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Deregulation, Entry of MNCs, Public technology procurement and Innovation capability in India's Telecommunications Equipment Industry

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DEREGULATION, ENTRY OF MNCs, PUBLIC TECHNOLOGY PROCUREMENT AND INNOVATION CAPABILITY IN INDIA'S TELECOMMUNICATIONS EQUIPMENT INDUSTRY*

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- This paper is part of a larger UNU/INTECH research project on *Development and sustainability of R&D capabilities and their linkage to manufacturing and services in the Telecoms Industry: cases from India, Brazil, Korea and Hungary*. I am thankful to the comments received from participants of an informal seminar at UNU/INTECH and in particular to Lynn Mytelka and Attila Havas. Further, I received very valuable help from M. Vijayabaskar and Mani Sridhar. The paper was also presented at an international seminar on *ICTs and Indian Development* at Bangalore, India during December 9-11, 2002. My grateful thanks to the participants and specifically to C. P. Chandrasekhar for useful suggestions. Subsequent comments received from a referee to the paper and those received during discussions with Lea Velho are gratefully acknowledged. The usual disclaimer holds good: the views expressed in the paper are those of the author and do not necessarily reflect the views of the United Nations.

ABSTRACT

India has a sizeable telecom equipment manufacturing industry. The industry, which was originally dominated by just one state-owned corporation, has now been deregulated. Currently the industry consist of twelve SMEs, which manufacture small and medium switches and seven large firms (of which five are TNCs) manufacturing large switches). The country has a history of extreme dependence on foreign technology imports through essentially the licensing route to manufacture large switching equipment. These imported technologies were shown to be inappropriate to the usage pattern prevailing in the country. Consequent to this, considerable investments were effected through in -house R&D to adapt this inappropriate technology to local usage conditions. However some systematic efforts towards building up of local innovation capability through 'green field R&D projects' were initiated only around the mid-1980s. The paper defines innovation capability in telecoms equipment in terms of the ability to conceptualise, design, and manufacture state-of-the-art tecommunications equipment coupled with the ability to keep pace with important technological changes. This definition of innovation capability is operationalised in terms of an index of R&D. By taking three cases of telecoms technologies namely (a) main automatic local exchanges; (b) a Wireless in Local Loop access technology; and (c) telecom software exports, it is demonstrated that the country has a growing innovation capability in this sector. A survey of the various contributory factors identifies public procurement as the main instrument that has stimulated this activity. But with the opening of the telecoms carrier industry to private sector providers, this may become less of an effective instrument in the years to come.

Key words: Innovation capability, C-DOT, corDECT, telecom software exports, public technology procurement.
JEL Codes:L63, O31, O32, O38

CONTENTS

THE CONTEXT

India's telecommunications sector has undergone many changes especially during the last three years or so. Although the sector has been growing at a rate of about 20 per cent a year for the last decade, it has not been able to cope with the rising demand for new connections. The level of fixed phone density in India is low at about 3.58 lines per hundred people, compared to the world average of 10.5. The situation is worse in India's rural areas, where teledensity is estimated to be roughly only 0.93 lines per hundred people. Out of 600,000 villages in India, just over half have access to telephone facilities. Furthermore, the growth of the cellular market—currently about 6.4 million subscribers compared to about 200 million in China —has been much slower than expected, although in the recent period the market has been growing at a rate of 80 per cent annually and according to some industry predictions, by 2006, India is expected to have nearly 40 million cellular subscribers[1]. This phenomenal growth of the sector is visible even when we take the most recent period. See Figure 1. The recent improved performance of the Indian telecommunications sector has attracted considerable interest within the research community. Although much of the attention in the literature has been restricted to understanding the nature and effect of the reforms in the telecommunications services sector. A critical summary of the reform process can be found in Jain (2001) and Mani (2000b and 2002). Further, of the eight full-length articles that were published in the journal *Telecommunications Policy* (since its inception in 1977 and until now), all the eight pieces dealt with various aspects of the reforms in the sector. On the contrary, although India is a sizeable manufacturer of telecom equipments, the changing nature of the county's capacities in research and production of telecommunications equipments have attracted very little attention[2]. Earlier attempts to analyse this issue especially up to the late 1980s could be found in Brundenius and Goransson (1985) and Mani (1992 and 1995). In the context, the purpose of the present paper is to map out the changing nature of research and production capacities in the Indian telecommunications equipment sector especially during the 1990s.

