major challenge to innovation is lack of trained professionals in its area of work. It depends heavily on free software tools and makes use of various free software forums to source knowledge. It doesn't consider state support for research and development necessary or useful.

Being in Technopark

According to the founders, the advantage of being located in Technopark is the social isolation it provides. They were able to set up the firm rather quickly in Technopark. QBurst also operates from an independent office outside Technopark.

4.2.3 SunTec

SunTec started out as a single man company in the late 1980s. Its founder, Mr Nanda Kumar, developed a billing application for the Department of Telecom, Government of India. In the mid 1990s, SunTec started attempts to enter the international market. In 1999, it bagged its major international order from Logica in Netherlands. The company never had to look back after that. Today it accounts for more than 250 installations around the world.

SunTec is one of the few software product companies in Technopark. Its main product is a transaction based billing system. Originally, it was a billing software exclusively for fixed line telecom service providers. Later, during an interaction with one of his clients, the founder got the idea of making it into a generic software product for any kind of transaction based billing. This allowed for the product to be deployed in different kinds of industries. The product which was earlier called Telecom Billing and Management System (TBMS) was renamed as Transaction Business Management System. SunTec made this change at a time when the financial sector was introducing transaction based and personalised pricing models in its services. TBMS perfectly fitted the needs of this sector. SunTec got

IMG bank, Netherlands, as a client from the financial sector. The first major innovation of the firm took it beyond telecom sector billing. The product got extended with several additional modules providing complementary functionalities like customer relation management and work flow management.

The major research activity being undertaken by the firm is the move from batch to real time billing scenario. Real time billing is essential in a situation where prepaid is becoming a popular model of payment. There are technological limitations to be overcome like telecommunication switches not being able to provide information in real time. As the world moves in the direction of real time billing, the firm needs to make its product ready for the new business scenario. SunTec has been continuously improving its product with changing technological regime. It started with Character Interface and progressed to Graphical User Interface, Client Server model, n-tire architecture and real time billing.

The product forms the basic platform for billing system. Solutions are built for different business firms on this platform. Right now, SunTec is the only important solution provider on TBMS platform; the others are insignificant in terms of scale and level of value add.

Innovation and Domestic Market

The scale and complexity of the billing solution for the Department of Telecom, Government of India posed a lot of challenges for SunTec. But the experience prepared SunTec to face challenges in the international market. According to a senior manager heading R&D of the firm, "After working in a challenging environment with DoT (a large domestic client), the international market was cakewalk". As DoT was the sole telecom provider during the early days of SunTec, the firm had to look outside the country for new clients. The domestic market provided learning opportunity for the firm.

Role of R&D

SunTec has been continuously updating its product based on changing platform software technologies. From non-graphical interface in Unix environment it moved to graphical interface in Windows operating systems

and then to web technologies. It is now attempting to do away with its dependency on Oracle database system so that software can work with other databases.

It is the responsibility of internal R&D team to monitor technological changes. The team decides on product enhancement in consultation with market research team. Both the teams work under the same leadership. As a technology person with a good understanding of market, the CEO too, is able to provide new ideas and inputs to R&D. Based on these inputs, a strategic roadmap is prepared for product development. R&D comes up with a new version of the product every 6-12 months as incremental and continuous innovation is an essential activity. There are 100 employees in R&D, which is a quarter of the total manpower of the firm at the moment. Of this only around 15 are involved in core research including market R&D.

Source of Innovation

One of the most important sources of innovation is user groups that SunTec has fostered around its product. These user groups bring together users of its products in various business domains. They function as online forums. These user groups share their knowledge as they use the product. Users also help each other by sharing ideas and experiences. Ideas brought into the user group forums and interaction of pre-sales team of SunTec with existing and prospective customers provide various inputs for the innovation. A lot of input for innovation comes from suppliers like HP and IBM.

Inter-firm Linkages

SunTec is planning to outsource some of its work like testing, to other firms in the cluster. Its internal processes have improved enough to enable it to outsource testing jobs. Firms specialising in testing have been evaluated by SunTec for one year and their capability has been found to be sufficient. In a year, SunTec will be outsourcing a significant part of its testing activity to local firms. It also has linkages with NIIT for training.

Worker Movement

It is seen that most of the experienced workers move to clusters outside as there is no other firm working in a similar business domain within the

cluster. Relatively less business specialised human resources like software testers move within the cluster. While SunTec does not find it difficult to get fresh talent, getting specialised human resource is a challenge. It does not find recruiting specialised human resource from outside the state a fruitful solution as people are not interested in moving to Trivandrum. Sometimes people do come from outside the cluster mainly because they want to relocate to their home town.

The firm's strategy to overcome challenges in recruiting specialised know-how, is to build its capabilities from within. Training and knowledge management team within the firm plays a very important role in addressing this challenge. SunTec's specialised training system helps to make fresh graduates productive within a short time.

Quality Processes

SunTec is CMM level 5 certified and is going ahead with its plan to make the organisation CMMi certified. The certification *per se* has not contributed much to the firm's innovation. However improvement in processes has improved its efficiency in deployment. Efficiency of development also improved with improvement in processes, enabling the firm to quickly transform an idea to a tangible product.

Challenges to Innovation

Economic recession did affect the R&D activities of the firm. Manpower is not considered a major challenge to innovation. The firm overcomes manpower challenge by means of a large pool of engineers working at different levels within the firm. An engineer working in solution deployment may be moved to development and research as and when the need arises. Internal knowledge management also helps.

4.2.4 InApp

InApp is a medium sized software service firm in Technopark. It was started in 1999 by three entrepreneurs. Two of them were based in Kerala at that time and one person was in the US. The promoter in the USA acted as a channel for sourcing projects for the firm. InApp represents a typical

software service firm in Technopark. It does not focus on any business vertical. Technologically it focuses on web technologies. InApp provides custom software solutions to various clients in the US and Europe. Despite being fairly small, it is well recognised because of the active participation and leadership of its promoters in local professional organisations. As a firm, InApp did not show rapid growth until recently, due to the deliberate decision of its promoters to keep it small. Recently they changed their policy, as a result of which the organisation is undergoing significant expansion. It has acquired two firms in the cluster. It is one of the early adopters of FOSS in the cluster.

Nature of Innovation

According to one of the founders of InApp, the firm did not make deliberate effort for innovation until the recent global economic recession. Till that point of time, the leadership had been quite content with the work flowing in and it never made an effort for growth. Recession changed the situation. With its regular source of demand weakening, the firm had to find new opportunities and markets, not just for growth, but for survival. This set the firm in two new directions. It recognized that India is emerging as a strong market, not much affected by the recession. It identified a couple of software products it had developed for clients which could be of demand in the local market. In consultation with its clients, it decided to launch those products in the domestic market. It found an opportunity when Hindustan Lever wanted a solution to manage its saloons and spa and InApp had a solution for this.

InApp floated a spin-off firm together with the original owner of the solution and successfully introduced it in the domestic market. The principal competitor was TCS. Despite being a very small firm in a remote corner of India, InApp could deploy and manage this solution across India because of the software's unique technological features. Technological quality demonstrated in the pilot phase and its installation base in Europe and the US, helped InApp gain over TCS.

The second strategy InApp identified to overcome recession was to enter the closed Japanese market. As one of the promoters had worked in Japan for long, it had some understanding to explore the market. It knew it was not a very easy task as there were linguistic and cultural barriers to

be overcome. InApp started training its staff in Japanese language and assigned one of its staff to move to Japan. With the help of a friend of the promoter, it started operations in Japan. Today, it has its first project coming up in Japan, though language and culture still remain major obstacles.

Another major innovation of InApp came from its users. Enquiries from its clients on application development for iPhone, Android etc., led them to work on this emerging technology. While it could move quickly with Android, it faced a lot of challenge in entering the iPhone market as entry is restricted by Apple. Without entering at least one application in the market controlled by Apples, it is very difficult to establish credibility. In terms of demand, iPhone is much more in demand than Android though the situation is changing. Openness of technology does seem to influence innovation possibilities of service companies.

Knowledge Spillover from Client

A lot of learning happens when the teams in the US(client) and India work together. InApp was able to gain experience in software quality process through this kind of learning. It first recognized the value of such learning when a testing team from InApp worked with a two member team in the US. Knowledge spillover in this process led to quality improvement in the testing process of InApp. Considering this experience, InApp now gives a lot of importance to knowledge sharing by team members at the end of each project. Working with demanding clients led to a lot of learning.

Inter-firm Linkages

InApp does not have any linkage with other firms in the cluster. Regarding knowledge spillover from the firm, what is notable is the active role of its founders in professional organisations like Institute of Electrical and Electronics Engineers (IEEE). Through this, the firm is able to transfer its knowledge to students and other professionals. While knowledge shared this way need not benefit the firm or even the cluster, it helps the society at large. One of the founders of InApp cited an instance of generating interest among students in Android application development. He believes

such knowledge sharing will lead to students studying these technologies. He himself gained knowledge from professional communities.

Worker Movement

Until recently there was a system within Technopark which restricted the mobility of new recruits with less than three years of experience. There was also an informal rule that when a firm wants to take a worker from another firm it will inform the latter before doing so. These rules are no longer in force. These were abandoned when a major Indian firm entered the cluster and decided not to comply with them.

InApp identifies two reasons for worker movement. One is related to marriage, where male workers want the label of a big firm to improve their prospects in the 'marriage market' and female workers want to be in their husband's place after marriage. Often, completion of an important project creates a sense of accomplishment in the employees, which may not be complemented with special financial incentives immediately. This prompts employees to leave the firm. Attrition rate of InApp is 3-5 percent.

Quality Practices

InApp is CMM Level 5 certified. Customers are divided on the nature of the processes to be used. In any case, InApp feels that adoption of CMM has led to creation of a common set of vocabulary for project related communication within the organisation, ensuring effectiveness. This also helped it identify and address issues in its functioning. Certification is an important differentiator in the market. It sends a positive signal to potential clients, in terms of organisational commitments.

NDA

InApp did not experience any constraint due to NDAs in their innovation process. It has not tried to use of any proprietary knowledge from clients for its innovation.

Being in Technopark

InApp had tried to set up a unit outside Technopark with out any success. InApp's employees in that unit, wanted to move to Technopark considering its brand value. Unlike firms like NeST and SunTec, InApp does not have a brand value that matches Technopark's. One of the founders of InApp feels that firms would have emerged even without Technopark, only that they would have been few in number and more dispersed.

R&D Funding

Although the firm spends on R&D, it does not account them separately. R&D expenditure is not well planned either. It has never obtained R&D funding from outside or felt the need to do so.

Challenges to Innovation

It is very difficult for a small firm to train and retain human resource e.g. when InApp wanted to enter iPhone market, it trained young recruits on Objective C programming. As soon as they completed their training, their market value changed and it became difficult to retain them. For small firms it is not sufficient that they produce an innovative output. They need to retain personnel with knowledge base so that production process can be sustained.

4.2.5 PIT Solutions

PIT Solutions was started by two friends from Kerala, who had worked together in Switzerland. Their firm focuses on web technologies. Unlike most other firms in the cluster, PIT Solutions has clients mostly from Northern Europe. The firm started its operations in Technopark, Trivandrum in 2000 with four members. Today it has more than 100 employees. The company grew rapidly during the last four years despite global economic recession.

Nature of Innovation

According to one of the founders, the company owes its growth to the early adoption of technologies. Its expertise in certain technologies like TYPO3

is unique to the cluster. TYPO3 is a web content management system very popular in some parts of Europe, but relatively unknown outside. The firm's expertise seems to be linked to its focus on certain European countries. Like InApp, PIT Solutions also focuses on providing software development service to clients. Its innovation comes from learning new technologies and expanding service capability.

