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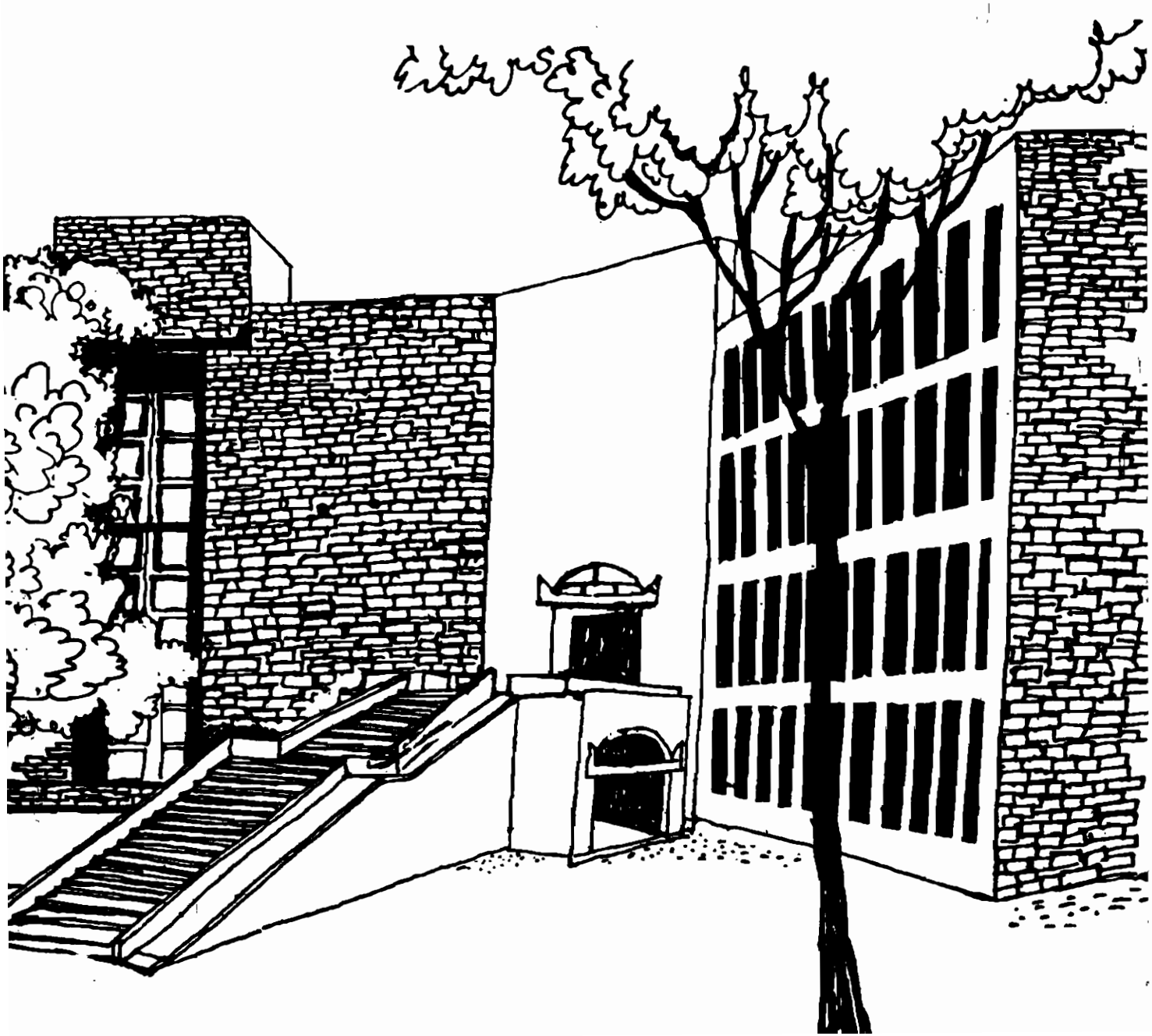

INTER-FIRM LINKAGES IN THE IT INDUSTRY IN INDIA: A CASE STUDY OF TELECOM TECHNOLOGIES

By

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Abstract

Indian firms in the IT sector have entered into a variety of inter-firm alliances in recent years. Many of these alliances have been with foreign firms. There is growing evidence internationally that such linkages affect the development of new technologies. However, it is not very clear how inter-firm linkages mediate the process of development of technological capabilities that in turn affect the extent of technology development.

In this paper we focus on the telecom segment of the IT sector with an objective to understand the nature and extent of inter-firm linkages in the industry, the role these linkages play in developing technological capabilities in participating firms, and the extent to which firms utilize these capabilities for growth and diversification. The study is based on a survey of large and small in the telecom sector and case studies of two interesting alliances – Nortel's alliances in India and China and technology development network of Indian Institute of Technology, Chennai. The survey data as well as the case studies suggest that inter-firm linkages have helped Indian firms build technological capabilities. This paper analysed inter-firms alliances and their role in capability building at different levels. Insights from published data were combined with results of a primary survey and case studies to identify the key processes at work.

The survey findings and the case studies add to the growing evidence that technology alliances of developing country firms with other entities (multinational or domestic) having excellent manufacturing and/or technology development capabilities in areas where the technology gap is relatively narrow can potentially play a crucial role in upgrading capabilities of developing country firms. While the participating Indian companies have gained a lot through the multinational arrangements, it needs to be ascertained whether such linkages can result in significant spillover benefits for the rest of the sector/economy. The key policy challenge therefor is to create conditions that facilitate the emergence of such linkage and the development of skills necessary to absorb the spillover benefits of such alliances. Policies that help create pools of skilled manpower are likely to achieve both these objectives.

Executive Summary

Indian firms in the IT sector have entered into a variety of inter-firm alliances in recent years. Many of these alliances have been with foreign firms. There is growing evidence internationally that such linkages affect the development of new technologies. However, it is not very clear how inter-firm linkages mediate the process of development of technological capabilities that in turn affect the extent of technology development.

In this paper we focus on the telecom segment of the IT sector with an objective to understand the nature and extent of inter-firm linkages in the industry, the role these linkages play in developing technological capabilities in participating firms, and the extent to which firms utilize these capabilities for growth and diversification. The study is based on a survey of large and small in the telecom sector and case studies of two interesting alliances – Nortel's alliances in India and China and technology development network of Indian Institute of Technology, Chennai. The survey data as well as the case studies suggest that inter-firm linkages have helped Indian firms build technological capabilities. This paper analysed inter-firms alliances and their role in capability building at different levels. Insights from published data were combined with results of a primary survey and case studies to identify the key processes at work.

The survey findings and the case studies add to the growing evidence that technology alliances of developing country firms with other entities (multinational or domestic) having excellent manufacturing and/or technology development capabilities in areas where the technology gap is relatively narrow can potentially play a crucial role in upgrading capabilities of developing country firms. While the participating Indian companies have gained a lot through the multinational arrangements, it needs to be ascertained whether such linkages can result in significant spillover benefits for the rest of the sector/economy. The key policy challenge therefor is to create conditions that facilitate the emergence of such linkage and the development of skills necessary to absorb the spillover benefits of such alliances. Policies that help create pools of skilled manpower are likely to achieve both these objectives.

Introduction

Recent literature on technological change and economic development has focused a great deal on the determinants of building technological capabilities in developing economies. Earlier research focus on macro changes has been gradually replaced by studies, which try to relate macro changes to micro (firm level) developments. A few noteworthy strands in this literature include role of multinationals (MNC) in developing technological capabilities, host country policies to attract foreign firms, nature and role of inter-firm linkages, and the impact of information technology on developing global inter-firm network.

Studies have shown that MNC activities can have a significant and positive impact on technological capabilities of firms in developing countries provided these firms make technological investments and countries adopt pro-competition policies (Kokko, 1992; Evenson and Westphal, 1994). Another set of studies begin with the premise that MNC activity can enhance capabilities and explore how policies can help developing countries win "locational tournaments" to attract foreign investments (Mytelka, 1998).

With the decline of Fordism, many researchers have started looking at inter-firm linkages with renewed interest in recent years. The growth in product sophistication and variety has induced inter-firm linkages as no single firm can develop capabilities in all aspects of product and process technology. Basant and Chandra (1997) have discussed this issue in the context of telecom technologies. Within inter-firm linkages, issues relating to "hierarchies and markets" and "strategic networks" have received considerable attention (Williamson, 1995; Hamilton and Feenstra, 1995). The information revolution has further added new dimensions to strategic alliances and flexible networks. As a result, global networks are increasingly becoming relevant for developing country firms (Kobrin, 1998). Given the above developments, an understanding of how inter-firm networks evolve and function and how developing country firms can benefit from these alliances becomes crucial.

Inter-firm linkages for raising equity, marketing and distributing products, licensing of technology and brands, sub-contracting etc. have been a common feature for several years. Technology co-operation/development agreements among firms, however, have recent origins. The potential role of inter-firm linkages in developing technological capabilities of partner firms (especially in developing countries) is well recognised. (See Bell and Pavitt, 1997 for a review,). In the hierarchy of linkages, technology development related agreements typically require more technological competence among participating firms than in production and distribution related linkages. The learning opportunities are also higher in the former. The key issue is whether firms participating in these linkages are able to reap potential learning benefits from such alliances. And if so under what circumstances? An exploration of these aspects is the focus of this paper. Specifically, we focus on the telecom segment of the IT sector with an objective to understand the following:

- the nature and extent of inter-firm linkages in the industry in general and specifically in this sector?
- What role do these linkages play in developing technological capabilities in participating firms?, and
- How do firms utilize these capabilities for growth and diversification.

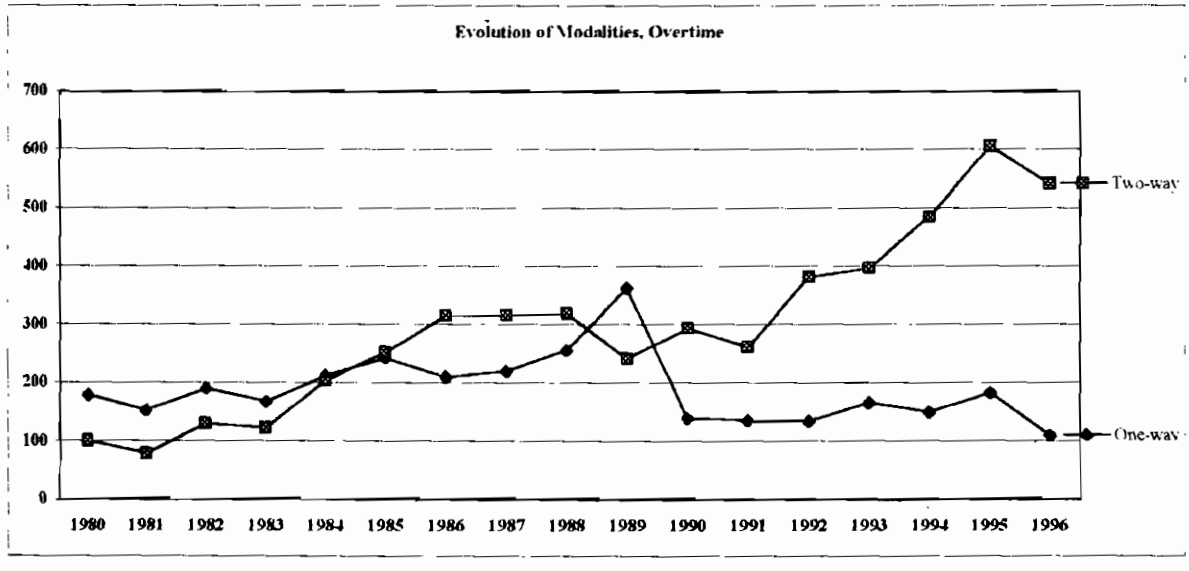
The paper is divided into five sections. In the next section we develop a taxonomy of inter-firm linkages and discuss how the structure of such linkages has changed in recent years. Based on secondary data, Section III examines the structure of recent inter-firm linkages among telecom related firms in India. This is followed, in Section IV, by findings of a survey of inter-firm linkages within IT firms that deal with telecommunication technologies. The cases of R&D networks of Nortel in both India and China are discussed in Section V. We assess Nortel's role in developing technological capabilities among the Indian participants of the network. The section also compares the Nortel network in China with its network in India to examine the relative advantages of the two vis-a-vis the learning potential for the domestic economies. In section VI we present a case study on technology development and commercialization in the telecom sector, at the Indian Institute of Technology, Chennai through formation of inter-firm linkages. The final

section summarises the key findings to highlight aspects of inter-firm linkages, which may result in higher learning for firms in developing countries.