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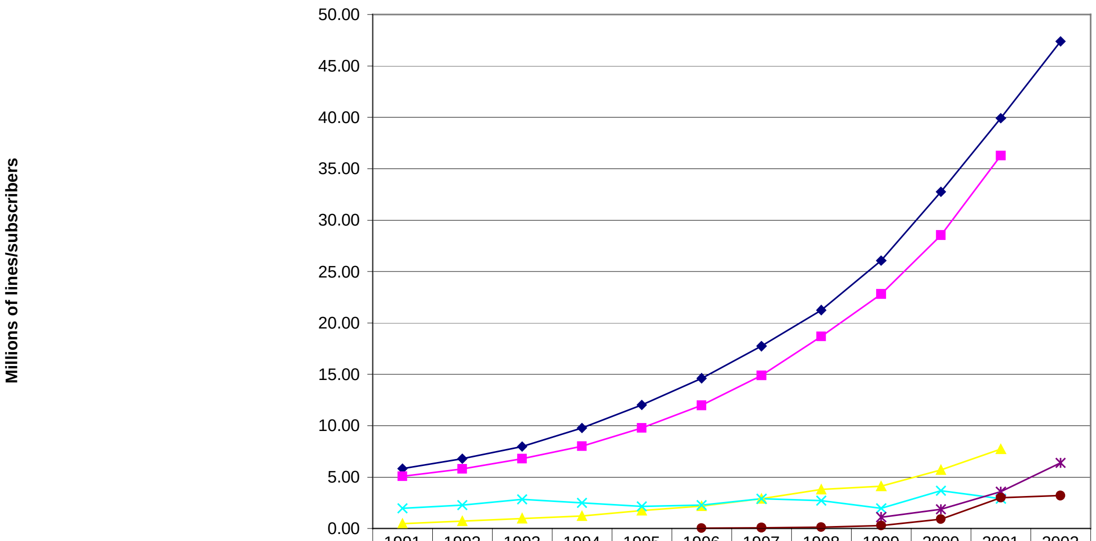
1 The number of mobile subscribers in India is expected to show rapid growth over the next four years. For example,

- the Cellular Operators Association of India (COAI) estimates that the number of mobile subscribers will grow to approximately 50 million by 2005; and
- Gartner (leading international business and technology intelligence firm) estimates that the number of mobile subscribers will grow to approximately 31 million by 2005.

2 There are very few studies on the telecommunications equipment industry elsewhere in other developing countries. However for an interesting study on the development of switching technologies in Brazil and Korea during the period up to the early 1990s, see Mytelka (1999). A more recent analysis of the Brazilian experience could be found in Szapiro (2000).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Switching Capacity	5.82	6.78	7.97	9.80	12.03	14.63	17.74	21.26	26.05	32.77	39.91	47.40
Direct Exchange Lines including cellurar and private basic)*	5.07	5.81	6.80	8.03	9.80	11.98	14.88	18.68	22.81	28.54	36.28	
Annual additions to DELs**	0.49	0.74	0.99	1.23	1.77	2.18	2.90	3.80	4.13	5.72	7.74	
Telephone Waiting List***	1.96	2.29	2.85	2.50	2.15	2.28	2.89	2.71	1.98	3.68	2.92	
Number of cellular mobile phones									1.12	1.88	3.58	6.40
Number of internet subscribers						0.05	0.09	0.14	0.28	0.90	3.00	3.20

Figure 1: Some indicators of the recent growth of the Indian telecommunications sector
Source: Department of Telecommunications (DoT) (2002a)

Since the industry (both the manufacture of telecom equipments and the distribution of telecom services) has undergone very many major changes, the imperative is that I place my discussion of the changes in the equipment sector against the external environment obtaining to the actors (research agencies and production enterprises). This external environment has become highly complex in recent times.