Worker Mobility and Challenges to Innovation

The founders of PIT Solutions noted that workers who gained experience and knowledge migrate to larger firms. Soon after a challenging project is completed, it found experienced professionals in those projects moving to larger firms. In the process, the firm lost important knowledge and skill which could have helped it innovate further.

Inter-firm Linkages

Recently PIT Solutions started outsourcing some of its work to smaller firms in the cluster because it could not cater to the increasing demand on its own. It was not in a position to reject the work either, as it would have affected its long term relation with clients. However, outsourcing has not been a positive experience as small firms do not adhere to the quality requirements of the client. At the same time PIT Solutions does have plans to outsource work in the future.

The firm also provides input on TYPO3 to other firms in the cluster. It does not feel that knowledge sharing will affect its business prospects. Knowledge sharing in this context takes place through formal exchange.

Quality Practices

Like most other small firms, PIT Solutions also rejects quality certifications like CMM. According to the firm, CMM is not popular in Europe and hence it has no marketing advantage. The firm also adopts agile methodology. However, a lot of learning comes from clients, particularly on quality and processes.

Being in Trivandrum

One of the major challenges to innovation is the difficulty in attracting professionals with specialised skills like large scale system architecture to Trivandrum. Although PIT Solutions was able to bring professionals with expertise in these specialised segments from outside Kerala to Trivandrum, they left the firm within a few months. One reason cited is the lack of cosmopolitan multi ethnic community in Trivandrum. Another reason is the lack of a vibrant urban culture like in big cities. Even reverse migration of Keralites has not helped in making specialised human resources available. The financial expectations of experienced professionals returning to Kerala is so high that small to medium firms are not able to attract them. In effect, the firm is not able to benefit from such return migration.

Technopark helped the firm to start operations quickly. The reputation and brand value of Technopark helps it attract employees, who value these over and above the firm's identity.

Challenges to Innovation

A major constraint to innovation is the lack of right kind of skilled personnel. Financial resource has never been a limiting factor. Interestingly, PIT Solutions is a firm which benefited from recession. It grew rapidly during this period, as its client base was not severely affected by recession. Worker movement was limited during this period. It could recruit the best students from colleges as most large firms had stopped recruiting during recession.

4.2.6 Ospyn

Ospyn, a very young startup, was started one and a half years ago by two employees of a software service firm in Technopark. Ospyn today employs 25 people.

Nature of Innovation

Ospyn's most important innovation is its business strategy to focus on free software and generic software tools for businesses. Its service is not based on

knowledge of any business domain like financial sector or retail marketing, but on capabilities it builds around free software to perform some of the common tasks in a business enterprise. The firm provides FOSS solutions to various business operations like reports creation, Enterprise Document Management etc. It also has capabilities in the emerging field of cloud computing.

Profiting on Recession

Ospyn was successful in finding business opportunity during recession. While firms had to cut down on their IT infrastructure costs, they had to remain competitive. In order to do that firms used FOSS with necessary customisation, wherever possible. Ospyn decided to leverage on this market by building specialised service capabilities in certain segments like Enterprise Document Management.

Focus on Technology

Though Ospyn's founders come from one of the largest software service firms in the cluster which focuses on a particular business domain, they want to focus on technology development. They do not want to develop domain expertise in any particular business segment. According to one of the founders, his most important learning from his previous firm has been about running business and developing strategies.

The firm depends on its tech-savvy founders for ideas and innovation. This is not unexpected, considering that it is in its early stage of development. On the other hand, the founders would like to create an environment in which employees learn and innovate. Innovation, according to the founders, comes from the freedom to explore. From the point of view of technology, Ospyn is building expertise in cloud based solutions. It is also building cloud based solution for its own operations management, which it hopes to make available to customers at a later stage.

Working with FOSS Model

A business model based on FOSS brings new challenges to the firm. In a commercial environment, the firm has to integrate FOSS system with other

proprietary systems. It needs to have legal expertise to help client firms in doing this integration.

NDA and Learning

NDAs have limited role in Ospyn as it does not deal with core business knowledge of the client. Services provided by the firm depend on the technical knowledge it has of various free software tools. Its value depends on the tools in which it specialises. It builds reusable software components to address some generic business needs like report creation and document management.

Quality Practices

Going by FOSS model, Ospyn adopts light weight software development processes like agile processes. While it finds value in having good processes within the firm, it does not think having certification like CMM is essential. Its potential client base — small and medium businesses — does not require certifications like CMM. Ospyn's founders believe that most firms 'buy' certifications to differentiate themselves in the market but they hardly implement processes properly to improve quality.

Worker Movement and Inter-firm Linkages

As a recent entrant which is small in size, Ospyn is yet to have any major effect from worker movement or inter-firm linkages. Its employees, at the moment, are fresh graduates. Since the firm is small, there is good interpersonal relation among team members which makes them stick to the firm.

Being in Technopark

The reason Ospyn chose to be in Technopark, is its brand value. Often a person is identified as an employee of Technopark, rather than any particular firm in it. This makes employment in firms within Technopark more attractive to prospective employees. Small firms like Opsyn think that it will be difficult to attract employees if they operate outside Technopark. Infrastructure provided by Technopark also gives a sense of value to global

clients. Opsyn, however, feels that infrastructure cost in Technopark is higher than that outside.

R&D Funding

The firm does not have R&D initiative. It is not interested in availing funding for R&D or product development. According to its founders, product development firms need long term planning and investment, which is beyond a small firm like Ospyn. In the long run, they would like to raise their own funds to develop software products. They think that they are better off using their own resources for learning technology and providing service customisation of technology.

Challenges to Innovation

A major challenge for innovation according to Ospyn's founders, is the dearth of quality human resource. They feel that educational institutions are not able to hone quality human resource. According to them, the focus on technology development is being lost in large service firms which limit themselves to body shopping. This approach indirectly influences education by reducing pressure on institutions to aim for technical excellence.

4.3 Insights from the Case Studies

4.3.1 Nature of the Firm

Entrepreneurship and Origin of Firm

Stories narrated in the case studies happen to be the stories of a few entrepreneurs from Kerala. These men and women had moved abroad years ago to make their fortune in software industry and built linkage with potential client market. Later, some of them returned home, set up business here to serve a market they had identified and contacted during their tenure abroad. Their linkage with potential market in the US, Europe or Japan was critical to their firm's origin. In the early days, working with foreign firms was what connected potential entrepreneurs and the foreign market. Recently, large firms within the cluster have taken that role.

Most firms were set up using promoters' own savings. The promoters never approached any financial intermediaries like banks. In general, firms are risk-averse and the small risks that they take are largely mitigated by the huge demand that exists. According to the founder of a medium sized firm, most software firms that started operations with borrowed money during the boom of 1999-2000 have failed.

Product and Service

All the firms started off as software service providers. While NeST specialised in Embedded Systems, the other firms focused on developing custom software. SunTec, which started as a provider of billing solution for Department of Telecom, later turned the solution into a generic software platform, a software product. It customises this product for various client needs. This product is not a typical Commercial of the Shelf Software, like Oracle database or SAP ERP system. Still, it demonstrates the high level of technological capability that SunTec has achieved. SunTec's investment in a generic software platform paid off in terms of increasing the firm's productivity. SunTec is now able to deploy complex custom solutions for clients faster. It is also able to provide service to more than one business vertical using the same generic software platform.

Other firms, such as Ospyn and PIT Solutions, do not have technological specialisation like NeST or domain specialisation like SunTec. They use FOSS platform, which is not their exclusive property to provide custom software. In a way, they also show some form of specialisation in their service. Among the generic service firms, the older ones like InApp and PIT Solutions have a few software products of their own. Their business model is not based on selling these products. These products evolved in the course of their work with various clients. They can be considered as reusable software modules that evolve from recurring requirements which provide some generic technical functionalities or domain specific functions. This represents learning by doing and knowledge accumulation within service firms. New firms like Ospyn do not have this stock, and their adoption of FOSS products is partly a strategy to overcome this gap.

4.3.2 Nature of Innovation

The case studies show that firms adopt diverse strategies for innovation. Even within the category of generic software with very low firm differentiation in terms of service offering, different types of innovation exists. While we cannot argue that this diversity is statistically significant, case studies point towards such diversity.

The most important form of innovation taking place within the cluster of software firms in Technopark is the adoption of new processes and technological capabilities. Innovation arising out of technological invention is manifested in two ways. One, by adding new features to an existing product using new technology. Two, by adding new technology based service to a portfolio of services offered by the firm. Except for NeST, no other firm attempted technology development on its own.

'Necessity is the mother of all invention', so goes an old adage. Likewise, for software firms in Technopark, innovation is also linked to the challenges they face. The most important and the most common innovation is related to human resource. Skilled human resource is the most important input for firms in software industry and it also forms its biggest challenge. None of the firms consider competition a major challenge. Nor are they short of demand. What they lack is the human resource to cater to high demand. Another challenge is the attrition of workers. Firms invest time and effort to train new recruits before they become productive. When an employee leaves a firm, it loses on its investment. It is not easy to replace employees as skilled resources are in short supply. Client demand also puts pressure on firms to address resource gap quickly. All the firms have their own innovative strategies to reduce attrition and recruit productive personnel.

Economic recession also forced firms to innovate. In the aftermath of the recession, InApp began to identify new markets. It started looking for business in the domestic market and in the relatively closed market of Japan. Ospyn tried to turn the recession into an opportunity for itself. It realised that clients would want FOSS based generic solutions over proprietary solutions, as a cost cutting measure for their businesses. Ospyn identified this market opportunity and became an exclusive and specialised provider of FOSS based solutions for businesses.

Another common innovation seen within the cluster of software firms, is the adoption of new production processes. Firms learn about production

processes of client firms and adapt them to their needs, thereby improving efficiency. Firms consider knowledge they gained on quality procedures in software production as particularly important.

Table 4.5: Innovation in firms under study

Firm	Firm Type	Type of Innovation	Source of Innovation opportunity	Knowledge Source	Significance of NDA	Learning Mode	Presence of formal R&D
NeST	Embedded	New technology development; HR process	Development in hardware technology	Hardware manufacturers (client), FOSS community, Research organisations	Strong	STI Mode	Yes
SunTec	Software Product	New features in product, HR process	New Platform Software technology; New business requirement(eg. real time billing)	Suppliers of Platform Software; User community	Nil	Combination of STI and DUI	Yes
InApp	Software Services	New market, New technological capabilities, New quality practices	Learning new software technology	Suppliers of Platform Software, FOSS Community	Moderate	DUI Mode	No
PIT Solutions	Software Services	New technological capabilities, New quality practices;	Learning new software technology	Suppliers of Platform Software, FOSS Community	NA	DUI Mode	No
QBurst	Software Services	New technological capabilities, New organisational practice	Learning new software technology	Suppliers of Platform Software, FOSS Community	Nil	DUI Mode	No
Ospyn	Software Services	New technological capabilities	Learning new software technology	FOSS Community	Nil	DUI Mode	No

Source: Own compilation

4.3.3 Systemic View of Innovation

Firms are at the core of any innovation. They take the lead role in identifying a potential need for which to innovate, sourcing various inputs required, interacting with other actors and finally introducing innovation in the market. The case studies illustrate that entrepreneurs are critical for innovation. In all the firms considered, there is an entrepreneur who is connected to the market, and has a base in the cluster to tap the resource available. As the size of a firm increases, other factors including employee capability, market research, product R&D etc., become significant. Considering that most firms in the cluster are small, relatively young and privately held by some technologist-entrepreneur, role of the entrepreneur is going to be important in terms of innovation.