II Recent Trends in Inter-firm Linkages

Firms are engaged in a various forms of collaborative activity (See Table 1). Two types of inter-firm linkages can be distinguished: those that involve a one-way relationship leading to a flow of technology from the licensor to the licensee or from the mother unit to the subcontractors; and two-way relationship involving joint R&D or research programmes to create common standards. While the unidirectional linkages have existed for a long time, the two way relationships are more recent; the newer forms of partnering activity in R&D, production and marketing have also become more prominent over the years (Mytelka, 1999; WIR 1998). Recent data for the years 1980 to 1996 show a marked shift away from the quasi exclusive reliance on one-way linkages to the development of two-way collaborative relationships in the 1990s (Figure 1).

Figure 1
Evolution in the type of inter-firm technology agreement: 1980-1996



Source: WIR, 1998, 25.

Furthermore, the nature of some of the traditional relationships like joint ventures and sub-contracting have changed considerably in recent years. For example, in many JVs in the life

sciences/ biotechnology industry, the intention is less to exercise control than it is for the larger firm, usually a major pharmaceutical or chemical company to provide the financial and marketing resources that the smaller dedicated biotechnology firm lacks. Similarly the emergence of some sub-contractors as partners engaged in a dialogue with their 'principals' has been documented in textiles and clothing, auto-components and the electronics industries. Customer-supplier relationships have also changed considerably as suppliers are drawn into joint research and collaboration in the design of new products for their clients and take on additional responsibility for the manufacture of whole modules subsequently assembled into complete products by their customers, notably in the automobile and the aircraft industries (See. for recent examples, Mytelka, 1999 and WIR 1998). Just like sub-contracting linkages have undergone significant changes in recent years, the nature of global software outsourcing (GSO), a kind of sub-contracting, has also changed with the outsourcing firms' participating more actively in such relationships. We will describe the evolution of one such relationship in a subsequent section.

Among the two-way inter-firm agreements, technology co-operation agreements have seen a significant rise in the 1990s. According to some estimates compiled by UNCTAD, the number of technology co-operation agreements per year was only 63 during 1975-79. This increased to 502 per year during 1988-91 and to 626 in 1992-95. In 1996 about 650 such agreements were signed. Moreover, technology co-operation agreements in knowledge intensive sectors like information technology and life sciences industry have risen most rapidly in recent years and now constitute about 55 per cent of all agreements; information industry alone constitutes about 37 per cent of such agreements (Mytelka, 1999; WIR 1998).

Participation of developing countries in inter-firm technology agreements is limited but has improved a bit in recent years. The share of developing countries in technology agreements has increased from 4.9 per cent in the 1980s to about 6.2 per cent in the 1990s. Even among those agreements, which involve developing countries, information technology related technology agreements dominate, their share being as high as 27 percent. Besides the share of two-way relationships among the agreements involving developing countries is also on the rise, which suggests that firms in developing countries are gradually becoming viable partners in joint

technology generation activities. (WIR, 1998: 27-29) For developing country firms, the two-way linkages are an important mechanism for accessing knowledge bases abroad. However, some studies have shown that among the third world countries only firms from some newly industrialising economies, especially South Korea and Taiwan, have any significant participation in technology/R&D co-operation arrangements (Hagedoorn and Freeman, 1994).

III Inter-firm Linkages in the Indian Telecom Sector

Telecom related technologies are undergoing significant changes. It has been suggested that development of telecom related software could prove to be a useful market opportunity for Indian software firms. But for exploiting such opportunities, access to hardware knowledge will be crucial. Technology co-operation between telecom hardware and software firms can provide such an opportunity (Basant and Chandra, 1997).

Capability levels in the Indian software industry are considered to be quite high. However, there are divergent views on whether the industry is "moving towards maturity" or is trapped in a low-level equilibrium. Heeks (1996) has suggested that Indian software firms predominantly participate at the low end of the global outsourcing arrangements and the movement to more complex jobs is constrained by the domestic market.[1] Besides, while global software skills shortage is likely to continue, the shortage may be more of analysts (or analysts cum programmers) than of programmers. Consequently, countries like India may face problems if they rely mainly on supplying programming staff. Bhatnagar and Madon (1997), on the other hand, cite evidence to suggest that Indian software firms have moved in recent years from low end tasks ("low value added body shopping" and "offshore customised software development") to more value added jobs ("starting up offshore package development" and in some cases "total offshore product development"). They also argue that the growth of domestic market is facilitating such growth. Irrespective of which of these trends are dominant, outsourcing for product development is likely to create significant opportunities for learning for participating firms in India.

[1] This market seems to have grown quite rapidly in the late 1990s, especially the last two years.

The Indian telecom sector firms are engaged in a wide variety of inter-firm linkages. Table 2 presents some estimates of the nature of alliances entered into by these firms in the late 1990s.[2] As can be seen, linkages for financial participation, joint production, supply of equipment and for accessing complementary assets (infrastructure, distribution and sales and marketing support) are most frequent. Joint R&D and other types of technology linkages are relatively less common. Joint service provision seems to be becoming somewhat more popular in this sector.

One interesting feature of these alliances is that except in a few types of relationships, bundling of activities does not take place. For example, linkages for the supply of equipment, provision of infrastructure or for accessing distribution and marketing channels are almost exclusively for these activities; financial participation and activities like technology transfer, servicing etc. are not part of these linkages (Table 2 and 3). Similarly, joint R&D and technology collaboration are also not part of "package" alliances, linkages are usually established to exclusively undertake such activities. Bundling, however, does take place with financial collaboration, which is usually combined with joint production and licensing of technology.

It is difficult to assess, on the basis of published information, whether the majority of these linkages are "two-way" or correspond to the "one-way" traditional relationships. However, joint production, service provision, bidding and R&D are obviously "two-way linkages". The linkages between software and hardware firms are significant in number but do not dominate the inter-firm linkages among firms engaged in telecom related activities. Of the 176 linkages on which we have information, 35 (20 per cent) were between software and hardware firms, 85 (48 per cent) between hardware firms, 39 (22 per cent) among software firms and the remaining 17 (10 per cent) among other firms, mainly between new service providers and software and hardware firms.

About 58 per cent of these linkages were between MNCs and domestic firms and the remaining involved only domestic firms. But the nature of linkages among these two groups of firms was different: while the linkages among domestic firms mainly involved provision of equipment and

[2] The data on alliances used in this section has been compiled at the Indian Institute of Management, Ahmedabad mainly from financial dailies and weeklies and publications of the Centre for Monitoring Indian Economy, Mumbai.

infrastructure and distribution arrangements, the links between MNCs and domestic firms were more varied and involved financial collaboration, joint production and accessing of marketing and distribution channels. (Table 4) Most of the technology related (joint R&D, collaboration, licensing etc.) linkages were between MNCs and domestic firms. This is expected, as the MNCs are the main sources of technology and they also need complementary assets to enter the Indian market; domestic firms prefer to collaborate more with MNCs for technology development and access and their need for complementary assets is relatively less. However, given the diverse and fast changing nature of the telecom technology and the rapidly changing market structure, both sets of firms need complementary assets of various kinds.

It must also be recognized that technology in this sector is changing very rapidly. Even the MNCs recognize the roles of specialised skills and technologies in keeping up with this change and linkages with firms in different sectors having such capabilities. This need is even stronger for firms in developing countries. Most MNC firms in India entered into an alliance with local partners for accessing their marketing and distribution assets (in a few cases, manufacturing facilities) and because of regulatory requirements. The domestic partners, in return, acquired technology from their partners. As policies liberalize and MNCs gain more experience in the domestic market, their need for local partners may diminish and they may opt out of these alliances. Domestic firms that hope to survive in this sector will have to pro-actively use these linkages to absorb and learn quickly not only about the technologies under transfer but also the process of technological innovation. As marketing and distribution assets become more generic from the MNCs perspective, technology related competencies can provide flexibility and growth potential for the domestic firms. Technologically capable domestic firms can either compete on their own or remain valuable partners in any alliance.

IV Some Aspects of Inter-firm Alliances: Findings of a Survey

The last section analysed published data to identify broad patterns of inter-firm alliances in the Indian telecom sector. The inadequacy of published information does not permit detailed analysis of the nature of alliances. Many of the issues relating to the links between alliances and learning at the firm level remain unexplored. To partly fill this gap we surveyed one hundred telecom

related firms and collected some detailed information about their linkages with other firms. This section summarises the key findings of this survey.

The survey sought to cover software as well as hardware firms in the Indian telecom sector.. Besides, some firms providing IT services were also included. The names of the firms which can be potentially covered were generated from IT magazines. The survey focused on four locations, namely, Delhi, Mumbai, Bangalore and Chennai. It needs to be emphasized that our sample may not be representative of the entire IT-Telecom sector in India. The available published information did not permit detailed stratification of firms so that an appropriate sampling strategy could be used. We hope, however that the insights derived from this survey will be indicative of the processes at work. It is in this spirit that we discuss the results of the survey. Table 5 suggests that our survey has covered a wide variety of firms in terms of sales and employment.

Broadly, data on inter-firm linkages was compiled at two levels: alliances and projects. Preliminary investigation showed that often enterprises have more than one alliance and within each alliance they work on multiple projects with their partners.

Nature and Objectives of Alliances

The survey covered alliances between hardware, software and IT service firms. Table 6 shows that the sample firms were engaged in a variety of alliances: hardware firms (or hardware segments of a diversified firm) entered into alliances with other hardware firms, software firms and IT service providers. The share of hardware firms in the total number of alliances was much lower than their share in the sample firms. While alliances with other software firms were dominant among sample software firms, these firms also had linkages with hardware and IT service firms. Interestingly, while software firms tended to have a larger proportion of their alliances with other software firms (and hardware firms with other similar firms), on average the IT service firms seem to have a highly diversified portfolio of alliances.

Detailed data was collected in the survey about the nature of alliances; whether the linkages involved transfer of technology, subcontracting, cross holding, marketing arrangements and so on.

Often the same alliance involved a variety of activities or dimensions, e.g. technology transfer, licensing of brand and a sub-contracting contract. To facilitate analysis the alliance activities were divided into five broad categories: technology related; production related; finance related, marketing & distribution related and those involving a management agreement. Table 7 reports the distribution of alliances across these activities and sub-activities within them. If an alliance had multiple dimensions, (e.g. involved technology transfer as well as joint production), it was counted in both categories, i.e., technology and production related. Appendix Table 1 reports the distribution by detailed categories bringing out the various combinations of alliances found amongst sample firms.

The alliances covered a variety of activities: while technology, production and marketing & distribution related alliances) were equally important (52-56 per cent alliance involved these), finance and management agreement related linkages were found to be less popular, as less than 25 per cent alliances involved such linkages.[3]

Appendix Table 1 highlights an interesting phenomenon: a large number of alliances cut across the broad categories defined above. However, while technology, marketing & distribution (and to some extent production related alliances are often found in "pure" forms, it is rarely the case with financial with collaborations. Virtually all alliances where financial links exist, technology, production or marketing linkages also are part of the inter-firm relationship.

Within technology related linkages, collaborations for establishing standards were dominant. Significantly, more than 26 per cent of the alliances involved joint research and development agreements. Besides, many of the technology related alliances involved joint R&D as well as collaborations for establishing standards. Unlike other sectors, where technology links are typically dominated by licensing arrangements, Indian firms in the IT-Telecom sector seem to be

[3] These patterns are different from the patterns observed in the last section where the data showed financial linkages to be more important. It is difficult to ascertain the reasons why the published data show different patterns than our survey data. There may be biases in the published information with only the relatively large firms' linkages getting covered. This and the smallness and diversity of our sample may imply that the two data sets are not strictly comparable.