SOME CONCEPTUAL ISSUES

The paper deals with two issues related to innovation capability. The first issue is on measurement of innovation capability in the telecommunications equipment sector in the country. I define this capability in terms of the ability of the country to conceptualize and design state-of-the-art telecommunications equipments that are suited to the specific usage pattern prevailing in the country[3]. There are two ways of measuring this capability in empirical terms. First, innovation capability may be measured in terms of the factors that contribute (input) to the building up and maintenance of this capability at the firm level. These factors consist of investments in R&D, availability of the requisite number of scientists and engineers, the organisational and other support measures. Needless to add this measures only the potential to generate this capability. Second, on the contrary it can also be measured in terms of certain outcomes of this activity. Given the fact that the definition of innovation capability that I have adopted is better served by measures of outcomes, innovation capability in the present paper is defined in terms of actually revealed capability to design quantity of telecommunications equipment, largely, in the domestic market. The second issue dealt with is the proximate determinant of innovation capability and especially the role played by demand side instruments of intervention such as public technology procurement in building up this capability. This is because in high technologies such as telecommunications traditional supply side innovation policy measures are not sufficient enough. Having a ready market for the products that are developed is an important sine qua non. This is because complex technological innovations have two characteristics, which leads to severe market failures. The first characteristic is the lumpiness in R&D investments and second is the short life span of the innovation. This means that the availability of an assured market is the only or the main factor that can correct for such market failures. R&D in complex technologies such as telecommunications equipment is thus an ideal candidate for such a demand-oriented public policy intervention. A recent study (Edquist, Hommen and Tsipouri, 1999) have examined the role of public technology procurement (PTP) in promoting both development oriented and adaptive innovations in digital switching systems across six developed countries. (Table 1). The authors make two kinds of distinctions: first between normal public procurement and public technology procurement. The former (public procurement) 'is a term reserved for cases where public authorities buy ready made simple products such as pens and papers-where no R&D is involved. Only price and performance Further the term PTP is further distinguished *between developmental public technology procuremen*t, i.e., cases where completely new products, processes or systems are created and *adaptive public technology procurement* which includes some amount of R&D to adapt a known technology to local conditions. It is in the latter sense of adaptive public technology procurement that the term is used in the present study.

[3] Since the tele density in the country is very low, each available telephone is used much more frequently than it is under those situations where the teledensity is high. Consequent to this the throughput of the switching equipments required for the Indian network, for instance, are much higher. An analysis of the history of technology import in this sector has shown that very often

In understanding the determinants of innovation capability, the study employs a sectoral system of innovation perspective (Edquist, 1997 and Malerba, 2002). Malerba (2002) provides a very useful working definition of the sectoral system of innovation. It is as follows:

'A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and an existing, emergent and potential demand. The agents composing the sectoral system are organizations and individuals (e.g. consumers, entrepreneurs, and scientists). Organizations may be firms (e.g. users, producers and input suppliers) and non-firm organizations (e.g. universities, financial institutions, government agencies, trade unions, or technical associations), including sub-units of larger organizations (e.g. R&D or production departments) and groups of organizations (e.g. industry associations). Specific learning processes, competencies, beliefs, objectives, organizational structures and behaviors characterize agents. They interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions (rules and regulations). Over time, a sectoral system undergoes processes of change and transformation through the co-evolution of its various elements'.

Based on the above definition, the three major building blocks of a sectoral system of innovation involves (a) knowledge and learning processes; (b) type and structure of interactions among firms and non-organisations; and (c) institutions. This useful framework is applied, albeit in an implicit manner, in understanding the innovation system of the Indian telecommunications sector.