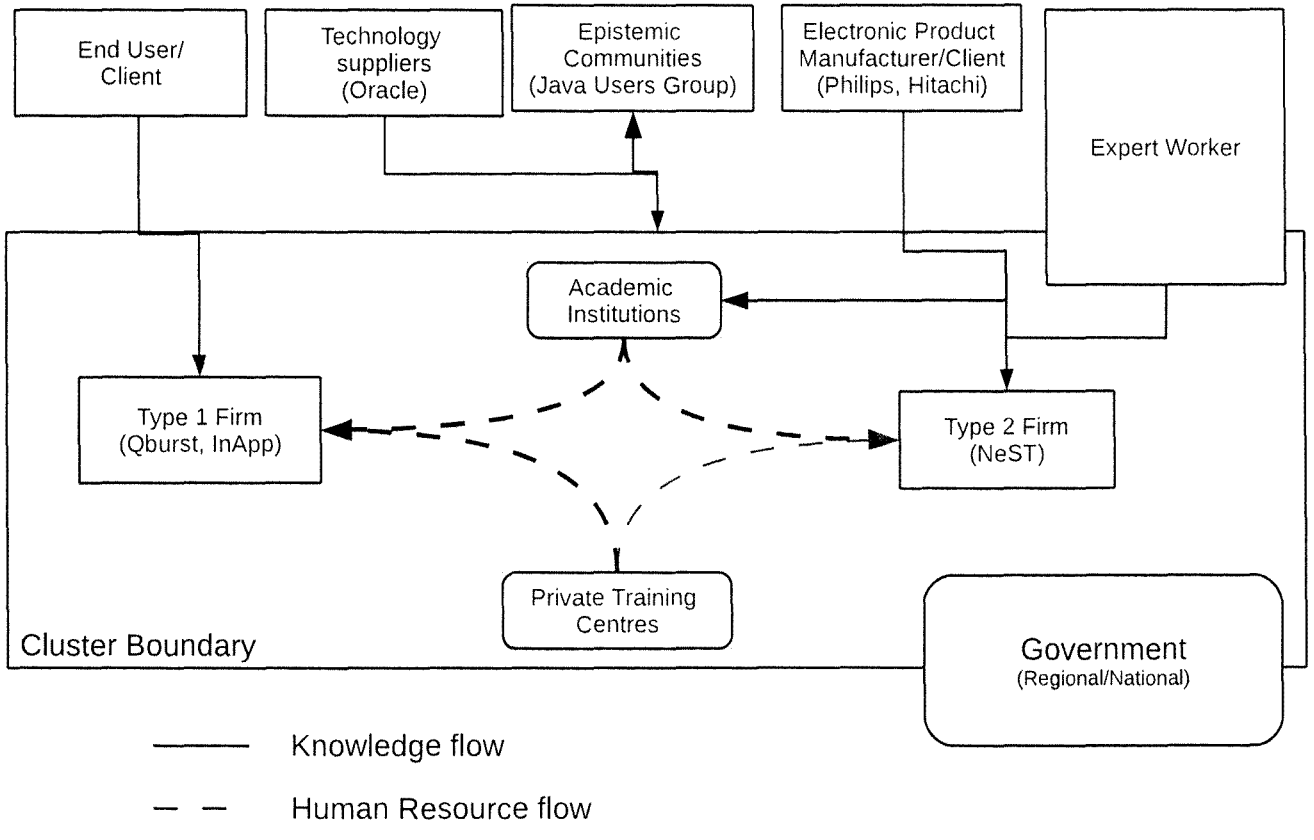
Table 4.5 gives an overview of innovation system as it emerges from the case studies. Based on learning mode, two different groups of firms appear in the cluster.

Most of the general software service companies like InApp come under the first group (Type 1 firm). They concentrate on DUI mode of learning and innovation. Firms like NeST, on the other hand, focus on development of new technologies either based on client needs or based on anticipated user needs (Type 2 firm).

This classification also matches with the nature of knowledge these firms use. The first group deals with knowledge of business. It combines business knowledge with software technology to create software that addresses some business need. The other group, deals with scientific and technological knowledge, where it produces new scientific and technological knowledge in the form of software as part of its production activity.

Two important inputs for innovation in general and knowledge based service like software, in particular, are knowledge base and human resource to process that knowledge. Diagram 4.3, shows how different actors of innovation system are linked through the flow of these two inputs. This gives a systemic view of innovation in the cluster.

Figure 4.3: Innovation system in Trivandrum Software cluster



Source: Own illustration

Important Actors

After the firm which is at core of innovation, the most important actors in the innovation system, are the users or clients. They have been identified as one of the most important source of innovation(Hippel and Hippel, 1988). Users contribute in several different ways. The first and foremost is co-production of service activity that firms undertake.

Developing custom software solutions for business needs requires clients to disclose their business practices, including proprietary information which is not legally protected. Such business knowledge, referred to as domain knowledge, helps firms to innovate and build products or solutions for firms working in that domain. Similar is the case with R&D related outsourcing seen in embedded system related service firms. There the client is forced to disclose a lot about the internals of its hardware systems to service firms. Access to proprietary information about hardware and its component parts is very important from a knowledge spillover point of view, as this forms part of the information that is most difficult to access. Unlike in the case of business knowledge spillover mentioned earlier, here knowledge may be protected by patents. Despite patent protection, this learning about hardware is a very important knowledge resource for future innovation.

Clients do try to restrict spillover through NDAs. They block firms from working for a competitor and restrict the movement of its project workers to a competitor's project. However, enforceability of these contracts, are weak in practice.

A user can tell the firm, what is needed or is in demand. The producer can then try to bring out an innovation that addresses the need. Linkage with lead user is identified to be particularly useful (Hippel, 1986). The success of SunTec is a good illustration of how a lead user helps a firm to innovate complex software. According to the manager of SunTec, "After working in a challenging environment with DoT, the international market was cakewalk". Here, the lead user gave the firm various scenarios the software will have to address. Once a large majority of scenarios for a leading user is complete, only a subset of it or minor additions need to be made for other users. Product firms like SunTec have created user communities on the Internet which help them to identify new requirements and faults in existing software. The virtual community of users that SunTec created is a very important strategic asset for its future innovation.

Clients can also draw a firm's attention to new technologies. A good example found during the case study is that of software for smart phones like Android and iPhone. Client request for these applications drives firms to build capability in those areas. This practice is observed in the case of all generic software service firms.

Academic institutions enter innovation process in two ways. They build human resource through educational activities and develop knowledge through research activities. For all the firms in the cluster, academic institutions like universities act as a source of skilled human resource. This has been identified as the most important role of academic institutions in the innovation system.

There is a growing trend among Type 2 firms to use these academic institutions as sources of knowledge. Firms specialising in Embedded Systems have linkages with institutions like Sree Chitra Thirunal Institute for Medical Sciences & Technology (SCTIMST), College of Engineering, Trivandrum and Centre for Development in Advanced Computing. NeST and another Embedded Systems firm, Vinvish, have collaboration with SCTIMST. They also have joint publications with SCTIMST. A few firms involved in bio informatics and clinical data research also have linkages with academic institutions like Rajeev Gandhi Centre for Biotechnology, Kerala University and Regional Cancer Centre. What is common to all of them is the fact that they need some basic scientific knowledge and skill set, be it biomedical or signal processing. Developments in these fields are close to basic research.

Demand for human resource has spawned a large number of private training institutions. These institutions provide technological skills to persons who do not have the skills required by software industry. They focus on specific technological skills that firms need, like programming in Java programming language. They also address the gap between a university level education and the industry's needs. Despite the efforts of these private training institutions and academic institutions, manpower shortage and the time lapse to make new recruits productive continue to be major challenges for firms.

Expert professionals, are the next set of actors who contribute independently to the innovation process of a firm. While there is a lot of discussion around reverse migration and knowledge coming back, none of

the firms studied here were able to give an example of an expert coming back to the cluster with new knowledge and enhancing the innovation potential of the firm. However, many of the entrepreneurs are expert professionals who have worked outside the cluster. Interpersonal relation is another channel through which an expert professional contributes to innovation process. This has been exploited in the case of Type 2 firms, where knowledge access is restricted.

Epistemic communities form a very important source of knowledge for firms in a cluster. Virtual communities in the form of mailing lists act as an important knowledge base for firms. There are communities centred around various technologies and products. Some of them are supported by supplier firms like a community of developers using a microprocessor or they are independent like free software users group. Unlike codified and explicated knowledge that is available through knowledge bases like scientific articles, books or patents, these communities are source of what is usually considered as tacit, contextual knowledge. The firms find it easier and efficient to use these community forums to raise questions about technical challenges they face. According to a manager of a research division, these community forums are a more efficient source of knowledge than even a known peer in the cluster, as chances of getting contextually relevant knowledge is higher in forums with a lot of professionals participating from different parts of the world. Often, they get response from someone who has experienced a similar challenge. In the process, a lot of contextual knowledge which was tacit gets explicated. Reciprocal relations that emerge out of being part of an epistemic community ensures continuous flow of knowledge. This situation exemplifies how new technologies have made location irrelevant.

R&D Funding

Only two firms, NeST and SunTec have in-house R&D division and budget for related activities. Being an R&D service firm, NeST undertakes research for clients. In addition to this, it also undertakes research on problems identified during its development activities, anticipating future demand. Its research at the moment focuses on image processing technology. Beyond being a provider of software, it has obtained the capability and trust of clients as a complete product development centre. It gets requests from clients to take on entire product development activity.

For SunTec, R&D activity mostly consists of market research to identify changing market needs. Based on identified user needs, it develops software in anticipation of future demands. Technical team in R&D investigates new technologies and adapts products for new technologies.

Other software service providers do not have separate R&D division and budget for it. But they do incur expenses on account of R&D activities. These expenses, for example, take the form of an employee taking time out of work for research or for exploring new market potential abroad.

When asked about the need for R&D funding to increase innovation, none of the firms felt that they had such a need. They are confident of finding resources within the firm if required. One of the firms was of the opinion that undertaking R&D and product development in the early stages of a firm can affect its growth, as these may distract it from immediate demands. Developing a product and introducing it in the market requires skills other than those related to technology. They also reported that in the future they may bring out software products based on the work they do. In general, firms do not seem to be taking risk in terms of investing in uncertain R&D activities. R&D in terms of technology development hardly exists.

Open Technology and Innovation

Open Technologies like web related technologies, and free and open source software have contributed significantly to innovations by firms. Open nature of knowledge and fewer cost barriers such as licensing, give firms easier access to knowledge. All the firms reported to be heavy users of free software. More than 50 percent of NeST's projects now depend on GNU/Linux Operating System, the most popular free software operating system. Firms become part of an epistemic community built around these technologies and access knowledge from it.

Smartphone application market is a good example of how open technology helps firms in a cluster. Two of the most important platforms for Smartphones today are Apple iOS and Google Android. Google uses GNU/Linux operating system as platform and Java as language for development. On the other hand, Apple uses a proprietary operating system called iOS developed by them and language called Object C. Though Object C is not a proprietary technology, it is mostly used only by Apple. This

technology was not much in demand until iPhone and related products like iPad became popular and a software market evolved around it.

In addition to technology, iPhone software market is controlled by Apple. One needs to get one's software approved by Apple before it can enter the market. It is a process that takes a lot of time. On the other hand, Android market is open with multiple vendors setting up virtual stores that sell software for Android. While stringent control by Apple forces firms to achieve higher quality, entry barrier may also force many out of the market. As one firm reported, demand for iPhone software development service is encouraging it to send some of its staff to the US for training. However, it also finds that risks in such investment is high as the demand for trained personnel in this technology is very high. This discourages firms from taking risks in investing in training their staff.