"more equal" partners in the technology development process. How "equal" these alliances are, is difficult to ascertain but it is clear that bulk of these are "two-way" alliances.

Subcontracting and supply arrangements are dominant among the production related alliances. Besides, joint production activities are also quite important. Distribution and sales arrangements are the most common marketing and distribution related alliances. While marketing links are also quite important, licensing of brands is not widespread. Once again the IT-Telecom sector seems to be different from many other sectors where Indian firms are actively seeking alliances for licensing brand names, especially foreign ones (for details see Basant, 2000). Of course, brand licensing is less likely among sample firms as they may not be making "final products" sold directly to the consumers.

Joint ventures constitute the most important form of finance related alliances. Bidding consortium seems to be another form of emerging inter-firm alliance in this sector. Minority and cross-holdings are not very common.

Broadly then, the inter-firm alliances among the sample IT firms focus on technology, production, marketing & distribution. Unlike, many alliances in recent years, linkages among IT firms do not seem to focus mainly on raising financial resources.

Participation of Foreign Firms

Table 8 shows that inter-firm alliances in the Indian IT sector have significant involvement of foreign firms. In fact, for all categories of alliances, incidence of alliances between domestic and foreign firms is significantly more than the incidence of alliances among domestic firms. Interestingly, the distribution of "domestic" alliances by categories is not significantly different from the distribution of "foreign" alliances. Technology, production, marketing & distribution related alliances dominate for both domestic and foreign alliances, with finance related linkages not as important.

Objectives of Alliances

The fact that IT-telecom alliances are not primarily entered into access financial resources is also evident from the Table 9 which reports the distribution of alliances by objectives (multiple objectives were permitted). Here again the focus on technology is clearly evident. Technology based objectives were clearly dominant in these alliances and took various forms. These forms included exploitation of technological complementarities among partners, monitoring technological opportunities, accessing partners' technology, acquisition of world class practices, reduction in innovation time span, conducting basic research and so on. All these, except basic research and reduction of innovation time span were reported by a large proportion of sample firms (41 to 71 per cases).

Market expansion and monitoring was the other important objective of reported alliances. Besides, a large majority of firms (79 per cent) entered into alliances to increase profitability. A significant proportion of firms (40 per cent) also established inter-firm linkages to reduce costs and risks.

Significantly, in a large proportion of cases the intended objectives were realised. Overall, the realisation of technological, market expansion and profitability objectives was more than for other objectives. In general, the estimates reported in Table 9 suggest that except for a few objectives like activating partnership with subsidiaries, controlling partners, and conducting basic research, the alliances succeeded in satisfying their objectives in more than half the cases. However, as compared to other objectives, the realisation rate was significantly more for objectives like exploiting technological opportunities, accessing and monitoring technologies, increasing market share, acquiring world class practices and increasing profitability. The alliances therefore seem to have a positive impact on sample firms' technological capabilities, market share and profitability.

Some More Features of Alliances and Capability Building

That the alliances were by and large mutually beneficial is also brought out by the information summarised in Table 10. In almost all the alliances the size of the projects and the number of employees devoted to the alliance increased over time. The proportion of alliances in which the

partner helped set up factory or other facilities was rather low (22 per cent). This can probably be due to the fact that not many alliances may have involved manufacturing linkages. However, in only about 44 per cent of the cases the partners helped improve managerial practices. Besides, in only about 53 per cent of the cases, alliances facilitated improvements in shopfloor or programming practices. While these low percentages may be partly reflective of the nature of alliances, one would have preferred a more positive impact of alliances on firm level practices. Perhaps, firms are not consciously trying to exploit this benefit.

On the positive side, a large proportion of alliances (about 45 per cent) facilitated development of new products. This would certainly have enhanced sample firms' product development capabilities. In about 41 per cent of the cases, the sample firms also had (either jointly with the partner or alone) the intellectual property rights (IPRs) over the technology generated through the alliance. In about 26 per cent of the cases, the partner firm owned the intellectual property developed through the alliance while in about one-third of the cases, nobody owned the IPRs, presumably because the partnership did not lead to any tangible intellectual property that can be protected. Interestingly, only about 65 per cent firms considered IPRs to be important in an alliance.

Apart from the direct benefits in the form of product or/and process (e.g. factory, facilities) capabilities, the sample firms seem to be benefiting from spillover effects as well. About 67 per cent of the sample firms reported that the investments in hardware/software made through the alliance are useable in other projects. Besides, in almost 70 per cent of the cases, the alliance helped in training employees other than those involved in the alliance projects.

Two more interesting features of the alliances need to be noted. One, most of the alliances are for the domestic market with only 34 per cent alliances focusing on the export market. It is difficult to ascertain the extent to which domestic orientation of alliances is a reflection of sampling biases that may have crept into the survey. However, to the extent these estimates are indicative, they suggest a maturing of the domestic IT-Telecom market. A movement towards maturity is particularly apparent when one juxtaposes this with the fact that a majority of the survey alliances

are between domestic and foreign firms. The second important finding is that for about 78 per cent alliances, electronic mail was an important source of communication. The emergence of e-mail seems to have facilitated the functioning of alliances in the IT-Telecom sector. Despite this, however, problems of coordination and communication remain. More on this later.

Some Dimensions of Projects Undertaken within Alliances

As mentioned earlier, more than one project may be undertaken within an alliance. Our survey collected some information at the project level. A total of 156 most recent projects across alliances were covered. Table 11 summarises the key findings.

On average, the sample firm made 73 per cent of the total financial investment in the project. This is consistent with our earlier finding that alliances captured in the survey were not primarily geared towards raising financial resources.

Provision of design, software and hardware can be seen as important aspects of inter-firm alliances. The estimates reported in Table 11 show that in a large proportion of cases, the sample firms provided design, software and hardware inputs. In fact, the proportion of cases in which the sample firms (either alone or jointly with partners) provided these inputs was higher than the percentage of cases where the partner alone provided them. The cases where both the firm and the partner provided these inputs can certainly be seen as "two-way" linkages. Besides, in most cases where the sample firm is providing the design, software and hardware linkages are likely to be of the "two-way" variety. Consequently, few projects can be characterised as "one-way" partnerships. This impression is strengthened by the fat that in more than 81 per cent of the projects the sample firm played an important role in planning. And in 83 per cent of the cases, the firms had access to the final product of the alliance.

Another important feature of the projects has been that in a large proportion of cases (58 per cent) employees with skills not hitherto available with the firm were hired for the projects. The projects, therefore, created opportunities of firms to enhance their knowledge base through

recruitment of better trained people. This advantage is over and above the benefit of training existing employees through such projects.

Capability Building through Alliances: Summarizing the Survey Findings

The survey findings discussed in this section seem to suggest that inter-firm alliances in the IT-telecom sector have been used to access technology and complementary assets (e.g. marketing & distribution, manufacturing) and expanding markets. Accessing financial resources does not seem to be a key objective. Of course, firms try to reduce risks & costs and improve profitability through such alliances. The survey results show that in a significant proportion of cases these objectives are met. The survey results also show that apart from other benefits, these alliances have facilitated building of technological capabilities among sample firms. As is the case in most situations, some firms have gained more than others. The survey data is inadequate to identify the characteristics of those firms which have benefited more than others. Some of these characteristics will be explored more through the case studies in the next two sections.

Further, while the alliances seem to have been largely "successful", it does not mean that firms are completely comfortable with them. Many firms reported that they are not able to completely remove technological and market uncertainties through alliances. Difficulties in predicting product life cycles, short technology life cycles and slow absorption of technologies makes operation of alliances difficult. Often new agreements have to be entered into with changes in technology. Besides, firms have to live with ambiguously defined scope of participation in their alliances. Commitment to alliances varies a great deal across partners; often the alliances are very fragile. Add to that the differences in the work cultures, objectives and financial strengths of the alliance partners and one has a recipe for unstable relationships. Despite these and many other difficulties and challenges, a large proportion of these sample firms seem to have benefited from alliances. They are probably learning to learn from alliances.

V Nortel's Network: Technology Development Processes in India and China

In this section we present a case study of an international technology development network in telecom software. Nortel Canada has several alliances across the world. We studied its networks in

India and China. The cases reveal that Nortel has used different strategies in the two countries. Interestingly, the objectives and strategies of partner firms in these countries have also been different. In the following sub-sections we first discuss the characteristics of the two networks separately and then provide a comparison of their strategies and learning.

V(a) Nortel Network in India

The R&D network of Nortel with four Indian software firms brings together hardware and software firms to develop telecom related software. This research is based on survey questionnaire and in-depth interviews of firms participating in the network.

Context

India is emerging as a major software development centre in the world with the current estimated exports of US $ 1.1bn worth of software and related services. Bangalore, Mumbai, New Delhi, Chennai and now Hyderabad have emerged as important centres of software related activity in the country. About 30 per cent of Indian software firms are located in Bangalore. They contribute about 25 per cent to the country's export revenues. The Bangalore cluster has slowly evolved from one that provided on-site turnkey services at client's location to one that is starting to develop branded products. Within this broad spectrum, global software outsourcing (GSO) has emerged as an important and rapidly growing activity. GSO arrangements have significant strategic implications as they not only have a potential of increasing the volume of business significantly but also require capabilities of higher order, improving thereby the opportunities of learning for the participating firms. Not much work has been done on GSO activities in India. A study by Barrett et al (1997) is an exception, which focuses on one such relationship in India to highlight changes in managerial practices in domestic firms.

One such experiment is Northern Telecom's (Nortel) partnership with four Indian software companies, three of which are located in Bangalore. The alliance is unique in various ways. It was envisaged as a long-term stable relationship among "peers" and not between "master and slaves". The Indian partners were asked to contribute to the mainstream of Nortel's work and the implicit division of labour that keeps "architects" in the North and "coders" in India was sought to be broken. Nortel, therefore, does not view its Indian partners merely as a cheap source of software production; financial gain by

squeezing the partners is not the long-term goal. Instead, they are willing to help them evolve into genuine two-way partners. Finally, the network in India is being developed in the image of the mother lab of Nortel in Ottawa, which does research in all areas covering a broad spectrum of telecom products. Some evidence to support this characterisation of the network is discussed below. The relevance of such networks is obvious. Such alliances, unlike many other 'one-way' alliances, have significantly higher learning potential for participating firms in developing countries. The conditions under which such knowledge generation is facilitated needs to be explored.

Participating Firms

Nortel is a leading telecommunication firm from Canada which specializes in developing technology for digital networks. Its revenue in 1997 was US$ 15.5bn, 37 per cent of which emanated from outside North America. Nortel has 38 R&D collaboration sites in different parts of the world including India. Recently, it has developed strong relationships with some leading software firms in India to develop products that will utilize the telecom knowledge of Nortel and the software expertise of Indian firms. Over the past ten years, Nortel and its Indian partners have been developing software and software testing tools for Nortel products like DMS, Meridian, Norstar, S/DMS Transport Node and products for the personal communications services market.

In 1989, the International R&D Group of Nortel entered into GSO arrangements with two Indian software development companies - Sasken [earlier known as Silicon Automation Systems (SAS)] located in Bangalore, and Tata Consultancy Services (TCS) which has headquarters in Mumbai. Two more companies were added to this arrangement in 1992. These were Infosys Technologies (Infosys) and Wipro Systems (Wipro), both of which are located in Bangalore. These firms compete with each other in the domestic and international markets. Infosys was founded in 1981. It is a premier software development company with an annual turnover of about US $ 37.8 mn in 1996-97. It spent around 5 per cent of its turnover on R&D. Infosys focuses on software services in the areas of distribution, finance, retail, telecom, insurance, internet and engineering services. In addition, they have products in the area of bank automation. Established in 1989, Sasken develops tools & services that enable the design of semiconductors, telecommunications, computing & networking equipment. The company's stated core competence is signal processing which has resulted in solutions for digital communications.

with specific emphasis in multi-media technologies. Currently it employs 300 people of which 250 are engineers. Its annual turnover in 1996-97 was US $ 4.6 mn. Setup over 30 years ago, TCS is Asia's largest consulting group with activities that range from management consulting to IT solutions, offshore development & branded software products. About 9,800 people work for TCS whose sales turnover in 1996-97 was US $ 201 mn. TCS invested about 8 per cent of its revenue on R&D. Wipro Systems is a division of Wipro Infotech that was started in 1984 (while Wipro Infotech was formed in 1981). Wipro Systems has over 2500 employees with an annual turnover of US $ 14.3 mn. in 1993-94. Within Wipro Infotech, Wipro Systems has been setup as a unit focusing on global software outsourcing. Each of these companies have offices in different parts of the world.