The paper is structured into four sections. The first section maps out the external environment obtaining to the India telecommunications equipment industry. This environment has two main discernible components: first, the changes in the world telecommunications equipment industry and also reforms and changes in the India telecommunications distribution sector or the carrier industry. The emphasis here is on distilling the implications of these for the Indian telecom equipment sector. The second section will focus on tracing the innovation capability of the sector in terms of a number of output measures the third section attempts at identifying some determinants of the building up of innovation capability in the domestic equipment sector. The fourth and final section will summarise the main findings of the study.

Table 1: Public technology procurement in digital switching systems across some European countries- A summary of the findings

Author	Country	Effect of public technology procurement on technological innovations (both developmental and adaptive) in digital switching systems
Fridlund (1999)	Sweden	*Positive:* The study shows that that a development pair between the public utility, the Swedish Telecommunications Administration (STA) and the main equipment manufacturer (Ericsson) led to adaptive technology procurements of an

considerable investments had to be made for successfully adapting imported technologies to local conditions.

		incremental character and informal collaboration laid foundations for more formal developmental procurement.
Llerena (1999)	France and Italy	*Positive*: The study shows that both France and Italy set out to develop 'national' digital switching systems. Italy's was more of an adaptive role while the French case was more developmental. This was due to the fact that France, unlike Italy, began with (and adhered to) a long term perspective or 'vision' of ending the domination of its domestic telecommunications sector by foreign subsidiaries and replacing them with a 'national champion' capable of competing on international markets with superior technology.
Husz (1999) and Tsipouri (1999)	Austria and Greece	*Positive*: Both in the case of Austria and Greece, the procurement processes were, from the outset, conceived of as 'adaptive' projects. However, they were also motivated by the desire to provide opportunities for 'development' rather restricting their aspirations to 'adaptation' only.

Source: Edquist, Hommen and Tsipouri (1999)

From the above cases, it is very clear that wherever, public procurement was part of larger vision to develop national competencies (e.g., the French case), and it has been successful. In fact in the Indian case too the existence of a credible procurement strategy has acted as a fillip to especially adaptive technology generation. In fact this is the argument that is pursued in this paper.

I. THE EXTERNAL ENVIRONMENT OBTAINING TO THE INDIAN TELECOMMUNICATIONS EQUIPMENT SECTOR:

It was argued by Mani (1995) that the innovation capability of developing countries in areas of high technologies such as telecommunications equipment sector are influenced in a significant manner by not only the domestic policies and support systems which favour such activity but also by the external environment. In current times, this external environment has two main components (Figure 2). First is the pressure exerted by powerful MNCs. These MNCs have become more powerful in the period since the mid 1990s and this can be measured in terms of one indicator namely increase in the market power of the MNCs which in turn is measured by their hold over the market for their products and secondly in their ability to make raid technological innovations. The second component of the external environment is the deregulation of the telecom network or carrier industry (or the distribution of telecom services segment). This part of the industry used to be the exclusive preserve of a state-owned monopoly, but has been gradually opened up to private sector carriers. Consequent to this the market for telecommunications equipment has widened and may value added services, which were hitherto not available, has been introduced for the first time. The new private sector carriers (some times these too are affiliates of MNCs) would like to purchase state-of-the-art equipments from abroad. Given this, despite the possible increase in the size of the domestic market, the domestic telecommunication equipment vendors may face tough competition from international vendors. Thus faced with increasing competition, it is possible that the innovation capability of the domestic agencies is adversely affected. Towards understanding this line of argument, I first present the changes in the world telecommunications equipment industry to show that the market power of the various firms in the industry has increased significantly in recent time. This is followed by the specific changes in the distribution segment of the industry in India that has a bearing on the domestic telecoms equipment industry.