It is interesting to note that QBurst, the fastest growing firm in the cluster, was able to come out with around 15 applications on iPhone platform successfully. This is a significant number, considering the challenges involved. It did not have to invest much to get its employees trained. Its achievement in this regard comes out of its innovative organisational strategies.

There is a significant concentration of firms working on web technologies in the cluster. All the generic software solution providers in the cluster work with web technologies. Among them, all those who have given details of technologies used, claim expertise in free software tools for web development. These free software tools are of a wide range. It varies from a simple tool to publish content on the web to software development framework to develop complex software for business needs. Availability of free software for all these needs helps firms to provide various solutions, from websites to high-value e-commerce and social networking solutions, easily and quickly. Free availability of tools helps firms to move up the value ladder. It is observed that firms start off as a simple website design company. Then they make use of tools like Content Management System to provide more complex websites and slowly move to higher value solutions such as cloud based software. From supply side, heavy concentration of firms in web technologies has to be understood from the point of view of low entry barrier with very low skill requirement, low cost of access to knowledge (open, non proprietary knowledge base) and advanced development tools

(free software) and high level of scalability from simple website to complex software (innovation potential). On the demand side, the industry has been moving more towards web based solutions for custom software needs. Demand for services also vary considerably in its quality, from a simple web site to complex software. Web has turned out to be the most important platform for software innovation in the last several years. Open nature of technology and advantage in terms of location agnostic nature, have helped it to grow rapidly. As cloud computing and software as service model expand rapidly, the web is becoming the dominant platform for software development, reducing the importance of software that runs locally on a computer.

Embedded systems is another rapidly growing area of software innovation, where again, free software is helping to promote innovation. Embedded technologies is an area where new firms have limited entry due to the closed nature of relevant knowledge base. NeST reports that Android has become almost a de-facto standard for embedded application development. The open nature of Android has enabled other firms like QBurst to enter this closed market. This may lead to rapid expansion of innovative activities in the sector, similar to those observed in web technologies. However, the recent patent fight between users of Android platform like Motorola, on the one side and firms like Oracle and Apple on the other, will determine how the market will evolve in future.

Learning and Related Institutions

Accessing and accumulating knowledge is one of the most important process that has been going on in firms. There are two important institutions that have come up prominently in the discussions — Non Disclosure Agreements (NDAs) and FOSS license. NDAs played a significant role in knowledge access for platform software firms. While the objective of NDA is to limit a firm's ability to exploit knowledge transferred to it, the case studies show that it was not successful in its objective.

Similarly, FOSS model of open and collaborative development hs brought a wealth of knowledge which firms leverage on. Stock of knowledge available openly for appropriation, enable new firms to leapfrog existing firms with accumulated knowledge.

As a source of knowledge, virtual epistemic communities have a prominent role. A lot of contextual and tacit knowledge flows through these communities. Considering the importance of tacit knowledge in production, it is important that the working of these communities is investigated more. SunTec has been able to create a community around its software, which provides inputs for innovation. It is an innovative approach to ensure continued flow of knowledge relevant for innovation from users to firms.

Movement of Workers and Related Institutions

Movement of workers is considered to be a very important source of knowledge spillover, particularly within a cluster. The firms in Technopark reported attrition as a challenge. They have developed innovative strategies to deal with this issue. There is a hierarchical relation in employee movement. It is mostly from small firms to large firms in a cluster or to firms in a larger cluster like Bangalore or from large firms to clusters outside, including foreign countries. A small firm noted that it acts as training ground for new recruits who later move to larger firms. What is to be noted here is that, small firms play a very important role in innovation system by creating skilled human resources. This role of small firms is often under-recognised. Firms do not report any significant flow of knowledge through the movement of employees.

The impact of movement of employees is felt mostly by small firms which take on the burden of creating skilled human resource for the cluster. Small firms are exposed to considerable risk as they are dependent on each staff for their delivery. Loss of even a single person at a critical point of a project can be fatal to these firms.

Until recently, the association of CEOs of Technopark, GTech, had an agreement which restricted movement of workers with less than 3 years experience within the cluster. There was no mechanism to prevent movement to firms outside the Technopark cluster. This semi formal arrangement was destroyed recently with the entry of Infosys, a large Indian firm. It was not willing to be part of this arrangement among the firms. To start its operations, it needed human resource that it could attract from other firms within the cluster. With Infosys taking this position, the informal arrangement came to an end.

Regarding movement of workers from an outside cluster to Trivandrum,

the case studies did not provide evidence. No firm reported any significant case of migration to Technopark. However, operationalisation of regional centres of large firms like Infosys involved movement of their staff working in their other offices to Technopark. Anecdotal evidence given by entrepreneurs show that some of these movements were costly failures. Experts who thus moved in, were not capable enough to bring value to respective firms. This has raised the question as to why experienced professionals return to the region.

Role of the State

The state plays very little direct role in innovation system. Its role is largely restricted to developing skilled human resources through its academic institutions. It also plays an indirect role in knowledge development within academic institutions. However, only a small group of software firms like those in embedded systems and bioinformatics benefit from this, and that too, only to a limit.

The state has been playing an important facilitating role by providing infrastructure facilities like Technopark. These facilities act as islands of good infrastructure which the firms can leverage on. Incentive schemes like tax holidays bring down the effective tax rate of the industry substantially, which act as fiscal incentive for firms. However, it may be noted that the industry is profitable even otherwise. To what extent the indirect fiscal incentive promote innovations by firms is a question which requires investigation. The response of the firms in the cluster, during the study, also indicate that lack of financial resources is not a major challenge for innovation. In general, the state's role as an agent in the innovation system of this sector is very much limited.

Global Linkages over Local

One interesting aspect that comes out in the case study is that, important knowledge related linkages of innovation are global. These linkages include the linkage between firms and user/market, between firms and suppliers of technology. Only a few firms have connections with other agents regionally or nationally. Hence, clusters like Technopark appear as nodes in a global

system of innovation. Their linkage with national or regional actors is primarily for skilled human resource.

4.3.4 Clustering and Innovation

As discussed earlier, existence of STPI and other technical institutions led to initial clustering of software firms in Trivandrum. Later, in 1994, Technopark gave it a further boost up. When asked why the firms chose to operate in Technopark, the common reason given was that Technopark provides social isolation. Industrial environment in Kerala is traditionally known for high level of labour organisation and collective bargaining by trade unions. The state is noted for excessive labour agitation and consequent disruption of work. This is one of the reasons attributed for low level of industrialisation in Kerala. IT and ITeS industry needed isolation from local social and political activism and labour militancy, which could disrupt work. For these firms working for clients abroad in a time-critical manner, any disruption of work can be costly, sometimes even leading to the closure of the firm. Even during a protest that disrupts life in the city. Technopark firms are able to operate normally.

Another important reason why firms flock together, is the brand value of parks. One of the medium sized firms started a centre outside Technopark. It expected that low cost of life and proximity to the city will motivate employees to work in this facility rather than in Technopark. To its surprise, attrition was very high in that centre. People preferred lesser paying jobs in Technopark to higher paying jobs outside it. Many firms have identified the brand value of Technopark as useful to attract labour. It is often Technopark which is identified with an employee and not the firm in which he or she works. Firms of medium and small size which do not have their own brand recognition have to resort to Technopark branding to attract workers.

From an infrastructure point of view also, Technopark provides some advantage. It comes with redundant power supply and data communication facilities. It also has common facilities that help small firms. Incubation facility is also being used quite well.

Clustering is expected to improve innovation through localised knowledge spillover. The most important channel is that of workers. As discussed

earlier, we hardly find any evidence for this. Input- output relation between local firms can lead to sharing of knowledge. But such relations are very limited. However, some changes are observed with the emergence of specialised service providers. Three firms studied here, reported that they have begun to outsource software testing related activities to another firm which provides exclusive software testing services in the cluster. Firms that started outsourcing within the cluster, consider this to be possible because of the operational maturity they have reached. They also had to develop confidence in other firms before outsourcing their work. This took them time. Similar to testing, Embedded Systems related service providers have started making use of web technology solution providers as the two technologies converge. It illustrates how technological change leads to new input-output relations. While all this show innovativeness from the part of firms, there is no evidence of knowledge spillover.

Other channels of knowledge spillover include localised epistemic communities, users groups, professional organisations, etc. Organisations like IEEE, Free Software Users Group, etc., are active in the region. None of the firms reported that these organisations in the region had any impact on them. At the same time, they consider these organisations as sources of knowledge at the global level. For example, while firms are able to access facilities of IEEE by virtue of their association with it, they do not gain in particular from the local chapter of IEEE. Technical conference is another mechanism that creates temporary clustering of professionals. However, participation in and utilization of these opportunities are also reported to be limited. Lack of regular and industry relevant events, except technical marketing events of vendors, may be a reason for this.

There is evidence of science and technology based firms collaborating with science and technology research institutions in the locality. Two firms have started developing biomedical technologies in collaboration with Sree Chitra Thirunal Institute for Medical Sciences & Technology which has specialised knowledge in this area. Similarly, CDAC has started acting as a knowledge provider in the area of SmartGrid in which it has experience and for which a market is slowly emerging. These collaborations are relatively new. How they contribute to the growth of the cluster remains to be seen. They highlight the role of specialised knowledge providers and synergistic relation that can be formed between industry and academic research organisations locally. Personal relations between professionals in research

centres and firms are reported to be important in establishing relations between public research institution and private industry. This points towards localised nature of such relations.

There is no evidence from case studies, for spacial clustering of firms leading to increased innovation. While there are no constructed barriers for knowledge spillover between actors in the cluster, evidence of spillover is weak. Rather, global sources of knowledge like client and online communities are more important sources of spillover. Since the work in the cluster focuses less on technology development, it does not foster development of epistemic communities locally.

Chapter 5

A Typology of Software Industry

The most commonly used typology of software firms is based on the nature of business— software service and software product(See 2.1.3). In this chapter, I propose a knowledge based classification of Indian software industry. I discuss this classification in the first section. In the second section, I examine the Indian software industry on the basis of the new typology proposed. In the third section, I reflect on some of the major changes in the industry and their effect on knowledge domain. I also highlight their effect on the existing structure of Indian software industry. In the last section, I reexamine some of the important discussions in the literature on the industry based on the new typology.

5.1 Knowledge based Typology of Software Industry

The study regards software as a form of knowledge. Writing a piece of software involves creating and representing knowledge in a form machines can understand. With this knowledge, a machine is able to absorb, process and transmit information. Based on the nature of knowledge used in software development, firms can be divided into business software firms and technology software firms. Business software firms are firms that develop software for specific business needs, like banking applications, billing software, ERP, etc. Technology software firms are those that develop embedded software,

operating systems, databases etc. Business software firms use knowledge from business domain to develop business software. Business software is always created on platform software. Business software firms learn and use software technologies made available through platform software. They don't have to construct technological knowledge on their own. Technology software firms develop platform software, which is based on creation of new scientific or technological knowledge. Apart from platform software, some general purpose software like word processor, spreadsheet, etc., may also be included in this category.

5.1.1 Characteristics of Knowledge Base

Scientific and Technological Knowledge

Scientific and technological knowledge relating to software were initially developed exclusively in research organisations or by hardware manufacturers. The source of software innovation was technological or scientific breakthroughs. Later on, software firms also started inventing technology. Hence source of technological and scientific knowledge in software are prominently hardware manufactures, research organisations and technology producing firms. This knowledge is often sticky and proprietary in nature. Case study of NeST shows that spillover as part of service is an important channel to access this knowledge.