Genesis and Formation of the Network

The International R&D group at Nortel started to think about forming linkages with firms in India in the late 1980s. Two senior employees of this group, both of Indian origin, spearheaded this effort. These two were involved in conceptualizing and implementing various aspects of these relationships. While the major impetus for forming this alliance came from Nortel, some of the Indian partners were also actively looking for such linkages. As a part of their preparation Nortel checked with Texas Instruments and Hewlett Packard about their experiences of working in India. With the help of individuals in these and in other companies known to Nortel initiators, a long list of potential partners was developed. With further queries, a short list of 30 companies was prepared. Each of these 30 potential partners were visited by the Nortel employees. Selection of the four Indian firms was done by Nortel on the basis of very specific skills and capabilities that these firms had developed over the years. There appear to be three broad reasons for this partnership to emerge - active interest of the two Indians at Nortel to develop long term links with India, emergence of India as a strong, low cost software development centre and the desire of Nortel to externalize its R&D work to reduce its costs. The Indian firms were looking to earn foreign exchange, keep their best people within the country, enter into domains like telecom and for opportunities to learn the latest technology & management practices and climb up the product complexity ladder.

Organisation of the Network

The partnership is not an equity-based joint venture. It is an ongoing contractual relationship between Nortel and its partners; each relationship is individually defined. Bulk of the physical investments were

made by Nortel. In each partners location, Nortel has created an infrastructure, which is comparable to what exists in Canada. Apart from the state-of-the art telecom hardware (switches etc.), Nortel has installed large capacity (2 gigabits) dedicated lines for communication between Nortel and its partners. Nortel also invested a great deal in training activity.

Linkages between Indian firms and Nortel are not organized in a manner, which requires interaction among the Indian partners; collaboration is extremely limited and informal. This interaction, typically focuses on sharing of some standards and practices but mainly on communication infrastructure related issues. Besides, training of partner firms employees is common. They, however, do not collaborate with each other on any project. Each Indian partner has an independent project relationship with Nortel. Allocation of projects to each partner by Nortel is governed by its overall strategy to map disciplines across partners and avoid overlap. Each partner in India has specialisations and "collectively" the four Indian partners are growing in the image of Nortel's mother lab in Ottawa, which works on a broad spectrum of telecom products. As the firms do not work together, Nortel remains the "Director" of the network.

The alliance does not preclude entry of new partners in the future. However, from Nortel's point of view, addition of new partners would imply investment by Nortel in developing infrastructure (including hardware) at partner's premises. This can be quite expensive. Moreover, catching up for the new entrant may be difficult. Nortel, however, is not averse to additional partners if they can bring in specialised know-how to expand the technology domain of the network.

Clearly, the parameters of these linkages are driven by Nortel's International R&D group. The relationship is somewhat hierarchical with Indian firms feeding into Nortel's research and product development activities. However, an attempt is made to minimise hierarchy, particularly at each centre, where young professionals are encouraged to interact with seniors and "participate" in a variety of ways in the operation of the group.

The Nortel projects, which started with low skill assignments such as program testing have gradually evolved into full fledged off-shore development centres for Nortel to develop, modify and support

software products or software components of Nortel products. The initial projects were arms-length technical contracts with very limited interaction between development teams of Nortel and the Indian firms. This relationship evolved with the successful completion of many of these projects. Gradually, Nortel commissioned larger and more complex development projects requiring more sophisticated hardware & communication infrastructure along with enhanced interaction between Nortel and Indian teams. Current projects include DMS-100 feature development for Asia/Pacific markets, such as Japan; interface approval for a cellular switch in India; DMS-10 and Meridian feature development for global markets. At the offshore development centres, Nortel has installed advanced telecom hardware for testing these software. It is hoped that with the synergistic interaction between increased access to telecom hardware & software, communication infrastructure and the improving project skills, these alliances will graduate to product design & development centres. Most of the current work focuses on the further development of existing Nortel products; only a small proportion can be categorised as research.

It must be re-emphasized, however, that at this point in time, each Indian partner works on independent projects; integration of these projects, if at all, is done by Nortel. There are reasonably well-defined rules for protecting the intellectual property of Nortel. Trust plays a key role in avoiding leakages of proprietary knowledge. While the relationship does not prohibit collaboration of Indian companies with Nortel's competitors, movement of persons working on Nortel projects to substantially similar projects of competitors is not permitted. An agreement on non-disclosure at the corporate level is signed and each person working on Nortel projects individually signs such an agreement. Anything the partners develop with Nortel belongs to Nortel unless they agree to negotiate and to share. Interestingly, within the Indian firms' premises, Nortel projects are located in physically separate areas with restricted access. Each of the Indian partners have different types of relationships with many international firms. For instance, one of these Indian firms also has a Nortel like offshore software development centre for NCR. Besides, the Indian firms have a large number of Fortune 500 firms as customers around the world like Microsoft, IBM, Oracle, Fujitsu, Philips, Hitachi, Sharp, Toshiba, National Semiconductors, Texas Instruments etc. The Indian companies compete fairly aggressively in the international market for projects.

Strategic Intent of Nortel

Software is increasingly substituting for a variety of tasks, which were earlier performed by telecom hardware. Software development in North America has become extremely expensive due to the shortage of skilled manpower. It seems that the strategic intent of Nortel was to outsource software development for telecom devices from relatively inexpensive off-shore locations. Indian firms provided a rich pool of software development capabilities as well as ability to gear up fast to develop new application software. However, their telecom related knowledge base was limited. This provided excellent opportunities of collaboration between firms with complementary capabilities. Nortel made specific efforts to develop/update the telecom hardware/software related knowledge of its Indian partners. While the expectation of cost savings was important and it fructified with Nortel saving of about $ 50 million per year due to the network, the long term perspective was probably more important. Only that can justify the kind of investments Nortel has made.

Nortel has been seeking opportunities to adapt its telecom technology for Asia-Pacific market. Besides, it has so far been unsuccessful in entering the Indian telecom market; its international competitors like Siemens, Allocate, AT&T and Ericsson are already present in India. This alliance, therefore, not only provides Nortel an access to the inexpensive software development resource in India, but also allows them to enter the Indian market with products specially designed for India. Moreover, an R&D arrangement of this kind brings product development activity closer to the markets in the Asia-Pacific region. The concept of a more open "two-way" partnership was partly necessary to attract good Indian firms and provide stability to the relationship. There was always a possibility of another international competitor to build such a network if Nortel had not taken the initiative. At the moment, however, the Indian market is not growing as rapidly as expected and on that count, Nortel's investment only makes long term strategic sense.

Benefits to Indian Firms

Benefits of this alliance to Indian companies have been numerous. The firms together make about $ 50 million per year for the country. The major gain has been in developing telecommunications related knowledge and acquiring expertise to produce to world standards and satisfy global markets in this sector. Since there was reciprocity and Nortel was not averse to connecting Indian firms to the world

market, the partners learned the whole package, got exposed to how Nortel functions, how it deals with the customers and so on.

Strategically, the entry of Indian firms into telecommunications software market has been a significant outcome of this alliance. This market is likely to grow rapidly in the near future. The alliance not only facilitated entry into this market segment but is also creating learning opportunities which may eventually help Indian partners to become important players in this emerging segment.[4]

The Indian partners also received training on telecom technology and Nortel's products. Such learning opportunities arose during visits of Nortel experts to Indian sites as well as visits of Indian engineers to Nortel's facilities overseas. Specific learning occurred through the use of new telecom related software (especially in switching), entry into new markets segments relating to various telecom product lines, development of new products (mainly in the form of new features on existing products), acquisition of knowledge relating to international programming standards as well as protocols/standards in telecom process (process & quality standards for developing highly complex products) etc.

The Indian firms feel that association with Nortel has accelerated the development of their technological capabilities in this business. However, since they have other linkages with large number of international firms, such capability building could have occurred, *albeit at a much slower pace*, in the absence of this alliance. All these firms also view this relationship in a long term perspective. They would like to graduate to become equal partners of Nortel in their product development process and marketing. As indicated earlier, Nortel too views this relationship in a similar perspective given its huge investment of time and resources in building these relationships.

There have been two other spillover benefits. The alliance has enhanced the credibility of and has provided better visibility to Indian partners. This, in turn, has helped them attract other customers. The Nortel development centres have had strong demonstration effects within each company. Similar spillover effects of the partnership on the telecom software sector is, however, difficult to ascertain.

[4] It has already started to happen. See discussion below.

The Indian software industry is very competitive with very high employee turnover. There are several other firms in the industry, which are as good as the Indian firms in the Nortel partnership. A large and fairly well distributed pool of software related knowledge exists in the country. This creates a potential for competing firms to learn from the Nortel partnership. The organisational form chosen for the alliance tries to minimise knowledge spillovers from one participating firm to the other and within the participating firms through certain norms and protocols. But knowledge spillovers through employee turnover continue to take place.

Looking Ahead

The long term sustainability of this alliance would depend on the nature of learning by the Indian partners and the extent of locked-in investment by the participating firms. Though Nortel has invested significantly in this partnership, it is not clear what role this alliance plays in its global network of alliances. Nonetheless, Nortel views this network as one of their most advanced ones. Likewise, Indian firms have developed similar linkages with other MNCs, probably not as intensive. There is no doubt that Nortel has shared with the partners a lot of its proprietary technology. As the technological capabilities of the Indian partners improve, Nortel will have to share more of such technologies to sustain the alliance. A significant part of the knowledge embodied in this technology is tacit and its mis-appropriation difficult to monitor and detect. However, the credibility of the Indian partners and, therefore, their ability to attract partners in future is highly dependent on their protecting Nortel's intellectual property. It is this "shared vulnerability" which is most likely to keep the alliance alive and help it grow. Some of the Indian partners may be asked to do the sunset phase of some telecom products, including dealing with Nortel's customers. Working with Nortel on its new products can also not be ruled out, although this might prove to be riskier for Nortel. In any event, it is important to note that if this relationship continues to grow as vigorously as it has in the past, at some stage the issue of the ownership of intellectual property will also have to be addressed[5].

[5] Recent developments have made IPR related issues more relevant. One of the partners in India has come up with three innovations, patent applications for which have been filed by Nortel in North America. The Indian firm and Nortel are co-patentees and will share the royalties based on a geographical division. The Indian firm certainly has rights over the Indian market but it is not clear if it has any other rights.

The organisational arrangement was probably optimal for Nortel. It is clear that intensive interaction among the Indian partners would have helped them learn more from the alliance. However, Indian partners may not have preferred such an arrangement given the fact that they compete with each other vigorously. In fact, Nortel claims that collaboration among Indian firms was part of its vision and they did make some rudimentary efforts at inducing more collaboration among the Indian partners. However, the Indian partners did not seem very enthusiastic. Being competitors and collaborators at the same time is probably not very easy Nortel also appreciates many of the concerns raised above, including those relating to IPRs and is open to sharing proprietary benefits, as they have done in the case of one of the partners (see foot note 1). Their expectation, however, is that such sharing of IPRs would require Indian partners to bring more to the table; be more entrepreneurial and take risks to develop new products and markets. Two of the Indian partners prefer the "command-execute" mode and are reluctant to take risks, while the other two are more entrepreneurial. As a result, the relationship between Nortel and the two entrepreneurial partners has matured more than its linkages with the other two firms. Nortel has some sort of a "World Product Mandate or Charter" with one of these entrepreneurial Indian firms to develop Meridian PBXs (small switches) for which there is demand in Europe. This project is being done on a risk-sharing basis. Significantly, the same Indian firm is one of the six groups in the world to develop a new ADSL – high band width over copper wire – technology on their own. This technology was offered to Nortel but Nortel has its own one megabyte modem, which is a competitor technology, and therefore they declined this offer. However, the Indian company now has two potential clients in the U.S. and thus has been recognised as a world source of technology. While Nortel claims that its alliance with this growing Indian partner was instrumental in instilling confidence in them, the MNC will have to deal with the issue that this Indian firm and other partners may come up with competing technologies in future as well.