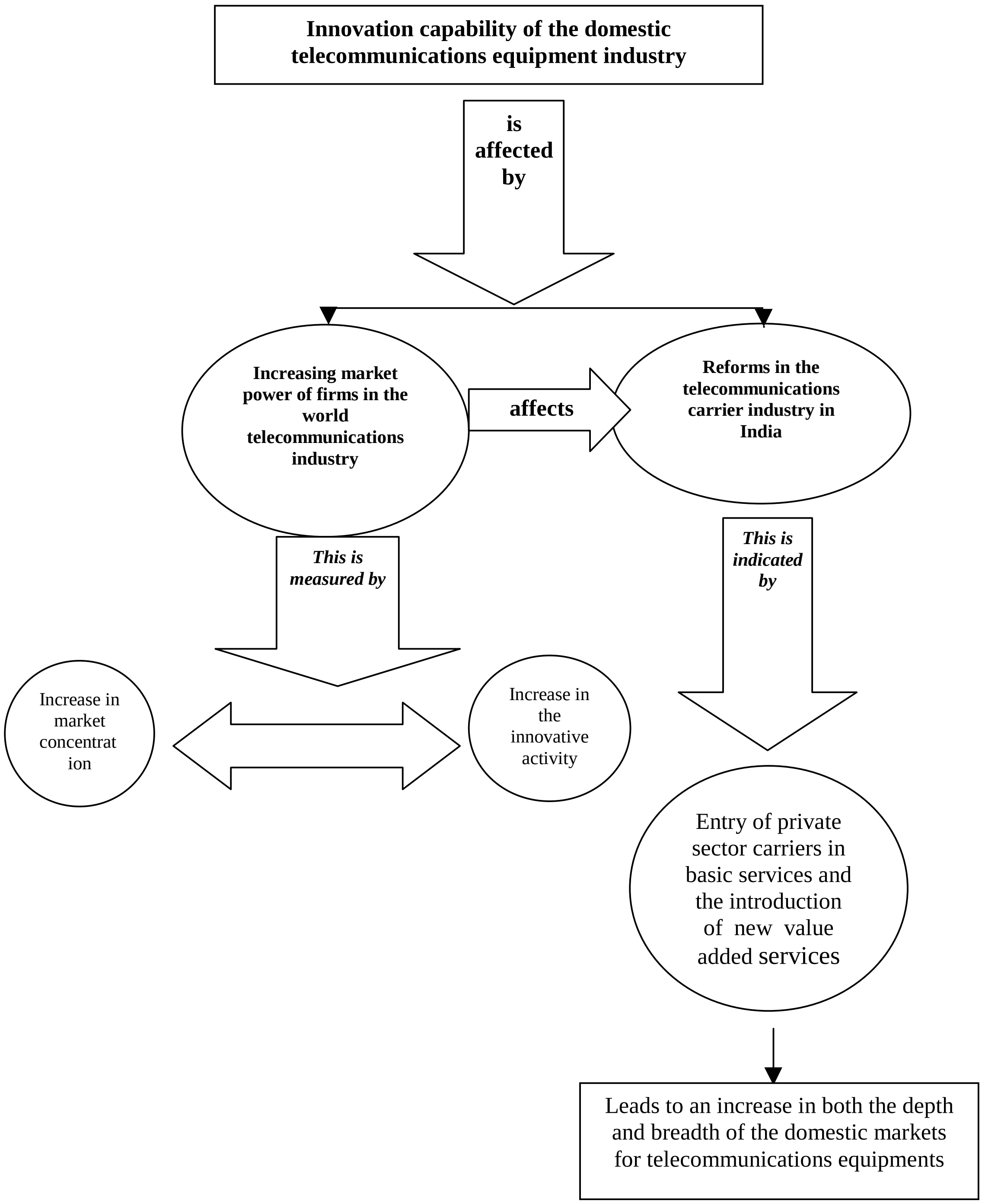


Figure 2: External environment obtaining to the Indian telecommunications equipment industry
Source: Own compilation

Changes in the world telecommunications industry: The international telecommunications industry has been in a state of flux especially after the burst of the telecom bubble in 2000. The industry has become so complex that it is convenient to invoke a "layer model" to understand what we mean by the telecommunications industry in the present century. Fransman (2002) divides the evolution of the industry into two separate phases: the old-telecoms industry up to the mid 1980s and the new tecoms industry which was born towards the beginning of the 1990s. Employing a layer model he identifies the main differences between the two models. The new telecoms industry is very often referred to as the infocommunications industry. See Table 2 for a characterisation of the old and new industries.