STI mode of learning is observed in software firms that use this knowledge. They invest in R&D activity. Linkages with academic and research institutions for knowledge are present in these firms.

Patents are an important institution in this domain of knowledge. Patent system makes scientific and technological knowledge excludable. Though software patenting is still being debated, it became an accepted practice in the USA, the primary market of software, in the early 1990s. Software that depend on knowledge developed in other domains of science and technology, are affected by patents in those domains.

The way in which patents have been used in the area of software is also important. The patent holder does not usually provide knowledge in an open market system. Rather, major companies enter into cross licensing of their patents. Cross licensing means that all parties to the agreement will have access to each others patents. A kind of cartel is formed by large

software firms around pools of software patents. Universities, large firms like IBM and certain firms that provide software licence, generate revenue from licensing software patents they hold. The role of software patents in limiting innovations in software sector is being discussed in the academia and among public policy makers and the need to do away with software patents is gaining support in these circles.

Business Knowledge

Business knowledge is of a different character. It often originates from the user, who acts as the source. While development of management research has contributed to increased understanding of how business works, much of the knowledge is held by its practitioners. Tacitness can be very high as knowledge often comes from practitioners' experience. However, standardisation and systematisation of business processes require that the knowledge be explicated, thereby reducing its tacitness.

When a software is being developed to manage the business process of a firm, the firm has to convert its tacit knowledge to explicit, coded knowledge. While an individual in the firm may try to hold the tacit knowledge, the firm's may want to explicate it. This leads to software providers gaining access to business knowledge from potential customers or users in the process of developing software for them. A software firm needs to have the skill to absorb the tacit knowledge vested with the user. DUI mode of learning is important to access business knowledge.

While a firm is interested in reducing tacitness of business knowledge within it, it is also keen on ensuring that its business knowledge does not flow to competitors. For example, a retail firm may discover a better way of displaying products to boosts sales. By converting its knowledge to a coded form, the firm risks losing this knowledge. The legal system for protection of business knowledge is weak. Client firms enter into contract with software providers to control knowledge flow. Software firms often agree to the terms if they expect long term benefit from that client. Patents are being used to protect business knowledge in the US. Whether business methods can be patented is a much debated issue. Yet there has been an increase in business method patents. However, compared to technological patents, they are difficult to obtain.

Table 5.1: Characteristics of different knowledge domains

Dimension	**Business Knowledge**	**Technical Knowledge**
Exclusion or Protection mechanism	Trade Secrets/Non Disclosure agreements	Patents, Copyrights
Scope of protection	Low	High
Source of innovation	User or Client, Technology suppliers	Hardware manufacturers/inventors, Academic institutions, R&D by firms
Nature of innovation process	Learning, driven by technological change	Research driven and breakthroughs in wide range of scientific and technological areas where software plays a role.
User incentive for knowledge sharing	High, Users need to share their business knowledge to get the solution they need.	Medium, users only need to share requirement and experience (fixing issues).
Lead user	Provides requirement - exposing innovation opportunities. Provides knowledge.	Provides requirement - exposing innovation opportunities.

Source: Own compilation

5.1.2 Division of Labour Perspective

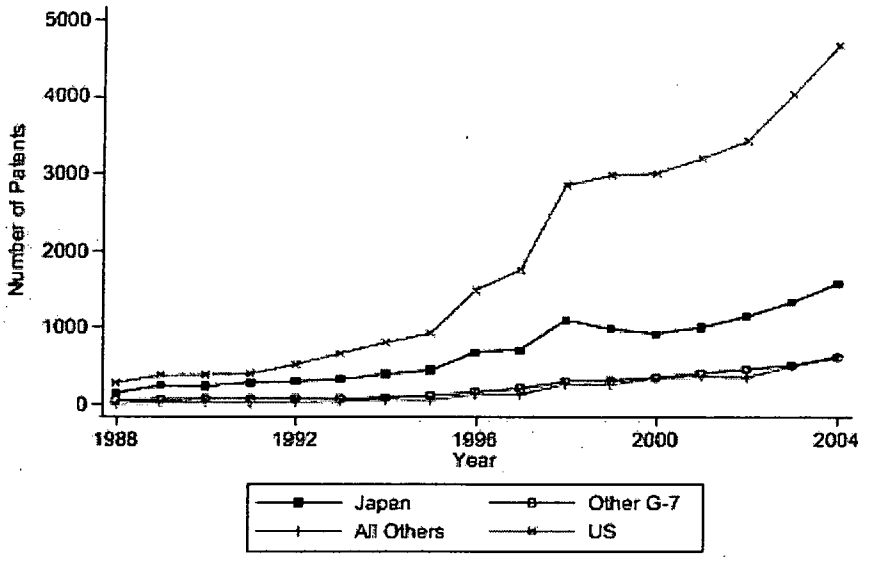
Typology of software firms outlined here can also be studied based on division of labour in knowledge production. Figure 2.3 shows that there is a vertical layering of actors in innovation system. The middle layer consists of supplier firms. This layer has to interact with two different types of organisations in the upper and lower layers. The upper layer consists of research and academic institutions and the lower layer consists of users. The two types of software firms proposed in this chapter suggest that the middle layer of supplier firm can be divided into two. The upper supplier layer closely interacts with research and academic institutions. It translates scientific and technological knowledge into software technologies that can be used to create software for users. The lower supplier layer consists of business software firms that interact with client firms or users. It interacts with users and brings out innovative software for them, taking advantage of software developed by firms in the upper supplier layer. The learning process and knowledge stock of the two types of firms proposed, differ in their roles in the system of innovation.

Going by the strict definition of sectoral system of innovation, the two types of software firms proposed, cannot be considered as forming two sectors(Malerba, 2005). However, the conceptual framework of sectoral system of innovation provides a tool to analyse the difference in innovation in the two categories of firms. As two sectors would differ in their knowledge base, actors and institutions, so do the proposed categories of firms. Division of labour perspective helps us to see the innovation system as consisting of two (or more) subsystems.

5.1.3 Concentration of Technological Knowledge

An analysis of software patents in USPTO by Arora *et al.* (2007) shows, that the US holds a substantial portion of software patents issued and its share has increased dramatically. USA is followed by Japan at a much lower growth rate. This pattern indicates that software technology related knowledge is still concentrated in specific geographical locations. The cumulative nature of knowledge creation is also evident, wherein firms with a large stock of patents show higher growth rate. It provides a logic for the global nature of knowledge related linkages observed in the software cluster

Figure 5.1: Software patents issued by USPTO



Source: Arora et al. (2007)

under study.

5.2 Understanding Indian Software Industry

5.2.1 Knowledge Domain

Based on the nature of software that is being developed, most of the Indian software firms belong to business software category. Indian software firms have been in the business of developing business software since early days. Initially, hardware vendors provided the knowledge for software creation. Later platform software vendors also took up this role. Business knowledge reached the firms directly from clients, who wanted software to be developed cheaply. All knowledge required for the production of business software production has been available from the initial days of Indian software industry.

The Indian government tried many strategies to access technological knowledge relating to software and computing from the 60s. Its attempt to coerce hardware vendors to provide the knowledge did not work out. Its attempts to develop technology indigenously also did not take off.

The case study shows that knowledge related linkages, including technical knowledge, are global. It also shows that knowledge stock for creation of new software technology is absent within the country. Analysis of patents held by Indian firms and organisation also shows that India does not have a significant stock of technological knowledge. At the same time, existence of MNCs doing technology related software and Indian firms like NeST and Sasken undertaking contract based R&D work involving technology creation, suggest that Indian software developers and the industry do have the capability required to produce technological knowledge.

5.2.2 Service Orientation

Governments and large businesses are the biggest users of complex software systems. They need software that help them accomplish various business activities. These include software for customer relations management, business accounting, resource planning, etc.

While some business activities are generic across users, a lot of it is specific to organisations. Often these organisation-specific activities are what make an organisation unique. For this, software has to be developed to suit specific organisational needs. This process is called custom software development. Custom software development is classified under services category due to its co-production nature. Considering that Indian software firms mostly develop business software and most of it custom software, Indian software industry at large, appears to be service oriented.

Software firms that work with business knowledge also sometimes come up with software products. SAP ERP, Tally financial accounting software etc., are some examples. These products represent business knowledge in a generic manner, like how accounting, order processing etc., are done in a firm. While some of these software can be used as such, like a simple financial accounting system, most of the complex software like Enterprise Resource Planning need heavy customisation to suit customer needs.

With technological development, business software also changes. Sometimes it leads to the development of a new software. With Internet as a platform for commerce, a lot of software solutions have cropped up to help firms do business on the Internet. Emergence of smart phones is now creating demand for smart phone based business software. Similar is the case

of core banking systems implemented in India recently.

5.3 Challenging the Existing Order

Emergence of FOSS and the new model of developing software is changing the existing structure of Indian industry which is dominated by business software firms. What FOSS alters is the bias in the technological knowledge base which is concentrated in a few developed countries like the US. FOSS is now available with source code on the Internet. Source code is codified version of knowledge relating to software technology. Today, firms in India can take this knowledge base and come up with technological inventions. Access to knowledge in this case, is in the form of a stock that can be used and as a source from which one can learn. This has opened many possibilities. The innovation system may change or may have to be influenced to take advantage of these possibilities. The case study shows that firms have already recognised the importance of FOSS in their innovation strategy.

Innovative software product companies emerged from the FOSS model. Zamanda and Gluster (formerly Z Research) are two infrastructure software product companies that have emerged from India. They follow the FOSS model, where the software product is free and open source and they generate revenue out of value added services on the technologies they have developed. Zamanda provides enterprise data backup solution with advanced capabilities like backing up to cloud platform. Zamanda's product offering is based on backup software developed in the University of Maryland called Amanda. Today, the development activities of Amanda are done primarily by Zamanda. Gluster is a free software for storing petabytes of data. This product competes with similar products from Yahoo and Oracle. Both Zamanda and Gluster are infrastructure software products based on scientific and technological knowledge.

Zoho is another innovative software company which works by the SaaS model and FOSS. Zoho provides generic software products like office applications, customer relation management systems etc., as web based applications. With a user base of 3 million, Zoho is competing with industry majors like Google (with Google Apps) and Salesforce.com. Unlike in the case of Zamanda and Gluster, the business model of Zoho requires large human resource with varying skill sets. This situation arises from the fact

that Zoho addresses general end users of computers, whereas Zamanda and Gluster provide specialised knowledge intensive service to enterprise customers, who are few in number. While labour cost is not a very important factor for Zamanda and Gluster, for Zoho it is so. From the point of view of knowledge, unlike Zamanda and Gluster, Zoho has to deal with both business knowledge and scientific and technological knowledge. Like the other two firms, Zoho also depends a lot on technical knowledge base made available under FOSS model. None of these firms would have existed without FOSS. It is also important to note that none of these firms depend on patents for their revenue generation.

A factor unique to all these three firms is that, while their R&D and production happen in India, they operate as American firms. Their decision to locate in the US, was influenced by two factors — one, proximity to the user and two, access to capital. The nature of organisation observed in the case of Israeli software product firms is the same. For example, Checkpoint, one of the largest software firms in Israel, moved its head office from Israel to USA while retaining R&D base in Israel. Researchers have brought out the important role of the lead users in innovation. Lead users provide innovators with information on gaps in current technologies which helps innovators to focus on a problem. The lead users will also act as early consumers once the innovation comes out. This is important for innovators, who may otherwise have to wait for the technology to get diffused to reap the full benefits of their innovation.