V(b) Nortel Network in China

In this section we describe Nortel's technology developments in China. In contrast to India, Nortel has established eight joint venture facilities and one R&D centre in China. The R&D lab was setup in 1994 as a cooperative arrangement between Nortel and the Beijing University of Post and Telecom (BUPT) in order to transfer telecom technology to Chinese Government. As part of the setup, a few key personnel were deputed both by the University and Nortel. Nortel

provided the initial capital (e.g., switches, office setup, computers, software etc.) while the University provided space and researchers. The mandate of the project at the beginning was to make Chinese adaptations to software in Nortel's technology. Now it has moved to doing various projects within China for a variety of agencies including MPT in addition to specialized subcontracting work for Nortel. There are two distinct areas at this research centre: one devoted to only Nortel's product development and the other for both Nortel and MPT projects.

The BUPT-Nortel R&D Centre is situated on the campus of BUPT. The lab is headed by two director generals: one each from Nortel and BUPT. It employs 85 employees of which 60 are software designers. At inception, it employed 40 people. Most employees were from BUPT though few have been hired from Quinghua, Beijing and other universities. The lab hires those graduates and employees of the University who are telecom/wireless/radio engineers and have a computer background. Several professors of the university are also involved with the activities of the lab. The lab faces a high turnover of engineers. As their work at the lab is research oriented, many go abroad (chiefly to US and Canada) for graduate studies. Nortel sends over some people from other facilities worldwide to this lab.

The lab is developing software for mobile networks, wireless in local loop, MTX switches, broad band networks, FWA products as well as helping MPT develop telecom standards. Nortel has four WLL sites in China. Some are GSM while others follow the CDMA standard. However, most of the GSM research at the lab is being done for China Telecom while the CDMA work is being done for Nortel. Some other projects that the lab has done over the years are: software for handset interface (this was bought over by Nokia), messaging for wireline, wireless and internet, enhancements to existing software for MPT and field installation at national & provincial levels, customization of some features for various municipalities on their telecom equipment, base station work for Nortel Maitra – contract work for GSM development in France etc. This lab has created a niche for its products in China. There are very few firms that are developing telecom software especially in the area of switching (MTX switches) or base station software, which is the focus of the lab, as they requires special capabilities. Its main competitor is Lucent China, which is working in the area of wireless telephony. There are a few Chinese software firms that are

developing software for some low to medium quality technology for switching that is still being used by China Telecom.

The first project of the lab was to develop a GSM provision centre (i.e., storage of customer profiles) which was a local Chinese requirement from it wireless equipment vendors. Now the lab is developing messaging models for various platforms – fixed to wireless, intra-mobile, and internet. This project is an example of how the complexity of tasks that are performed at the lab has gone up. And with this product, the lab is starting to compete globally. BUP-Nortel facility is becoming more integrated with Nortel. They follow Nortel standards and practices. While the Nortel hardware has not changed much, software has changed rapidly. It has also increased the spectrum of languages that are being at the lab – ranging from Protel (Nortel's Proprietary Software Language), C++, Opex to Rose Modeling where the document gets updated automatically. Marketing at the head office helps find Nortel projects for the lab.

V(c) Nortel's Linkages: Comparing China & India

In comparison to Nortel's network in India, its alliance with BUPT has the following differentiating characteristics:

- BUPT & Nortel are involved in joint development of software with the presence of Nortel personnel as opposed to subcontracting in India. This was operationalized by setting up a research centre at a telecom university in China with joint management; while in India separate linkages were formed with four Indian companies working independently of each other.

- The alliance with the telecom university has the potential of upgrading technology, teaching material and skills of both faculty and students. Besides, the location also provides an academic & research focus. In essence Nortel was participating in developing manpower for the industry as well as future researchers. In the Indian case, only the four firms benefited.

- The alliance in China had a strong domestic focus assisting in the development of local telecom sector. The Indian firms were developing products for Nortel's markets abroad. It appears that Nortel's objective in India was to tap the superior software capabilities while the focus in China was to support the large local market.

- The Chinese professionals participating in the alliance combined software skills with strong telecom knowledge. In the Indian case, Nortel provided the telecom knowledge while the domestic firms brought in their software skills.

- In both the alliances, projects have moved up the complexity ladder. It is believed that the Indian projects were more complex than the ones in China though it needs to be confirmed.

- The number of professionals involved in the Chinese alliance was much smaller as compared to those in India (around 600).

- While the Chinese alliance may be developing less complex projects, they were more focused in terms of developing complete products. The Indian teams were developing parts of a product, which was being integrated by Nortel.

Some of these differences can be explained by the fact that China has a large telecom market (about US$ 1bn per year) which has not suffered from the Asian financial crisis. Besides, Nortel has a large presence in the Chinese telecom market and they are present in a larger segment of the telecom supply chain in China (e.g., from manufacturing semiconductor to transmission devices and telecom services). Their eight joint venture facilities are spread out in eastern China (in Beijing, Shenyang, Nanjing, Shanghai, Xian, Guangzhou, Shekou and Shunde). Hence the strong need to service the domestic developments. Nortel is barely present in India.

VI Case of Wireless Technology at Indian Institute of Technology, Chennai

The TeNeT group at the Indian Institute of Technology (IIT), Chennai realized the need to make the access part of the telecom network efficient as it contributes almost 65% of the total network cost and is increasing each year. Access network connects homes and offices to the local exchange. While the fiber in the trunk exchange network were dramatically increasing the bandwidth over the backbone and reducing its cost, the 'last mile' problem of wired access remained which restricted penetration (especially in India where population density in urban centres is very high). Technology developed by the TeNeT group created a new standard in the usage of wireless for the access portion of the network or wireless-in-the-local-loop (WLL) at considerably low costs. More interestingly, it's a story of how R&D developers at an academic institution formed inter-firm linkage to commercialize and successfully deploy technology globally. This case study highlights the structure and processes that the group utilized to develop and commercialize hi-tech solutions on a large scale.

The TeNeT group was formed by nine faculty members from the Electrical Engineering and Computer Science departments of IIT Chennai with an objective of creating indigenous technological solution for reducing the access network costs in India. The group that was formed 12 years ago (by Professors Ashok Jhunjhunwala, Bhaskar Ramamurthy and Timothy Gonzalves), started by developing TDM-TDMA-PMP systems for C-DOT. The positive spillover was that a large number of students got trained in this process. In 1995-96, after N.Vittal (formerly Secretary Telecom, Government of India) talked about replacing the 'wired' with "wireless" in the country, the group started to work on wireless based solutions for the access problem. The target that the group, led by Professor Ashok Jhunjhunwala, set for itself was to design an access system which could serve anywhere from 200 –2000 users at a time and one that could handle both voice and data (at that time voice and data packets were being handled by separate networks). Technologically, the challenge was to get the advantage of both circuit switch network (where dynamic assignments of circuits take place using shared resources as is used for in voice transmission) and packet switching (where transmission occurs in batches and where resources are utilized more efficiently as it is used for bursty data traffic) together in a single system.

The group has developed the following systems over the years and has commercialized them through targeted entrepreneurial ventures:

- CorDECT: a wireless in local loop (WLL) solution for access networks (including integrated access centre technologies to be located at street corners)
- DIAS : a direct (wired) internet access system
- OPTIMA: fibre in the loop solutions – where the fibre connects the access centres while the backbone has a radio link.
- CYGNET : a network management system

The TeNeT group realized that none of the cellular standards like GSM or IS95 satisfied the requirements of a developing country – they were expensive, required more base stations to serve more consumers, consumed more power due to need to operate switches in an AC environment, etc. The Japanese standard, PHS, was useful but it was a 'closed standard' which made it highly

proprietary. The group, however, chose the historical European DECT standard to develop its products as it had the potential of providing high capacity WLL at low cost. The group developed its low cost wireless technology using the DECT standard with the help of a number of student projects at IIT Chennai. This technology was simple, robust and used standard connections – a proof of concept was established in the IIT labs. At about this stage of development, the group faced a dilemma. To deploy this technology for the betterment of telephony in developing countries, the technology had to be commercialized; the issue, however, was how to make that happen in an academic setting.

MIDAS Communications Technologies

IIT addressed this dilemma through a bold leadership initiative – it allowed the group to help setup an enterprise. The initial product based on this DECT technology would be jointly owned by IIT and the new company while the company was fully owned by the promoters. The TeNeT group started to scout for people who could promote such a company. What the group was sure was that they wanted to develop the firm without financial support from government, that they needed a team of excellent engineers and that they wanted to compete with the best in the world, both in terms of technology and cost. The IIT linkage once again came in useful. The group created a wish list of people whom they would like to bring together for setting up the firm. The group persuaded nine of their former graduates (all of whom had worked with Professor Jhunjhunwala, and the TeNeT group at various points in time) to start a company called MIDAS Communications Technologies that would commercialize the CorDECT technology.

MIDAS was started with equity provided by the nine former students. Technical support was provided by the TeNeT group. The product, CorDECT, was jointly owned by IIT and MIDAS. In the initial days, the firm 'operated' out of IIT laboratories where all worked together on the CorDECT project that was spawned by IIT and MIDAS. Research funding came to MIDAS and IIT raised the project. Research assistants were hired and the project went off ground. Early on in the project, the group realized the critical role of high quality specially designed ICs in the development of their product and also appreciated that such ICs (especially in small volumes) could not be developed in India. The group contacted Ray Stater, Chairman, Analog Devices,

USA who evaluated their technology and agreed to develop the ICs designed by IIT. Analog Devices agreed to market their ICs outside India and give the group a royalty. They also agreed to help the group license the ICs within India. But most important, Analog Devices agreed to advance funds to the group against future royalty payments. The group needed Rs. 80 lakhs and hence decided to license their technology to other companies in India. Crompton Greaves, ECIL, WSTelecom and Shyam Telecom were initial licensees for IIT's TDM-TDMA technologies. This funding helped raise several research projects that got MIDAS off ground! These four companies agreed to pay a 3 percent royalty on the products but there was no pre-condition on the volumes they would sell. However, ECIL worked out an internal agreement with ITI who would in turn use this technology thereby generating some sale.

By the year 2000, MIDAS had 128 people working across all departments. Seventy percent of employees were working in the Design and Development area – both in Wireless (e.g. CorDECT) and Fibre applications. About 20 percent of the employees belonged to the Technical Assistance cell that performed business development, validation and testing, installation and field support, manufacturing support and pilot production. The remaining worked in the non-technical groups. MIDAS has developed fifteen vendors that manufacture various components and assemble their finished products (on a technology licensing and transfer basis). However, the firm assembles small quantities of its products in-house for its own internal usage as well samples that are to be sent abroad.

Interestingly, the frequency used by CorDECT (i.e., the DECT band) in India was being used by the Defence establishment. The government was reluctant for quite some time to release this frequency for non-defence usage. The group approached Mr. N. Vittal for assistance in getting the clearance of frequency. The government never believed that their technology could work. However, Mr. Vittal set up a group from the Telecom Engineering Centre (TEC) to draw up the specifications on MIDAS' products (e.g., features, frequency etc). Then trials were done by TEC on CorDECT and upon successful completion the government decided to release the frequency on a case-by-case basis (i.e., permission was given for each application). This paved the way for commercialization of technology. By 1996, Voice only systems were deployed in CorDECT

which was further enhanced in 1999 to include both voice and data (i.e., internet application). MIDAS conducted trials at its own cost in Brazil while they found licensees in Nigeria, Kenya, Fiji, Madagascar and Argentina who purchased CorDECT technology and performed tests locally. One innovation followed another at IIT. The team has developed a prototype of a new CorDECT box which can allow a DOT line to serve four independent telephone sets (or customers) thereby reducing the cost to Rs. 8000 per box. Research is under way to further increase the number of connections per box to twelve (of which any four can talk at a point in time). This will reduce the cost of the box to Rs. 3000-4000 and will facilitate its installation in low-income group areas with a coverage of 10-20 sq. km.