Table 2: Characterisation of the old and new telecommunications industry

Layers of the Old Telecom Industry **Layers of the New Infocommunications**

Layer	**Activity**	**Layer**	**Activity**	**Example Companies**
III	Service Layer (voice, fax, 0800 services)	VI	***Customers/consuming***	
II	Network Layer (circuit-switched network)	IV	*Application Layer, including contents packaging* (e.g., Web design, on-line information services, broadcasting services, e-commerce etc)	Bloombergs, Reuters, AOL-Time Warner, MSN, Newscorp
I	Equipment Layer (switches, transmission systems, customer premises equipment)	III	***Navigation&Middleware Layer*** (e.g., browsers, portals, search engines, directory assistance, security, electronic payment, etc)	Yahoo, Netscape, Vizzavi, Google, Genie etc.,)
		TCP/IP Interface		
		II	***Network Layer*** (e.g. optical fiber network, mobile network, DSI, local network, radio access network, Ethernet, frame relay, ISDN, ATM. Etc)	AT&T, BT, NTT, WorldCom, Qwest, Colt, Energis, Vodaphone, NTT DoCoMo etc
		I	***Equipment and Software Layer*** (e.g. switches, transmission equipment, base stations, routers, servers, CPE, billing software etc)	Nortel, Lucent, Cisco, Ericsson, Nokia

Source: M.Fransman, http://www.TelecomVisions.com

The model helps us to understand the evolving structure of the telecommunications industry. In the present paper, our concern is primarily with the first two layers of the new infocommunications industry. There are atleast three trends in the industry that is worth noting, namely (a) the industry is becoming very oligopolisttic consequent to a wave of mergers and acquisitions; (b) there has been significant increase in the innovative activity of these enterprises; and (c) the major market for telecommunications equipments is going to be in the Asia-Pacific region. China and India are the two single most important markets in the region. . All these three trends put together has meant that telecom manufacturers and research agencies in developing countries have been completely dwarfed by these developments.

(a) The World telecoms equipment industry is becoming more oligopolistic over time

Owing to its natural monopoly status the telecommunications industry (especially the network or carrier segment) has always been monopolistic. The recent wave of liberalization of the industry has sought to make the industry more competitive in terms of increasing the number and size distribution of firms constituting the industry. While there has been some deconcentration of the carrier segment across the world, the degree of concentration in the equipment sector has increased significantly. This is an interesting finding as the equipment sector was largely in the private sector across the world excepting in some developed and most developing countries. In order to measure the degree of concentration over time, I employ the familiar Herfindhal Index (H.index)[4]. Even the equipment sector is not a homogeneous one. The network industry can be decomposed into at least three segments, namely switching, transmission and terminal equipment segments. For a guided tour of the equipment sector see Box 1.

Box 1: A guided tour through the telecommunications equipment industry

- Telephone networks are made up of three main elements: switches, transmission and terminal equipments.
- Switches allow the routing of voice, video, and data signals throughout the network.
- Transmission can be decomposed into *wireline(*twisted pair of copper wires, coaxial cable, fibre optic) and *wireless*(via satellite, cellular radio, microwave, personal communication services, or PCS)
- Relative to wireline transmission, wireless transmission offers end users the benefit of mobility; however, wireless equipment, especially if it is to offer advanced services, is expensive, and wireless transmission faces interference and especially bandwidth (capacity) problems.
- Consequent to the recent technological evolution has been a sharp *decease in the cost of transmission and switches.*
- Another recent key development has been the substantial increase in the *intelligence of the network.*
- Terminal equipments are those which are available at the subscriber's premise. Examples of this would be telephone instruments, fax machines and so on. Telephone instruments can also be either fixed or cordless.

Source: Mani (1992); Laffont and Tirole (2001)

Based on this, I define two variants of the H.Index. The first one to be denoted as H_1 measures the degree of concentration in the whole equipment industry and the second one to be denoted as H_2 measures the degree of concentration in just the switching equipment segment. Based on the data provided in Dorrenbacher (2000), the two variants of the H.Index have been computed for 1995 and 1998. See Figure 3.