5.3.1 'Servicisation' of Software Products

Software as a Service (SaaS) is fast becoming a delivery model for software products. In this model, a software is deployed on a server and the user can access that software through Internet. The user has to pay for the software on a pay-as-you-go model. Such service providers may generate income from other services like online advertisements. Internet based innovators like Google and Yahoo successfully utilise this model of software delivery. Salesforce.com is a firm that grew with SaaS model deployment of business applications. Firms like Google and Zoho, market office applications in the SaaS model to replace traditional office suites like Microsoft office or Open Office that run on personal computers.

SaaS model is part of utility computing model in which the comput-

ing resource is given to a user as a public utility from a centralised system. Here, the Internet is the channel of service delivery. While hardware cannot be delivered through this channel, a virtual computer is made available to users through the Internet. Billing is done based on the duration of usage, utilisation of computational resources like processing power, data storage, data transfer etc. This new approach to computing is called Cloud Computing. Cloud Computing is defined as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". Software and hardware, as per this model, is no longer a product to be sold in the market. It is rather a service to be provided to the user.

Another major development is that of a new model of business based on FOSS. In the FOSS model, software developers around the world collaborate through networks to build software. The developer communities have shown that they can successfully develop complex platform software and general purpose software tools. Some examples include GNU/Linux operating system, Apache web server, Mozilla Firefox browser and Android mobile platform. Some of these software were developed by non profit foundations like Apache Foundation and Mozilla Foundation, which generate funds for development through donations and grants. In some cases, commercial organisations spearhead the development of FOSS. While they do not generate revenue through the sale of software, they generate income by providing services like custom development of the same software for specific user needs, training and consultancy. FOSS based platform software like GNU/Linux operating system and Apache web server are becoming standard platforms in enterprise computing environment.

Technological and business innovations are replacing software products market with new services market. Innovations in Indian software industry will be determined by this change.

5.4 Reflecting on Literature

Based on the understanding that software industry is not a single entity and the picture of innovation at the firm level, I look at some of the conceptions

and opinions on Indian software industry in existing literature.

5.4.1 Why Software Products over Service ?

Moving from software services to product is considered important on many accounts. Economic reason for favouring software product comes from the fact that it allows the firm to benefit from economies of scale. From the innovation point of view, we can identify three important reasons to favour increased share of software products in total software production.

1. It indicates higher production capability where firm is able to manage entire activity in software production process and come out with software products
2. A software product represents a firm's ability to come up with generic solution to address business needs of many users and employ an innovative approach to solution
3. Software product represents new technological innovation

Firm Capability

An important assumption in the literature has been that Indian firms focus on low value activities in software production process(See 2.1.4). In the case study we find that, SunTec started as a custom software development service provider and later brought out a product. NeST and InApp also share the same story. Analysing history, we find that firms like TCS and Wipro managed the entire software production process and successfully came out with products. All these imply that, product development capability has existed within Indian software firms, since the early days. It is not just low value activities that they do.

Generic Solution Development

Software products sold in the market have to provide some generic business functions. Case studies of SunTec and InApp show that, firms come up with software products as they accumulate relevant business knowledge. Clearly, emergence of new software products is an indicator of innovation. However,

to bring out generic software products, firms have to take considerable risk. Arora (2008) recognises this when he talk about "penny pinching and risk averse management habits" of Indian firms. Experience of Wipro with its InstaPlan software product shows that existing market monopolies limit market entry of software product firms. Combining the above two arguments I argue that Indian software firms' strategy of taking up custom software development was an innovation in itself.

New Technology

Successful introduction of new software products depends on new features or improvements to existing products. This involves creation of software technology. In this context, software product implies development of new technologies. R&D activities of NeST and SunTec all aim at building such new feature sets for their products or their client's products (R&D services). Importance attached to the growth of Embedded System related software industry needs to be understood as an increase in technology software firms.

Fuzziness in Literature

While emergence of software products is a sign of innovativeness, different authors point to different aspects. In the case of technical software firms, emergence of new products is closely linked with advances in technology, whereas in the case of business software firms, it is about knowledge accumulation(e.g. BANC2000). As the case study of SunTec illustrates, for a business software firm, most of the revenue comes from customised software that it develop on its product and not from sale of the product itself. The product it comes up with, is only a reusable code representing accumulated business knowledge. On the other hand, introducing general purpose business software like SAP ERP, Tally, etc., is much more challenging. Firms need innovative strategies to overcome monopolies in the market.

5.4.2 Innovation Indicators

There are several indicators of innovation that have been used to monitor innovation at the macro level. This section looks at two important indicators that appear in literature.

Share of Revenue from Products

At the macro or industry level, the share of software product and R&D exports in total exports is considered as indicator of innovation. In this chapter I have discussed the importance of software products as an indicator of innovation. However, this indicator is not relevant at the industry level as export of software products means different things for different firm categories.

For software product firms like SunTec, which provide business software, revenue comes not from sale of products, but from the development of custom software products for its clients. The product of the firm will be an important component of the total software. When the firm sells its service, it may not value licence part of the service associated with software product revenue as much as it values customisation. The product is more incidental to the service. This is in contrast to technology software firms where the entire revenue of the firm comes from licensing the technology or selling software products. Considering that Indian software industry predominantly consists of business software firms, the indicator discussed could underestimate the innovation in the industry. Changing share of software product and service can be considered as a move towards technological software over business software.

R&D Expenditure

Despite the difficulty in R&D accounting at the firm level, R&D expenditure is an indicator of innovation. For technology software firms, it is an investment for technological inventions. For business software firms, it is more about market research and learning. R&D expenditure is accounted clearly in the case of technology software firms like NeST and software product firms like SunTec. Most of the software service firms do not account R&D expenditure separately. Considering that most of the Indian software firms are in services, this will grossly underestimate the innovation that happens in the sector.

Chapter 6

Conclusion

6.1 Innovation

The software industry in India has been growing in quality and quantity. Its growth record has proved all pessimistic observers wrong. Discussions in the previous chapters demonstrate that the industry is innovative. Knowledge accumulated through learning forms the most important source of innovation. The industry has been improving its capabilities through improvement in process, absorption of new technological capabilities and identification of new markets. History shows that it has also been responding to changing market conditions by swiftly responding to changing demands.

Some argue that the Indian software industry is not innovative as it does not come up with new technologies. However, if we consider innovation as bringing about change, then the Indian software industry is innovative. Its orientation towards business software and thereby towards service segment of software industry in itself is a major innovation. Athreye (2005) also suggests this when she says "The particular strength of Indian firms was their ability to assemble teams of talented engineers and deliver a technical, outsourced service to exacting and different customers anywhere in the world. They also leveraged their capabilities for maximum economic value through the adaptation and perfection of a new business model."

Traditional manufacture oriented perspective of innovation fails to recognise innovation that happens in business software industry. Even those who recognise the service nature of this industry are influenced by the paradigm of manufacturing in their analysis. This is evident from the fact that a lot

of emphasis is given to new software products as an indicator of increased capabilities and innovation. A lot of discussion on Indian software industry is centered around the nature of activities it undertakes and share of those activities in the total value added. Linear model of production borrowed from industrial factory model underlies the conception that bringing out a software product is the highest capability that a firm in the industry can achieve.

Case study of firms in Trivandrum, along with other evidence from literature suggest that firms in India are capable of handling all the stages of software production. They have come up with successful software products that have been deployed across the world. With the introduction of innovative business models in software such as SaaS and FOSS, even traditional software product business like platform software business, has become a service. Product based software business is slowly coming to an end.

Shifting the focus from product-services duality, this research brings in knowledge as the key characteristic that determines the nature of the industry as well the innovation that happens within it. In the context of software industry, this knowledge has been recognised as business knowledge and scientific and technological knowledge. From the discussion in the previous chapter, it is evident that the Indian software industry is heavily biased towards business knowledge. The innovation system of the industry evolved around this bias. This has to be seen and appreciated from an evolutionary perspective. While this bias, as I argue, arises out of complementary relation between hardware manufacturers and software industry that existed in the early days, it has not hampered growth and innovation in Indian software industry. Yet, it may severely limit the scope of the industry.

Technological invention is an important factor for innovations in services sector. This is not to argue that service innovation just follows technological invention. Offshore development model perfected by the Indian software industry, is an example of innovation in services. E-commerce facilitated by development of web technology is a good example of service innovation that arises out of technological invention. At this point of time, the Indian software industry, both service and product, severely lack the ability to come up with technological invention. It has to depend on and follow technological invention in leading countries like the US and Israel.

R&D centres of major software developing firms like IBM, Microsoft and Oracle testify to the capability of Indians to undertake technological invention in software. Many of these organisations have tie-ups with Indian universities. Poor access to scientific and technological knowledge relevant to software had limited domestic firms from undertaking technological invention. Market conditions like existence of large monopolies also limit their opportunities. This situation is now changing and new opportunities are arising. There is a growing trend of R&D outsourcing to Indian firms, reflecting the client firm's confidence in the quality of service delivery. R&D outsourcing activities are also leading to significant technological knowledge spillover from the client firms. It is now very important that the industry and the government try to address the gaps in India's software innovation system. Software products will follow.

6.2 Clustering

The analysis of Trivandrum software cluster suggests that localised knowledge spillover is not an important explanatory factor for clustering of software firms. Mapping the innovation system of the cluster shows that its source of knowledge largely lies outside the cluster, or outside the country. Knowledge spills over from clients as well as technology providers who are mostly outside the country. This is good news for all the regions that want to become the next Silicon Valley of India, as knowledge is not localised in any particular region of India. This does not mean that the industry does not cluster. Clustering does happen and it is mostly due to the availability of human resource, infrastructure facilities and complementary services. Spreading is limited by economies of scale that can be achieved. It may not be economically viable to provide complementary services that the industry requires at every location. Localised system of innovation does evolve as cluster grows, with firms getting connected through input-output relations. This suggests that in older clusters like Bangalore, knowledge based clustering forces may exist. Innovation system for firms that work with scientific and technological knowledge includes knowledge based linkages with other local organisations, like research centres, thereby bringing in a regional dimension to knowledge exchange.

6.3 Domestic Market and New Technology Start ups

The contribution of software industry to the Indian economy is significant. Apart from direct economic contribution, there are significant indirect benefits. It created an image for the country as a destination for knowledge intensive industries, benefiting other industry sectors as well. It also created new entrepreneurial culture within the country which could contribute to further growth not just in software sector(Arora and Athreye, 2002).

The economic growth of the country, to which the software industry also contributed significantly, has created new domestic demand for software. Like the experience in telecom sector, an opportunity has opened up, where innovations are made for India and then taken to the global stage. Particularly of importance, is the development of cost effective software technologies. Growth in sectors like automobile, pharmaceuticals, space technology, etc., can help in the development of software firms providing specialised software services to the respective industry(NASSCOM, 2007).

Changes that are happening in software business model, like the move from software product to SaaS is an opportunity for Indian industry. The industry has already started responding to it. The FOSS model, which is becoming the de facto model for development of platform software, has opened up a large amount of technological knowledge to domestic firms. It is up to the Indian industry to leverage on this knowledge pool. Thus barriers to technological knowledge have significantly reduced.

Changing market conditions (like the change in business model), knowledge availability and entrepreneurial culture create an opportunity for new innovative enterprises to come up. They have to venture into uncharted business environments with their inventions which will introduce them to bigger risks. They will manage their risks by specialising in some areas and taking advantage of their small scale of operation. Large firms will depend a lot on these smaller firms for innovative inputs like R&D services and new technologies. They find it better to take technology from an innovative small enterprise than take the risk of attempting a new technology on their own. Emergence of small specialised start ups with high level of knowledge can be an useful indicator of innovation in software sector.