The group is working on a number of allied initiatives. The DECT standard (which is the European standard) has better bit rate, low cost but the range is limited. A new cellular standard called, '3G', is being developed which harmonizes all other standard – it has high bit rate for short ranges or can deliver high range with low bit rate. The group is working to develop products using a new standard called "DECT 3G". This development has reached the commercial stage but is currently based on old air interfaces (like CorDECT used standard air interface, standard network interface but other interfaces were proprietary). Research is being done to utilize other 3G interfaces for improving the existing products. The group is also working to modify their products so that they can be used for new airwave ranges – this work is at the proof of concept level. The competitors for the IIT-MIDAS team are Siemens (they provide DECT link and are starting to get into 3G based products), Lucent (they have bought DECT technology and is developing 3G), and Alcatel (they also have DECT and 3G systems). Interestingly, Erricsson recently stopped developing DECT and WLL technologies and has decided to get out of this business.

Banyan Networks

While MIDAS was trying to address the last mile problem of telephone access by WLL, the internet revolution took place. IIT recognized early on that this would require local wired access for handling data through the net. It once again helped start a company, with its former students that would work on the data-voice convergence. This was how Banyan Networks was founded in

1995. This time the company was formed with the help of former IIT students and external promoters. Ray Stator of Analog Devices provided angel funding. Banyan also invited another well wisher, Arun Jain (Chairman of Polaris Softwares, Chennai) to become the Chairman of Banyan and provide leadership to the group. Informally, Polaris had been involved in helping the team with business planning.

Banyan came up with a number of related products. One of its earlier products, 'Nova Ethernet Switch' was developed jointly by Banyan, IIT and Analog Devices (in Boston). Analog Devices started a new company to market this product in the US. The product was a finalist in the Las Vegas IT show. Another product, DSP (Digital Switch Processing) was ahead of its time – it was licensed to Fujistar. Then came DIAS (Digital Internet Access System) – a product that performs both data and voice transfer at the same time. It replaces the modem and helps in reducing overload at the exchange (a problem that occurs when modems are used as they lock a circuit). DIAS combines the wireless technology of WLL with wired ethernet connections provide voice and data transfer over the internet. Banyan licensed technology to their manufacturers (HFCL, Shyam Telecom and ARM, Hyderabad) in the country – the seed money provided by these licenses as well as US earnings helped develop this product. The firm is currently developing another product, LAN Phone Set, which sends voice over Lans – here each user on the lan gets a private telephone number and can perform voice transfer simultaneously. This technology can bypass existing ISDN technologies once Voice–over–IP becomes legal in India. BPL has agreed to license their technology from Banyan. Some network management systems, that sits on operators' console and performs diagnostics on the network and gathers data, have also been developed.

Banyan hired a professional manager from a consulting firm to head the organization. Arun Jain played a useful role as the Chairman of the firm to re-structure the organization and create well-defined roles for the IIT and Banyan teams – a clear improvement over the organizational structure and practices at MIDAS. Equity from external agents was brought in – another step in professionalizing the commercialization process of IIT's technology. Intel Corporation, USA joined as the lead investor in Banyan with ILFS (which receives funds from the Tamil Nadu

Venture Fund) coming in as the second investor. Banyan, however, has no formal linkage with other firms incubated by the IIT team.

Nilgiri Networks and nlogue.com

One of the original team members of the TeNeT group, Tim Gonzalves, took leave from IIT Chennai and started a firm in Ooty called Nilgiri Networks. This firm is developing 'network management systems' for products developed by the group as well as other products. Polaris Softwares is a co-promoter of this company. They have recently developed a product called 'Cygnet'. Polaris will use this product and build applications and interfaces around it.

The most recent venture of the IIT Chennai group is a new company called nlogue.com whose objective is to run telecom and internet business on a franchise basis in rural areas and small towns of India using the access network developed by MIDAS and Banyan. The plan is to provide the subscriber with a CorDECT box that will give telephone and internet services at no internet charge. The only variable cost is the cost local telephone connection. The group has already hired a CEO for the company and is conducting a pilot project in Nellikuppam using EID Parry's sugar factory as the base Access Centre.

Ashok Jhunjhunwala and Bhaskar Ramamurthy have now established a section 25 company which will hold equity in nlogue.com.

This case is a unique example of academic entrepreneurship based on technological innovation – a strong testament of academic leadership, societal concerns and technological learning through inter-firm linkages. It is this last issue which we would like to explore further though all three are closely linked in this case. Some key questions explored through this case are:

- What did IIT Chennai have as a core strength that enabled it to incubate firms successfully?
- What was the basis of formation of various inter-firm linkages?
- What were the learnings of various entities through this formation?

The core of this entire effort revolves around the vision, leadership and concerns of Professor Jhunjhunwala. He brought in the technological base, linkages with well trained students, a strong concern for societal change in developing countries, ability to draw together a team of well educated and trained people, international training and exposure, reputation of being part of an excellent institution and the credibility of an academician who was not partisan to the development of low cost telephony in the country. Then came the technological expertise of the TeNeT group. The group possessed world-class technological capabilities and abilities to transfer innovations into commercial applications. IIT provided a conducive environment for application research – with a large pool of enthusiastic and bright students. The student researchers were involved in developing the 'proof of concept' while prototype and manufacturing was done by respective companies. The TeNeT group managed to create a well-defined focus in their research for a significantly long duration of time and could enthuse the academic community at IIT to participate with them. This approach of focussed, agenda based research is often missing in Indian academia. Another feature of their efforts was the ability of the group to quickly recognize implications of emerging trends in technology and then riding the waves of technological development. This allowed them to look for novel technological solutions to persisting last mile problem through WLL and then recognize the role of internet and build research products around this development. This ability kept them at the forefront of technological revolution in IT and telecommunication. The IIT Chennai administration also exhibited some leadership in recognizing the potential of the efforts of the group and allowed the group to play the role of academic entrepreneurs – a role which is often stifled by administrators in Indian academic institutions.

The core strengths of the IIT team when coupled with the low cost of performing R&D in India provided a formidable combination for forming partnerships with firms that possessed other complementary assets. Indian firms like Shyam Telecom, HFCL etc. were looking for new products for the Indian market. Several of the fifteen vendors of MIDAS also benefited from this approach. For example, Andhra Electronics which develops oscillating crystals initially lost some money but took some risks and stuck with the group. It is now producing large volumes and earning profits. The IIT-MIDAS team also played the coordinator's role where they held hands of manufacturers and established the production requirements. Interestingly, initially IIT Chennai

performed all the R&D as well as commercialization activity – now the IIT team concentrates more on academic R&D while MIDAS and Banyan perform the commercialization activity. This also reflects the changing roles of different players as the technology supply chain becomes more sophisticated and the inter-firm partnerships mature. Perhaps as this evolves further, MIDAS and Banyan may start performing more applied research themselves while IIT team may shift upstream on the technology Supply Chain – performing more fundamental and theoretical research in this area. Earlier, MIDAS provided about 25 per cent of the research budget while IIT brought in the remaining 75 per cent. Now, MIDAS contributes 85 per cent of research expenditure while IIT provides the remaining 15 per cent.

Formation of partnerships were based on derivation of mutual benefits though elements of risk taking were involved – a common feature of most technology linkages. Academic linkages of Professor Jhunjhunwala helped forge technological and commercial links both for the TeNeT group as well as for MIDAS and Banyan. One of the most enduring linkages of the entire IIT–MIDAS–Banyan network has been the one with Analog Devices, USA. Analog Devices was interested in the activities of the group as they were chip makers who were looking for chip designers. Since they were not equipment producers, they did not foresee any competition from MIDAS. Moreover each time MIDAS used their DPS chip (general purpose chip) for building its designs, it increased the sales of Analog Devices. MIDAS also helped this Company find several good chip designers in India (including some in the IIT team). In return, the IIT team benefited by securing help of this company in producing specialized ICs for them in smaller volumes, finding in the company a marketer of their IC designs, and a funder of their projects (Analog Devices advanced money to the group against future royalty for their designs). In the initial stages of Banyan, a number of engineers from Analog Devices helped Banyan with resolving technical problems. They also helped Banyan procure components from US.

Similarly, Intel's participation as the lead investor in Banyan Networks was motivated by its interest to sell its chips for new applications especially in emerging technologies. It was also a pre-emptive strategy in case the group at IIT developed a competitive technology. Banyan benefits, other than through direct funding, by networking opportunities with various other partners of

Intel. It also allows them to attend various product portfolio conferences of Intel globally (and especially in Asia Pacific) and thereby track developments in chip designing and new applications.

The most interesting linkages have been formed between 'member companies' of the group. The different companies, i.e., MIDAS, Banyan, Nilgiri and nlogue.com represent different stages of the wireless based technology chain for delivering low cost telecommunication options in India and other developing countries. MIDAS has used Banyan's wired capabilities in their wireless products while Banyan is using MIDAS' CorDECT boxes in designing its wired solutions. Similarly, Nilgiri is developing network management systems for MIDAS and Banyan products in addition to other platform. nlogue.com is simply a management of franchise effort using technologies developed by the other three companies. This may be the starting of an integrated solution management endeavor jointly by all the firms.

This case study highlights several important features that are useful to understand the processes involved in the formation of inter-firm linkages around academic institution:

- technology vision of the key promoter and the group was critical for the longevity of the effort. In this, the similarity of purpose of the entire TeNeT group contributed significantly to its success;

- riding the wave of global technology developments helped the group stay at the front of these developments;

- leadership of academic administration at IIT Chennai helped come out of a government institution's mindset and take risks based on academic innovation – relationship with MIDAS was managed well through joint ownership of products, use of MIDAS to pay and procure for things and expertise which rules at IIT may not have allowed thereby keeping the spirit and dynamism of effort intact;

- several Indian patents were filed by IIT and allied companies. An arrangement evolved where IIT would hold patents for new technology while the companies would give royalty to the institute;

- MIDAS alone spent over US $3 million on IIT research / laboratories, students etc. Research found way in the classroom. Both faculty and students understood telecom technology well – faculty could train students become better technologists, master's students picked up precious designing skills and got trained in product development while undergraduate students worked on real projects and got paid for their work. The IIT team learnt how to take an idea from the laboratory to market.

- new technology adoption/setting of standards is facilitated if the promoter is an important stakeholder yet an independent entity in the commercialization process. Perhaps the most important reason behind the release of the 'frequency' by Government of India was the fact that request came from Professors of a reputed academic institution who had not benefited financially from any of the endeavors so far.

- location of R&D in India helped considerably due to low R&D costs;

- network linkages helped generate minimum order sizes/large orders (and hence obtain volume discounts) for various components, e.g., MIDAS wanted to purchase 10,000 units of flash memory (costing at US $0.25 million) but were told by the agent in India that its too small an order as Nokia had just purchased the same worth US $3 billion. The group coordinated with their licensees (e.g. Shyam, ARM, HFCL etc.) and ordered their requirements (including those required for non-CorDECT applications) as a single large order and thereby procured items at the volumes and costs that they wanted;

- the group, through its linkages, learnt about industry practices, organizational systems and structures, costing of products etc. Analog Devices, for instance, helps the group follow the

chip development trajectory and global trends. This has helped them to develop / modify products based on the chips that may be coming to the market in the near future;

- the group is also learning about issues related to product integration (across member companies). This will also raise issues about who would market these integrated products or how would revenues from such products be shared across companies etc.

The above case study is a good example of a network based enterprise development when the core is technology R&D. It also reflects new vistas of academia-industry partnership and shows rudiments of organic evolution of a focused technology cluster. This "Centre-Satellite" model with a strong central R&D infrastructure and dynamic satellite application firms covering different stages of the technology supply chain provides a viable model for technology development and implementation in India. The desire to develop technology for developing countries without direct government funding, access of quality engineering manpower and wanting to compete with the best in the world provides this cluster a unique strength. Linkages were seen by the group as a source of acquiring complementary assets. The network is at an interesting stage of evolution: earlier, all network firms interacted with each other through IIT and most of the R&D was being performed by IIT; now, the firms have started to perform some applied R&D and have built direct linkages with each other. Moreover, network firms have also started to build their own independent linkages with firms outside the group. The differences in the processes used to establish MIDAS and Banyan suggest that the promoting group is increasingly recognizing the role of industry professionals in managing the organization in addition to developing technology.