[4] This index is computed by summating the squared market shares of all the firms in a specific industry. The index ranges from zero to one, and higher the value of the index higher is the degree of concentration.

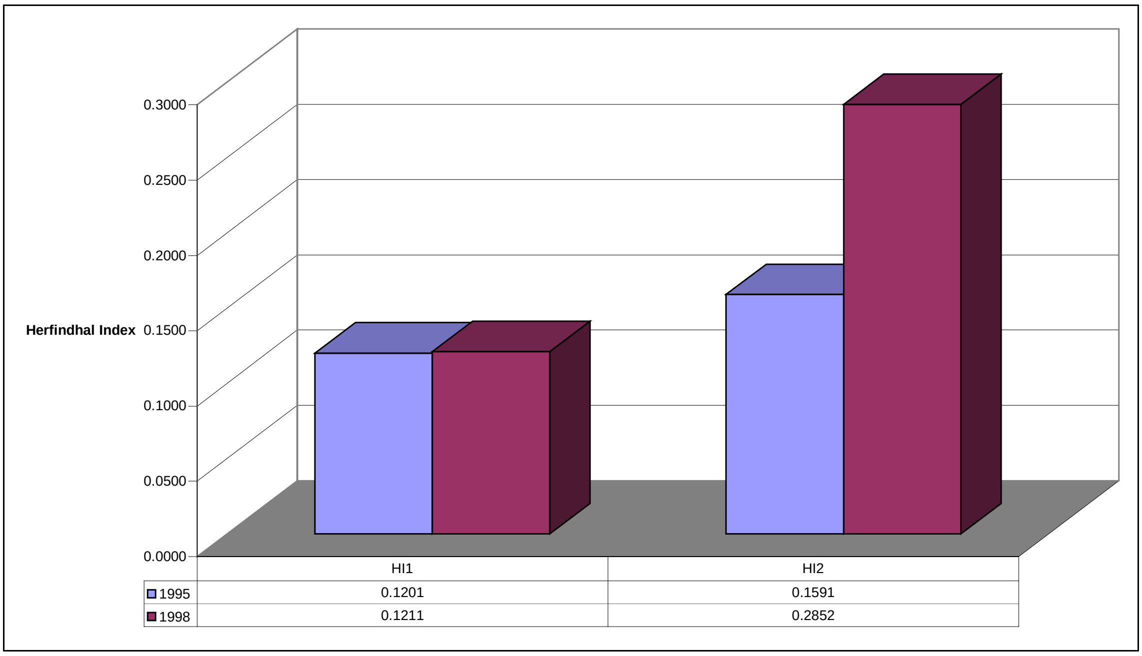


Figure 3: Degree of concentration in the world telecommunications equipment sector, 1995 and 1998
Source: Dorrenbacher (2000)

The following inferences can be drawn:

- The level of concentration in the overall telecoms industry has virtually remained the same over the two periods under consideration;
- However the level of concentration in the switching equipment industry has registered a significant increase of about 79 per cent. In fact in 1998, the top four firms in the industry, namely Lucent, Ericsson, Alcatel and Nortel accounted for about three quarter's of the total switching equipment sales in the world.
- Also the level of concentration in the switching equipment segment has always been higher than in the overall industry.

Box 2: Three cases of recent mergers between traditional and new telecommunications equipment manufacturers

1. Nortel-BayNetworks Merger in 1998

Nortel had 1997 revenues of US$15.5 billion and as of July 1998 had approximately 73,000 employees worldwide. It works with customers in more than 150 countries and territories to design, build and integrate their communications products and advanced digital networks. Customers include public and private institutions; Internet service providers; local, long-distance, cellular mobile and PCS communications companies; cable television companies; and utilitiesBay Networks, a Nortel subsidiary, is a leader in the worldwide networking market, providing a complete line of products that serve corporate enterprises, service providers and telecommunications carriers. The company offers Ethernet and ATM LAN switches, routers, shared media, remote and Internet access solutions, IP services and network management applications, all integrated by Bay Networks' Adaptive Networking strategy.