6.4 Public Policy

The fact that software industry is not a single sector in terms of knowledge domain, has not been recognised by researchers. A lot has been written about the need to expand knowledge, R&D, university-industry linkages, domestic demand, Embedded Systems sector, etc. While these include an implicit demand for increased focus on technology oriented software like platform software, this has not come out clearly in existing literature on Indian software industry. Discussion so far has shown that the Indian software industry is weak in creating new software technologies.

The Indian software industry is severely limited by its poor access to scientific and technological knowledge relevant to software. When we accept this as a fact, we may need to revisit public policies on knowledge access. Software patent is a case in point. Data on software related patents show that Indian firms have very little share. Despite increased R&D services, their patent portfolios have not improved. Parthasarathy and Aoyama (2006) notes a comment by a CEO of an R&D services firm "It will not be our name that will be mentioned but we will all know that it is our software running". If this is the case, excludability of knowledge through patenting does not help local software firms as patent right of their invention goes to the client. This raises the question as to what extent software patenting can help Indian software industry. It may be argued that allowing software patents in India could attract knowledge rich MNCs and motivate Indian software firms to invent. However, it is to be noted that software innovation depends on multiple ideas and chances of benefiting from a single patented innovation is very low in software sector. As for MNCs coming to India, already most of them have come despite the lack of provision for software patenting in India. They came mostly due to the low cost of operation and availability of highly skilled workers in India, not for its knowledge base. Similar is the case of policy on adoption of proprietary technologies in e-government activities. Demand generated by these activities can be a learning opportunity for domestic firms. Having proprietary software systems in these projects will have only limited learning opportunity for Indian software firms compared to openly available FOSS technologies. Extremadura region of Spain has shown an example of how directing public spending to FOSS based firms can generate local industries with specialised knowledge capabilities(Lippoldt and Stryszowski, 2009; Hoe, 2006).

Concrete action has to happen with regard to improving quality of research in academic institutions by facilitating collaborations with the industry, building multidisciplinary venues for research and development in software, etc. These efforts can improve technological knowledge base relating to software. However, this needs to be carefully undertaken on a need based manner. Huge investments in this regard may not be helpful. Experience from the 1960s and 70s shows that industry-academic collaboration need not necessarily produce the desired result. A more important strategy is to improve the quality of academic institutions in such a manner that they can produce highly capable human resource. This is particularly important for the emergence of small specialized startups discussed earlier. Indirectly, improvement in the quality of academic institutions in terms of human resource development, will have a positive impact on their research.

6.5 Changing Pattern of Innovation

The current model of Indian software industry is based on learning the latest technologies, combining them with business knowledge and building solutions for specific needs of customers. It follows Schumpeter Mark II model characterized by 'creative accumulation'. The industry is dominated by a stable core of large firms and they present a significant barrier for new firms to enter. Changes in the existing structure of the industry with the availability of technological knowledge through FOSS, as discussed earlier, combined with low appropriability and low cumulativeness (at firm level) can lead to changing patterns of innovation. The industry may move to Schumpeter Mark I model characterized by 'creative destruction'(See Malerba (2002) for discussion on this). Rather than follow technologies developed outside, the industry may build new technologies at home. The industry may come up with new products and services that address as well as create new demand. The current stable organisation of industry could be replaced by a more turbulent one, with new firms emerging with new technologies or addressing new demands. This change may not be reflected quantitatively. It can be a qualitative change that influences the entire industry as illustrated by the examples of Gluster, Zamenda and Zoho.

6.6 Some Research Questions

Empirical evidence from software firms in Trivandrum, support the idea that characteristics of knowledge domain shape the nature of innovation. Given this evidence, it should serve us well to explore this at the national level. Since software production in India is dominated by a few large firms, it is particularly important that we learn how they innovate. Discussion on innovation in the Indian software industry would be incomplete without an analysis of how the larger firms innovate.

While global knowledge sources like FOSS play an important role in innovation, local sources of knowledge like academic institutions in the country seem to play a less significant role. With the expansion of platform software development services which require technological knowledge, STI-learning has become indispensable. This makes industry-university linkages important. Some signs of such linkages have been found in the case study. At the same time, there are evidences that cast doubt on Indian universities' capability to be a knowledge source. As the history of software and computing in India has shown us, the policy of domestic industry and academic institutions working together to advance local technology capabilities is a failure. If patents are indicators of invention, then Indian academic institutions are not inventive[1]. There has not been any case of successful innovation or innovative enterprise coming out of Indian universities. Even some of the celebrated initiatives like Simputer, in retrospect, have not been really successful. On the other hand, at least a few technology based innovative enterprises have come out of FOSS. In this context, the call for improving industry-university collaboration as a means of improving technological invention cannot be taken at face value. It is important to investigate the role played by Indian universities in software innovation so far.

The role of open innovation model of FOSS in promoting technological invention in India, remains under- recognized although this relationship has been well established internationally through several studies. Even if we accept the significance of FOSS in innovation, it is not clear how it influences the innovation process. Is it that firms are just using the technology (or knowledge) which is made available at almost zero cost? Are the firms able to absorb the technology and come up with something new? How

[1]Some weakness of this argument has been discussed in the section 3.2.3

does FOSS influence the technological competence of employees? There are many such questions that need to be answered in order to understand the role of FOSS in software innovation. The relative role of FOSS and academic institutions may differ in the context of large and small firms. Large firms may have access to other sources of knowledge courtesy their partnership with technology suppliers, foreign universities, etc.

Many researchers have pointed out that a high-tech industry is prone to agglomeration because of the localised nature of knowledge spillover. This study suggests that it is not the case. Tacitness of knowledge which is supposed to provide location stickiness has also become insignificant with the emergence of virtual epistemic communities. Then how does one account for the agglomeration of software firms in places like Bangalore? Though observations made of Trivandrum cluster may not hold true for larger and mature clusters, it is important to know what acts as the agglomeration force in the Indian software industry. This will help us understand how locally sticky the industry is.

It has been argued that tacit knowledge is the most important resource that determines the competitiveness of firms as explicit knowledge is really easy to access. In such a situation, it is counterintuitive to see a lot of contextual and tacit knowledge being shared in various virtual epistemic communities, undermining competitiveness of firms from which it is flows. It begs the question why people participate in these communities and share their valuable resource. Explanations offered centre around the idea of gift economy, where a person shares his/her knowledge with the expectation of being returned the favour in future. For firms in catching-up economies, these communities provide economically valuable resources. However, when it comes to returning the gift, the contribution of firms and individuals from these economies is negligible. Persistent parasitic behaviour can destroy these communities in the long run. If these communities are critical for innovation in Indian software industry, it is important to look at their dynamics. This gives rise to questions such as, how long will the approach of only receiving sustain? Will these countries give back? Is such a giving back already happening?

Lundvall (2007) says that in the development context, system of innovation approach needs to improve its understanding of power relationships. Some of the policies like introduction of software patents and preference

given to proprietary systems, which may not be in the interest of Indian software industry need to be reinvestigated. This will shed light on the power relations within the innovation process.

System of innovation approach provides a powerful tool to understand innovation and its role in development(Johnson *et al.*, 2003). Despite this, systemic understanding of the software sector is weak. More research on various aspects of this industry, keeping with the systemic nature of the problem is necessary. Listed here, are some questions encountered during this research.

Looking back, prospects of growth for the Indian software industry is high. The weakness of the industry has been recognized by industry associations like NASSCOM. However, more clarity is required as to where the weakness in innovation lies and how to address it. Further microlevel investigation of innovation in firms is required to bring more clarity. This study is a small step in that direction.

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Appendix A

Firms in Technopark

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
3E IT Solutions Pvt Ltd	61	2004	General Software	IT	NA	6
Aaric Technologies Pvt.Ltd.	41	NA	BPO/KPO	ITES	NA	NA
Accentia Technologies Limited	112	2006	BPO/KPO	ITES	Indian	4
Advanced Media Technologies Pvt. Ltd(AMTEC)	8	NA	Media	ITES	Indian	NA
AES Solutions Pvt. Ltd.	41	2007	SAP	IT	Foreign/NRI	3
Airframe Aero Designs Pvt.Ltd.	8	2006	Engg Service	ITES	NA	4
Akira Software Solutions Pvt Ltd	8	NA	General Software	IT	Indian	NA
Akros Tech Labs Pvt Ltd	8	2010	Software Product	IT	Foreign	0
Alamy Images India Pvt Ltd	230	2003	Media	ITES	Foreign	7
Aletheia Info Solutions Pvt.Ltd	8	NA	BPO/KPO	ITES	Indian	NA
Allianz Cornhill Informations Services	1754	2004	BPO/KPO	ITES	MNC	6
Amstor Information Technology India Pvt Ltd	NA	1996	Engg Service	ITES	NA	14
Amstor Softech (India) Pvt. Ltd	NA	1996	General Software	IT	NRI	14
Applexus Software Solutions (P) Ltd	NA	2008	SAP	IT	NRI	2
Aptara Learning Pvt Ltd	67	2009	BPO/KPO	ITES	Foreign/NRI	1
Aqlanza Info Systems Pvt. Ltd	8	NA	General Software	IT	Indian	NA
AR Software Solutions Pvt Ltd	67	NA	General Software	IT	NRI	NA

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Arackal Digital Solutions	67	2000	General Software	IT	NRI	10
Ariva Med Data Infotech Pvt. Ltd	64	NA	BPO/KPO	ITES	NA	NA
ARS Software Engineering Pvt Ltd	167	2001	GIS	IT	Foreign	9
Artin Dynamic Controls Pvt Ltd	100	NA	Embedded	IT	Indian	NA
Assuretech Business Solutions Pvt. Ltd	35	NA	Software Product	IT	Indian	NA
Attinad Software Pvt Ltd	33	NA	General Software	IT	NA	NA
Azinova Technologies Pvt. Ltd.	18	2007	Media	ITES	Indian	3
Cadmium Technologies and Solutions Pvt.Ltd.	8	NA	General Software	IT	Indian	NA
Captech Solutions India Pvt Ltd	8	NA	General Software	IT	Foreign	NA
Cell Technologies Pvt Ltd	10	NA	BPO/KPO	ITES	NA	NA
Collabera Enterprise Software Solutions Pvt Ltd	334	NA	General Software	IT	Foreign/NRI	NA
Confianz Information Technologies Pvt. Ltd.	29	2008	Media	ITES	Indian	2
Cre8tivebug Software Pvt Ltd	8	2008	Media	ITES	Indian	2
Datec Systems Pvt Ltd	67	1999	General Software	IT	Indian/NRI	11
DeoGracia Infotech Pvt Ltd	8	NA	Portal	IT	NA	NA
Dev Web Services India Pvt Ltd	8	NA	General Software	IT	Indian	NA
DeviceDriven (India) Pvt Ltd	72	2006	Specialised Software	IT	Indian	4

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Digital Brand Group Inc	17	NA	Media	ITES	Foreign	NA
Digitella Outsourcing Pvt Ltd	78	2006	BPO/KPO	ITES	Foreign	4
Dimensions Cybertech (I) Pvt Ltd	83	2000	General Software	IT	Indian	10
DSI Technologies Pvt Ltd	41	2001	Engg Service	ITES	Foreign/NRI	9
E-Team Informatica India Pvt. Ltd.	62	2005	General Software	IT	Foreign	5
EastEnd Health Care Solutions Pvt Ltd	8	NA	Portal	IT	NA	NA
Eco White Architectural Engineering & Technology Services Pvt. Ltd	61	2001	Engg Service	ITES	Foreign	9
Elementz IT Solutions Pvt.Limited	8	2007	General Software	IT	NA	3
Enigma Solutions Pvt Ltd	NA	NA	General Software	IT	Foreign	NA
Enter Technologies Pvt Ltd	100	1999	BPO/KPO	ITES	Indian	11
Ernst & Young Middle East Technologies Pvt Ltd	332	NA	BPO/KPO	ITES	MNC	NA
Exalt Integral Solutions P Ltd	66	2003	General Software	IT	Indian	7
Experion Technologies (India) Private Limited	144	NA	General Software	IT	Indian	NA
Extolution Software Pvt Ltd	31	2006	General Software	IT	NA	4
eZe Care Systems and Solutions Pvt Ltd	41	2005	BPO/KPO	ITES	NA	5
Firstpos Retail Softsolutions India Pvt. Ltd	33	2009	Software Product	IT	Indian/NRI	1