VII. Conclusions and Policy Implications

Indian firms in the IT-telecom sector have entered into a variety of inter-firm alliances in recent years. Many of these alliances have been with foreign firms. The survey data as well as the case studies suggest that inter-firm linkages have helped Indian firms build technological capabilities. This paper analysed inter-firms alliances and their role in capability building at different levels. Insights from published data were combined with results of a primary survey and case studies to identify the key

processes at work. In what follows we try to highlight some key insights and explore their policy implications.

The case study on the Nortel networks in India and China suggests that MNCs may follow different strategies vis-à-vis inter-firm technology related linkages in different host countries; they might follow a "domestic market supported" R&D model in countries where the market is large and growing and where the MNCs have significant presence, while following "domestic market independent" R&D strategies where market is relatively small and MNC presence is insignificant but where specialized skills are available. The latter strategy not only permits the use of specialized and often low cost skills of the host country, it may also facilitate market entry for the MNC at a later stage. These two strategies will have obvious implications for the host country firms participating in the alliance as both the technologies they can learn from and the participation of the MNCs in the learning process will differ in the two cases. The foreign firms may wish to share more technology, especially the tacit variety, where they have more control over the use of that technology. The links of Nortel manufacturing facilities with Nortel-BUPT provided such control in the case of China, while Nortel retained the role of managing the network and integrating technologies developed by different partners in India to try and retain this control.

Unlike the Nortel network in India which was developed through the initiative of the MNC (i..e, Nortel), the IIT network was the result of an indigenous initiative. And while the former was "domestic market independent" the latter was "domestic market supported". Significantly, IIT network also used MNCs to its advantage whenever there was a need for such a link; the link with Analog Devices being the most important. But the control of the network and the focus of its research activities were largely controlled by the domestic entities that formed the network.

The fact that MNC strategies have implications for the learning of host country firms can be seen in another context. Any restructuring at the international level by the MNCs can impinge on the desirability and/or the nature of inter-firm linkages. Significantly, Nortel's merger with Bay

Networks has created such a situation for the Nortel network in India.[6] The key issue is that host country firms participating in Nortel like alliances will have to be prepared for such changes. Restructuring of this type may result in a shift in the focus of the MNC leading to a change in strategy with respect to how the MNC deals with the firms in such networks.[7] In the same vein, participation of Analog Devices in the IIT network was also of its overall international strategy to pre-empt competition and get access to good quality and relatively inexpensive chip designers. Any inter-firm network dominated by domestic entities and seeking support of MNCs needs to be conscious of such strategies.

From the perspective of host country entities, some key elements that facilitate capability building through linkages are apparent:

- Rapid changes and convergence in telecom technologies and continuous unbundling of telecom service provision provides ample scope for firms to specialize and benefit from linkages with firms having complementary capabilities. As mentioned, linkages are critical even for the large MNCs to keep pace with the fast changing technology frontier.

- In general, firms with good skills & capabilities along with risk-taking ability are likely to gain more from such alliances, as they will prove to be more valuable to the foreign partner. However, the issue of IPRs will still need to be resolved.

- Give their technological capabilities and expertise, academic institutions centered networks like that of IIT can attract a variety of MNCs as partners. But they will need to choose their partners very carefully to exploit technological complementarities and synergies in alliance objectives.

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[6]. Since the merger with Bay Networks [with major installations in Wellfleet, Massachusetts and San Francisco], Nortel Networks, as it is now called, is undergoing a major restructuring. This will affect its central R&D laboratory and its functions. Nortel henceforth will be structured into its five business lines with the former Bell Northern Research [BNR], i.e. the central R&D functions being decentralized to each of the five business lines. The head of each of these lines will now take on greater importance and the central laboratory will virtually disappear. As mentioned, the Indian network was fashioned as a multidimensional laboratory modeled on the old BNR falls between the cracks.

[7] For example, in the case of Nortel, the restructuring has also meant some personnel changes and a small number of layoffs. One of the major changes in the current context is that the Vice President to whom the champions of the Nortel network in India reported has now been let go. The project champions are still there and now will need to save the Indian network and restructure it into the new interests of the company. The CEO, John Roth believes that Nortel needs "to move like Cisco (in data communications) and have the respect of Lucent (in telecommunications)". A leitmotif is the notion of a "webtone", that is to make the web as easy to access as the dialtone. Bay networks has been integrated into the Nortel business line "Enterprise Data Networks" and will give this new approach a major boost. The key issue then is whether and how the Indian market and firms with capabilities like the four Indian partners fit into the new scheme of things.

- Presence of telecom related skills may facilitate movement along the learning curve as well as provide impetus for incremental and eventually significant innovations. If telecom is seen as a major area of growth then public intervention may be required to solve the long-term supply of skilled personnel in the telecom sector. Support for IIT types of networks can go a long way in generating such a skill-pool, as spillovers through training and research are very high. In a sense, the IIT network is able to generate the same kind of externalities as was achieved by BUPT, China through its links with Nortel.

- The survey findings as well as the case studies suggest that the domestic software (hardware) firms may need to proactively forge linkages with hardware (software) firms to reap the synergies between software and hardware skills in telecom. Besides, there seem to be several other advantages to such alliances.

- Learning from alliances will need to be a strategic intent of the host country firms and they will need to make conscious efforts to learn from different projects and consolidate learning across projects. Mechanisms will need to be devised to disseminate the learning within the organisation. Movement of key personnel from one project to the other may facilitate diffusion of knowledge within the organisation. Our survey findings show that the firms participating in alliances are already exploiting such spillovers. They need to be somewhat more proactive about such learning. Of course, turnover of employees will automatically result in spillovers of knowledge gained though inter-firm linkages to other firms in the industry.

- Learning of standards and getting observed in the international market are important advantages of inter-firm alliances. The developing country firms may, however, need to worry about a trade-off. Long term association with a single partner develops trust and facilitates technology transfer and learning. But given rapid developments in telecom technologies emanating from a variety of firms, multiplicity of linkages may be more useful to avoid "lock-in" into one firm's standards or technology. However, "open-access" strategy of host country firms creates a potential of technology spillovers across networks and the MNC partners may be reluctant to facilitate learning of domestic firms under such conditions.

Frequent changes in technological trajectories and standards by the government prevent MNCs from investing in R&D in developing countries like India. Firms are unable to predict patterns of usage of equipment & services and hence are unsure of making investments. Given the possibility of government failures and a situation where technologies are changing very rapidly, it is difficult to make a case for a state mandated long term choice of technological trajectories which can potentially lock-in the economy in specific technologies. However, all efforts need to be made to reduce such technological uncertainties. Apart from ensuring competition in the telecom market, the government can zero-in on a few technologies and announce that these will constitute the standard in the medium term. This

choice of technology can be reviewed periodically as international competition throws up new technologies. This will reduce technological (if not market) uncertainties and facilitate flows of foreign direct investment and inter-firm linkages in the telecom sector. It needs to be emphasized that it was the government failure of a kind that delayed the implementation of TeNeT"s WLL technology in India; if the government had more well-defined policies regarding spectrum allocation and technology choices, this technology and the associated linkages would have emerged much earlier. Government policies should take cognizance of rapid technological change, especially in the IT-Telecom sectors where technology changes are frequent. This implies quick decision making and flexibility in related policies.

The cases of Nortel and IIT networks throw up several other questions on the potential of developing, nurturing and sustaining such hi-technology networks in developing countries. Given India's reasonable capabilities in telecom technology (for example, switches developed by Centre for Development of Telematics, C-Dot) and high knowledge base in software, and given the tremendous potential of synergies between these two knowledge systems, one would have expected "Nortel and IIT like" arrangements to emerge within the country among Indian software and telecom hardware firms. Why did this not happen? Why is it that the IIT case is the only one of its kind? One possible answer can be that the telecom activity was largely in the domain of the public sector and the State did not recognise the value of innovation related interactions between manufacturers of telecom equipment (e.g., Indian Telephone Industries, ITI) and technology developers (e.g., C-Dot, IIT and software firms). The other explanation can be sought in the fact that Indian telecom firms were not competing on the basis of innovations in domestic or export markets. They mostly focused on adaptation activity for the local market and on cost reductions. In fact, there was hardly any competition among telecom firms. Consequently, the need for such partnership was not felt. Only now one sees emergence of competition in the telecom sector. Besides, convergence of technologies is creating newer opportunities for inter-firm alliances.

Nortel, on the other hand, was both a manufacturer and developer of technology, competing with other international firms on the basis of state of the art technology. Unlike many other multi-nationals, Nortel was unable to enter the liberalising Indian telecom sector with its existing products. It foresaw, on the

one hand, the large and significant emerging role of software in telecom technology and recognised on the other, the potential of Indian software firms in contributing to the development of these technologies. It also needs to be noted that the technology gap between the Indian software firms and their counterparts abroad was relatively narrow. It can be argued that in technologies where the gap in capabilities among the participating firms/countries is high, such linkages may not come about or may not result in significant learning for a developing country partner.

The IIT network emerged from the vision of the group as consciously tried to combine social objectives with scientific and technological objectives without losing sight of the commercial viability of such an effort. In one sense, the researchers at IIT were as close to the technology frontier as the Nortel researchers. Consequently, they could identify technological opportunities just like a sophisticated lab of large MNC would do. They just did not have the financial muscle. Without such perspectives on technological trends and opportunities, the IIT type network is unlikely to emerge.

The survey findings and the case studies add to the growing evidence that technology alliances of developing country firms with other entities (multinational or domestic) having excellent manufacturing and/or technology development capabilities in areas where the technology gap is relatively narrow can potentially play a crucial role in upgrading capabilities of developing country firms. While the participating Indian companies have gained a lot through the Nortel arrangement, it needs to be ascertained whether such linkages can result in significant spillover benefits for the rest of the sector/economy. If yes, under what conditions? Does the spillover potential depend on the nature of the organisation of such arrangements or the technology gap between the participating firms and their competitors within the domestic economy? The Chinese strategy of locating such alliances in a specialised university has obvious advantages vis-à-vis training and other spillover benefits. The IIT case suggests that such possibilities exist in India and can be exploited to the advantage of the country. Do we also need to pro-actively build/develop telecom universities or departments in existing educational institutions or hope that the market forces will automatically create such facilities?

For an MNC like Nortel, in addition to cost advantages, such alliances can provide an opportunity to enter emerging markets like India through the "technology development" route and this collaboration

may prove to be extremely useful for Nortel's entry into India in the near future. In fact, it has nw set-up a subsidiary in India. How can one encourage such "entry" by MNCs? Technology gap may prove to be crucial in this regard. For example, Bangalore was the right choice for Nortel - with three of the four partners located there, the cost of installing additional infrastructure (in addition to what the city already provides) was relatively low, and the ease of installation was high. Moreover, the pool of competent people, with software as well as telecom related skills, was very high. It is noteworthy that, both ITI and C-Dot, which had the potential of forging such networks on their own are located in Bangalore. Interestingly, most of the alliance partners in India depended to a significant extent on telecom engineers from these two public sector firms to set up their respective Nortel facilities.

Under what conditions would the Indian partners collaborate on product and technology development, since that seems to be an optimal strategy to maximise learning? The tendency seems to be already there but we need a major acceleration in this direction. Can the much-maligned Indian public sector still take the lead in this direction and facilitate co-operative R&D among competitors? Will the lack of significant public or private investments in telecom training not act as a barrier to the growth of such alliances in future? Would it have been possible to have an IIT like network without the investments in IITs and other similar institutions during the post-independence period? For how long can we survive on the capabilities and externalities generated by public investments made before 1980s in the Indian educational establishments in science and technology. Answers to these questions may partly define the future of collaborative product development and research in this sector.