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Fischer Systems India Pvt Ltd	33	1998	Software Product	IT	Foreign	12
Flip Media P Ltd	64	2003	Media	ITES	Foreign/NRI	7
Flytxt Technology Private Limited	NA	2007	Mobile	ITES	Foreign	3
Founding Minds Software Pvt. Ltd	66	NA	General Software	IT	NA	NA
GD Innovative Solutions Pvt Ltd	33	NA	General Software	IT	NA	NA
Gemini Software Solutions Pvt Ltd	167	1998	General Software	IT	Foreign	12
Geotrans Technologies Pvt Ltd	31	NA	GIS	IT	Indian	NA
Global Design and Engineering Services Pvt Ltd (GDES)	67	2005	Engg Service	ITES	NA	5
Green Craft IT Solutions Pvt. Ltd	48	NA	General Software	IT	NRI	NA
Greenchild Image Solutions Pvt Ltd	8	2007	Media	ITES	Foreign	3
Grid Design Solutions Pvt Ltd	16	2007	Engg Service	ITES	NA	3
Gridzone Software Solutions Pvt Ltd	8	NA	General Software	IT	Indian	NA
Hages Business Solutions Pvt Ltd	NA	2007	SAP	IT	Indian	3
IBS Software Services Pvt Ltd	6000[1]	1997	Software Product	IT	Indian	13
IDynamics Ltd	76	2006	General Software	IT	Foreign	4
InApp Information Technologies P Ltd	33[2]	1996	General Software	IT	Indian/NRI	14

[1] Approximate size based on various reports including firm website
[2] Two firms have merged with InApp later increasing its size

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Indriya Technologies Pvt.Ltd	29	2007		NA	NA	3
Infoblox Technical Support and Software Development Pvt.Ltd.	17	2007	Software Product	IT	MNC	3
InfoMind(IM) Technologies Pvt Ltd	8	NA	RNM	ITES	NRI	NA
Infosys Technologies Ltd.	1862	NA	General Software	IT	Indian Major	NA
Innoz Technologies Pvt. Ltd.	8	NA	Mobile	ITES	Indian	NA
Inometrics Technology Systems (P) Ltd	8	NA	Embedded	IT	NA	NA
Integrated Dynamic Solutions India Pvt Ltd	NA	2005	General Software	IT	Foreign	5
Intigen Technologies Pvt Ltd	8	NA	General Software	IT	NA	NA
iTraitz IT Solutions Pvt. Ltd	17	NA	General Software	IT	NA	NA
IVL India Pvt Ltd	167	1991	SAP	IT	Indian	19
JouvertMatics Technologies Pvt Ltd	8	NA	General Software	IT	NRI	NA
Kameda Infologics Pvt Ltd	NA	2000	Software Product	IT	Foreign/NRI	10
Kreara Solutions Pvt Ltd	31	2004	Clinical research	ITES	Indian	6
Krigansys Technologies & Applications Pvt. Ltd.	8	NA	SAP	IT	NA	NA
Leeds Technologies Pvt. Ltd.	NA	NA	General Software	IT	Indian	NA
Lino Computer Technologies Pvt Ltd.	8	NA	Embedded	IT	Indian	NA
M Squared Software and Services Pvt Ltd	NA	1996	BPO/KPO	ITES	Indian	14

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Macrosoft IT Solutions India Pvt. Ltd.	33	2005	General Software	IT	Foreign	5
Maxartists Technologies Pvt.Ltd.	52	2005	General Software	IT	Indian	5
McFadyen Consulting	33	2005	General Software	IT	Foreign	5
Mirox Cyber Security & Technology Pvt Ltd	8	NA	Specialised Software	IT	Indian	NA
Mobatia Technology Pvt. Ltd	NA	2010	Mobile	ITES	NRI	0
Mobshare Mobile Systems India Pvt. Ltd.	8	NA	Mobile	ITES	Indian	NA
NaviCare Solutions Pvt Ltd	8	1999	Software Product	IT	Foreign	11
Network Systems & Technologies (P) Ltd [NeST]	1000[3]	1991	Embedded	IT	Indian	19
Offshore Commisioning Solutions (OCS IT)	8	NA	RNM	ITES	MNC	NA
One View Systems Pvt Ltd	33	NA	Software Product	IT	Indian	NA
OptioLogic Technologies Pvt. Ltd.	8	2009	General Software	IT	Indian	1
Ospyn Technologies Pvt Ltd	39	NA	General Software	IT	Indian	NA
OzTern Technology Pvt ltd	8	2009	General Software	IT	Indian	1
Palnar Transmedia Pvt Ltd	46	1998	General Software	IT	NRI	12
Paragon Biomedical India Pvt Ltd	122	2005	Clinical research	ITES	Foreign	5
Penta Circle Informatic Pvt Ltd	23	NA	General Software	IT	NA	NA
Phykon Solutions Pvt Ltd	62	2008	BPO/KPO	ITES	Indian	2

[3]Approximate estimate given during interview

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
PIT Solutions Pvt Ltd	128	2000	General Software	IT	Foreign/NRI	10
Pivotsys Technologies Private Limited	33	NA	General Software	IT	NRI	NA
Prapty Data Solutions Pvt Ltd	8	NA	SAP	IT	Indian	NA
Proxy Systems Pvt Ltd	33	2002	GIS	IT	Foreign	8
QBurst Technologies Pvt.Ltd.	300[4]	2004	General Software	IT	Indian	6
Qik Trans Solutions Pvt Ltd	8	NA		NA	NA	NA
Quintessence Technologies Ltd	17	1999	Media	ITES	Indian	11
Rain Concert Technologies Pvt.Ltd.	56	2006	General Software	IT	Indian	4
Reflections Info System Pvt.Ltd.	8	1999	Media	ITES	Indian	11
Reno Development Technology(P) Ltd-	8	2007	Specialised Software	IT	Foreign	3
RevenueMed India Pvt Ltd	312	2004	BPO/KPO	ITES	Foreign	6
Reynex Softwares Pvt Ltd	31	2009	General Software	IT	Indian	1
RickshawSoft Smart Solutions Pvt. Ltd.	33	2009	General Software	IT	Foreign	1
RM Education Solutions India Pvt. Ltd.	374	2002	Specialised Software	IT	Foreign	8
RR Donnelley India Outsource Pvt Ltd	676	1991	BPO/KPO	ITES	MNC	19
RWDI Consulting Engineers & Scientists India Pvt Ltd	40	2006	Engg Service	ITES	Foreign	4
Saihati Engineering Services India Pvt Ltd	33	2008	Engg Service	ITES	Foreign	2

[4]Approximate estimate given during interview

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Sandblue Software Pvt Ltd	62	2002	General Software	IT	Foreign	8
Sansys Software Solutions		2003	General Software	IT	NRI	7
Sarfinity Consulting P Ltd	64	2001	General Software	IT	Indian	9
Satmetrix Systems	145	2007	Software Product	IT	Foreign	3
Saturn Systemwares Pvt Ltd	18	NA	General Software	IT	NA	NA
Screencaster India	NA	NA	General Software	IT	Foreign	NA
Se-Mentor Solutions Pvt Ltd	8	2007	Specialised Software	IT	Indian	3
Seaview Support Systems Pvt Ltd	150	1996	BPO/KPO	ITES	Indian	14
Sherston Educational Software Pvt Ltd	263	2003	Media	ITES	Foreign	7
Shree Deepam Infotec Pvt Ltd	8	NA	BPO/KPO	ITES	NRI	NA
Sigtech Wireless Technologies Pvt. Ltd.	8	2009	Embedded	IT	Foreign	1
SLASHOME Technologies	8	NA	RNM	ITES	Indian	NA
Softex Digital P Limited	38	2003	Specialised Software	IT	NA	7
Softlution Web Technologies Pvt Ltd	133	1999	General Software	IT	Foreign	11
SooryaKiran BioInformatics Pvt.Ltd	8	NA	Specialised Software	IT	Indian	NA
Speridian Technologies Pvt Ltd	206	2003	General Software	IT	Foreign/NRI	7
SRC Software Private Limited	67	2003	General Software	IT	Foreign	7
Sree Anand Travels	8	NA	Portal	IT	NRI	NA

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
Srishti Innovative Computer Systems Pvt. Ltd	17	NA	General Software	IT	NA	NA
Stabilix Solutions Pvt Ltd	100	2002	General Software	IT	Foreign	8
Standout IT Solutions Pvt Ltd	33	2004	General Software	IT	Indian/NRI	6
SunTec Business Solutions Pvt Ltd	400[5]	1990	Software Product	IT	Indian	20
Swami Cyber Solutions Pvt Ltd	33	1999	General Software	IT	NRI	11
Tata Elxsi India Ltd	343	2001	Embedded	IT	Indian Major	9
Techband Technologies Pvt. Ltd.	8	NA	Media	ITES	NA	NA
Techping Internet Solutions Pvt Ltd	8	NA	General Software	IT	Indian	NA
Tetra Tech India Ltd.	NA	NA	Engg Service	ITES	MNC	NA
ThinkBig Software Solutions Pvt Ltd	8	NA	General Software	IT	Indian	NA
Thoughtline Technologies Pvt Ltd		NA	General Software	IT	NRI	NA
Toonz Animation India Pvt Ltd	298	1999	Media	ITES	NRI	11
Transversal e Networks Private Limited		2004	General Software	IT	NRI	6
Travancore Analytics Pvt Ltd	NA	2007	Specialised Software	IT	Indian	3
TRIV Software Pvt Ltd	67	NA	Software Product	IT	Foreign	NA
Ushus Technologies	167	1999	Embedded	IT	Indian/NRI	11

[5]Most of its staff work in an office outside Technopark. Employee size is as reported during interview

Table A.1: List of firms in Technopark (as of Nov 2010)

Name	Size	Year	Domain	IT/ITES	Ownership	Age
UST Global	6000[6]	1999	Specialised Software	IT	NRI	11
Vanilla Networks Pvt Ltd	50	2004	General Software	IT	Foreign	6
Vinvish Technologies Pvt.Ltd.	79	2004	Embedded	IT	Indian	6
Virtus IT Services Pvt Ltd.	41	NA	General Software	IT	Foreign	NA
Visionics India Pvt Ltd	35	1995	Software Product	IT	Foreign	15
Visual Graphics Computing Services India P Ltd	247	2002	Media	ITES	MNC	8
Viswarethna Technology Solutions Pvt Ltd	8	2005	General Software	IT	NA	5
Vyga Animation Systems Pvt Ltd	167	2008	Media	ITES	Indian	2
Xminds Infotech Pvt Ltd	8	2008	General Software	IT	NA	2
YSC Engineering Services Pvt Ltd	76	2006	Engg Service	ITES	Foreign	4
Zafin Centre of Excellence Pvt. Ltd.	145	2007	Software Product	IT	Foreign/NRI	3
Zoondia Software Pvt Ltd	8	2008	Media	ITES	Foreign	2
Zyphix Technologies Pvt. Ltd	8	NA	General Software	IT	Indian	NA

[6]Approximate size based on various reports including firm website

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