Table 1: A Matrix of Inter-firm Linkages

Nature of Linkage	Technology Generation and Transfer	Pre-Production	Production	Post-Production
One Way	• Licensing • Cross-Licensing		• Arms-length buy-sell contract • Sub-contracting • OEM • Long-term sourcing • Acquisitions/ Joint Ventures • GSO arrangements	• Franchising (Licensing of brand) • Distribution • Marketing • Service provision (after sales support)
Two Way	• R&D Consortia/ Joint R&D for Technology Development • Joint efforts at setting standards • Customer-Supplier Networks • Inter-firm technology collaboration agreements • University industry partnerships	• Joint bidding • Joint project development	• Joint production • Use of common components • Modularisation • Joint ventures • New forms of sub-contracting • Subsidiaries • GSO arrangements	• Joint marketing • Shared Distribution/ Service • Joint service provision • System products • Standardisation of interfaces

Source: Adapted from Mytelaka (1999)

Table2: Distribution of Alliances in the Indian Telecom Sector by Broad Categories, 1995-98

Nature of Alliance	Frequency	Percentage
Financial Collaboration	38	21.6
Joint Research and Development	7	4.0
Technical Collaboration/Assistance	9	5.1
Bidding Consortium	3	1.7
Licensing/Licensing of Production	6	3.4
Licensing of Brand	3	1.7
Joint Production Contract	30	17.0
Joint Service Provision	13	7.4
Supply Arrangement (Provision of Equipment/ Infrastructure)	49	27.8
Distribution and Sales Arrangement	32	18.2
Marketing Arrangement	25	14.2
Customer Service Support	3	1.7
Subsidiary	8	4.5
Total	176	100.0

Source: IIMA Data Base.

Note 1: No cases of subcontracting, minority holding or cross holding were found in the database.

2: In addition there were 12 cases of acquisitions and mergers.

Table 3: Distribution of Alliances in the Indian Telecom Sector by Detailed Categories, 1995-98

Nature of Alliance	Frequency	Percentage
Financial Collaboration + Joint R&D	1	0.6
Financial Collaboration + Bidding Consortium	2	1.1
Financial Collaboration + Joint Production	26	14.8
Financial Collaboration + Joint Service Provision	5	2.8
Financial Collaboration + Marketing	2	1.1
Financial Collaboration + Joint Production + Marketing	1	0.6
Others	1	0.6
Financial Collaboration (Total)	**38**	**21.6**
Only Technical Collaboration/Assistance	8	4.5
Only Bidding Consortium	1	0.6
Only Joint R&D	6	3.4
Only Joint Production	2	1.1
Only Joint Service Provision	8	4.5
Supply Arrangement (Provision of Equipment/ Infrastructure)	49	27.8
Only Distribution &Sales	27	15.3
Only Marketing Arrangement	17	9.7
Only Customer Service Support	1	0.6
Technical Collaboration/Assistance + Marketing	1	0.6
Joint R&D + Marketing	1	0.6
Marketing + Distribution & Sales	1	0.6
Distribution & Sale + Customer Service Support + Joint Production	1	0.6
Joint Production + Distribution & Sales + Licensing of Brand	1	0.6
Licensing of Production + Licensing of Brand	2	1.1
Licensing of Production + Marketing	2	1.1
Licensing of Production + Distribution & Sales + Customer Service Support	1	0.6
Licensing of Production + Distribution & Sales	1	0.6
Subsidiary	8	4.5
Total	176	100.0

Source: IIMA Data Base

Table 4: Distribution of Domestic and International Alliances by Broad Categories in Indian Telecom Sector, 1995-98

	Alliances among Domestic Firms		Alliances among Domestic and Foreign Firms	
Nature of Alliance	Frequency	Percentage	Frequency	Percentage
Financial Collaboration	10	13.5	28	27.5
Joint Research and Development	1	1.4	6	5.9
Technical Collaboration/Assistance	1	1.4	8	7.8
Bidding Consortium	0	0.0	3	2.9
Licensing/Licensing of Production	0	0.0	6	5.9
Licensing of Brand	0	0.0	3	2.9
Joint Production Contract	8	10.8	22	21.6
Joint Service Provision	6	8.1	7	6.9
Supply Arrangement (Provision of Equipment/Infrastructure)	38	51.4	11	10.8
Distribution and Sales Arrangement	14	18.9	18	17.6
Marketing Arrangement	3	4.1	22	21.6
Customer Service Support	0	0.0	3	2.9
Subsidiary	2	2.7	6	5.9
Total	74	100.0	102	100.0

Source: IIMA Data Base.

Note 1: No cases of sub-contracting, minority holding or cross holding were found in the database.

2: In addition there were 12 cases of acquisitions and mergers.

Table 5: Distribution of Sample Firms by Sales Turnover and Size of Employment

Number of Firms	100
Turnover(Rs Crores)	Percent of Firms
0 - 50	53.3
50 - 100	10.9
100 - 150	9.8
>150	26.1
Minimum	0.25
Maximum	24000
Average	212.5
Standard deviation	436.3
No reply	8
Number of Employees (Number)	Percent of Firms
<100	40.6
100 - 500	32.3
500 - 1000	10.4
1000 - 1500	5.2
>1500	11.5
Minimum	6
Maximum	47000
Average	1749.4
No reply	4

Note: The data for a sample firm. Indian Telephone Industries has been excluded to generate these estimates.

Table 6: Distribution of Alliances by Type of Alliance Partners

Firms	No. of Firms	%	No. of Alliances	%	Partner Firm					
					Hardware	%	Software	%	IT Service	%
Hardware	20	20.8	39	8.6	24	61.5	12	30.8	3	7.7
Software	38	39.6	101	22.1	19	18.8	80	79.2	2	2.0
IT Service	38	39.6	116	25.4	42	36.2	33	28.4	41	35.3
Total	96		256							

Note: Four firms could not be classified in the three categories defined in the table. In the case of two alliances, the relevan details were not available.

Table 7: Percentage Distribution of Alliances by Nature of Alliance		
Nature of alliance	Frequency	Percentage
Technology Related		
Joint research and development arrangement	68	26.4
Technology collaboration for establishing standards	116	45.0
Cross Licensing	3	1.2
Licensing	12	4.7
All Technology Related	143	55.4
Production Related		
Joint production contract	44	17.1
Subcontracting	60	23.3
Supply arrangement	66	25.6
All Production Related	134	51.9
Finance Related		
Subsidiary	8	3.1
Financial collaboration	18	7.0
Joint Ventures	32	12.4
Minority holding	5	1.9
Cross Holding	2	0.8
Bidding consortium	27	10.5
All Finance Related	65	25.2
Marketing & Distribution Related		
Distribution and sales arrangement	121	46.9
Marketing arrangement	95	36.8
Licensing of brand	9	3.5
All Marketing & Distribution Related	145	56.2
Management agreement	50	19.4
(Total no of Valid Alliances)	258	

Table 8: Extent of Participation of Foreign & Domestic Firms in Different Categories of Alliances (Percentages)					
Category	Distribution of Alliances by Categories		Share of Alliances among Domestic & Foreign Firms		Total Valid Responses
	Domestic	Foreign	Domestic	Foreign	
Technology related	28.7	25.9	20.1	79.9	134(100)
Production related	21.3	25.2	16.1	83.9	124(100)
Finance related	14.9	11.6	22.6	77.4	62(100)
Marketing & Distribution related	25.5	27.6	17.4	82.6	138(100)
Management agreement	9.6	9.7	18.4	81.6	49(100)
Total number of alliances	94 (100)	413 (100)			507(100)

Table 9: Distribution of Alliances by Objectives

Objective	Intentions Frequency	Percentage	Realised Frequency	Percent Realisation
To Reduce Cost & Risks	104	40.3	71	68.3
To seek Financial Support	44	17.1	27	61.4
Exploit Technological Complementarity among Partners	184	71.3	142	77.2
To Reduce Innovation Time Span	73	28.3	41	56.2
To Acquire larger Market Share	144	55.8	117	81.3
To Conduct Basic Research	10	3.9	4	40.0
To Monitor Technological Opportunities	139	53.9	104	74.8
Expansion of Market	170	65.9	128	75.3
To Access to Partner's Technology	130	50.4	109	83.8
To Monitor Possible Entry of Potential Competitors	57	22.1	30	52.6
To Seek control over Partner	9	3.5	2	22.2
Outsourcing of Peripheral Activities	17	6.6	7	41.2
To Acquire World Class Practices	107	41.5	78	72.9
To Activate Subsidiary Partnership	11	4.3	2	18.2
To Strengthen Customer-Supplier Partnership	95	36.8	59	62.1
To Increase Profitability	204	79.1	170	83.3
Others(New products. Cost effective out sourcing)	10	3.9	5	50.0
(Total no of Valid Alliances)	258			

Table 10:Some Features of Alliances and their Evolution	
	Percentage
Size of the projects increased over time	91.6
No. of employees devoted to alliance increased overtime	87.9
Partner helped setup factory / facilities	21.5
Partner helped improve shopfloor / programming practices	53.4
Managerial practices changed	43.9
Alliance helped to develop new products	44.8
Investment in hardware/software useable in other projects	66.8
Alliance helped in training of people other than involved in projects	69.6
Projects are mainly for the export market	34.3
IPRs are held by (or plan to hold) :	
Partner	25.5
Firm	19.1
Both	21.7
None	33.8
Alliances in which e - mail was used as a Communication channel	77.6

Note: The number of responses varied for each question and therefore, the percentages were computed for valid responses onl

Table 11: Profile of the Projects and the Associated Learning Potential

Average share of the Firm in Investment		73%
Average share of the Partner in Investment		21%
Percent Cases in which Design was Provided by :	Partner	43.2
	Firm	48.9
	Both	7.9
Percent Cases in which Software was Provided by :	Partner	40.3
	Firm	32.3
	Both	27.4
Percent Cases in which Hardware was provided by :	Partner	41.9
	Firm	33.3
	Both	24.8
Percent Cases where Planning done Jointly was Significant		50.4
Percent Cases where Planning done Jointly was Moderate		30.7
Percent Cases where Planning done Jointly was Low		19.0
Percent Cases where Firm has Access to the Final Product		82.9
Percent Cases where number of People Hired with New Skills		58.2
Alliance Involving Hardware Manufacturing :		
Percent Cases in which Manufacturing Equipment was provided by Partner		17.3
Percent Cases where Design Improvement made to the Product		47.1
Percent Cases where New Equipment Bought		58.9
Percent Cases where Equipment Modified		27.7
Percent Cases where New Products Developed		37.1
Total number of projects		156

Appendix Table 1
Distribution of Alliances by Detailed Categories

Category	Frequency	Percentage
Only Technology Related	44	17.1
Only Production Related	22	8.5
Only Financial Related	2	0.8
Only Marketing & Distribution Related	43	16.7
Only Management Agreement	4	1.6
Technology + Production	18	7.0
Technology+Production+Financial	7	2.7
Technology+Production+Financial+Marketing & Distribution	14	5.4
Technology+Production+Financial+Marketing & Distribution+Management Agreement	10	3.9
Technology+Production+Marketing & Distribution	16	6.2
Technology+Production+Marketing & Distribution+Management Agreement	7	2.7
Technology+Production+Management Agreement	2	0.8
Technology+Financial	7	2.7
Technology+Financial+Marketing & Distribution	3	1.2
Technology+Financial+Marketing & Distribution+Management Agreement	1	0.4
Technology+Marketing & Distribution	8	3.1
Technology+Marketing & Distribution+ Management Agreement	1	0.4
Technology+Management Agreement	2	0.8
Production+Financial+Marketing & Distribution+Management Agreement	8	3.1
Production+Marketing & Distribution	17	6.6
Production+Marketing & Distribution+Management Agreement	5	1.9
Financial+Marketing & Distribution	1	0.4
Financial+Marketing & Distribution+Management Agreement	1	0.4
Financial+Management Agreement	2	0.8
Marketing & Distribution+Management Agreement	4	1.6
Production+Marketing & Distribution+Financial	6	2.3
Technology+Production+Financial+Management Agreement	2	0.8
Technology+Financial+Management Agreement	1	0.4
(Total no of Valid Alliances)	258	100.0

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