2. Alcatel- Xylan Merger in 1999

Alcatel has devised and is implementing a comprehensive strategy to become a key worldwide player in the Internet field, capitalizing on its leadership position in major telecommunications markets and technologies. This strategy encompasses the targeted acquisitions of leading IP-focused companies, leveraging Alcatel's strengths to leapfrog competition. A major step is the acquisition of Xylan, a long-time partner, The combined Alcatel/Xylan strengths in voice and data networking for enterprises will constitute a very powerful force in world corporate markets. In addition, Xylan technologies for carriers' data networks will remarkably complement other actions underway to build a leading Alcatel offering for converged voice/data carriers' networks.Xylan provides Alcatel with a superior portfolio of data switching equipment and a fast-growing position in the enterprise data market, where Xylan is developing well above market trends. The combined Alcatel/Xylan product offering will surpass competition in the enterprise market, both in terms of performance and spread of functionalities. Xylan's strong inroads in the carriers' markets, in particular, managed LAN services and the forthcoming traffic aggregation equipment, will substantially enhance solutions developed by Alcatel for service providers. Alcatel said it has started to sell a new line of switching devices for corporations called the OmniSwitch 7000. The OmniSwitch line originated from Alcatel's 1999 acquisition of Xylan.

3. Lucent -Ascend Merger in 1999

Lucent Technologies completed its merger with Ascend Communications in August 1999, creating the industry's broadest, most powerful and most reliable data networking product line. The merger, valued at about $24 billion becomes one of the largest technology mergers in U.S. history. Ascend Communications and its personnel has now become part of Lucent's new InterNetworking Systems unit, which is focused on delivering next-generation, broadband networks to all classes of service providers and enterprises. Lucent already leads the communications industry in several key areas: optical, wireless and circuit switching technologies; communications semiconductors; messaging; and networking software, services and support. With Ascend, Lucent adds critical aspects of data networking leadership to its portfolio and becomes:

- The leading provider of ATM switching for service providers
- The leading provider of WAN access for carriers, including Internet service providers
- The leading provider of frame relay switching for service providers
- The leading provider of Voice-over IP networks to carriers, Internet service providers and enterprises.

Sources: http://www.nortelnetworks.com; http://www.alcatel.com; and http://www.lucent.com/

In fact through a recent wave of mergers and acquisitions, the traditional equipment suppliers whose core-competencies and activities are in switching and transmission for traditional telecommunications infrastructures have extended their control over the new equipment suppliers whose core competencies are in switching and transmission for new telecommunications infrastructures. Thus the leading switching equipment manufacturers such as Lucent, Alcatel and Nortel have not only consolidated their position in their traditional fields of competence but also have amassed considerable technological and market clout in the new technologies (Box 2). Thus the traditional equipment companies have become even more formidable as they have access to a wide variety of markets. Gaffard and Krafft (http://www.wu-wien.ac.at/inst/vw1/gee/emaee/emaee0~1.pdf, Accessed on 19/11/02) have mapped of this complex vertical integration strategy of the traditional equipment manufacturers (Figure 4). According to them the different arrows contribute to explain the different stages of evolution of the vertical structures between telecommunications carriers and equipment suppliers.

They identify three stages in the evolution of vertical structures in the industry. In the first stage represented by Arrow 1 describes the initial situation when the traditional equipment suppliers at the upstream level have only one category of customers, namely the telecommunications carriers at the downstream level[5]. Arrow 2 represents the second stage and it represents the role played by the new telecommunications equipment suppliers on the entry of new firms at the downstream level. Finally in the third and final stage represented by Arrow 3 represents the merger strategy of the traditional equipment suppliers to have access not only to the core competencies of new equipment suppliers but also to extend their share of the new market created by the new carriers. In short the world telecommunications equipment industry have become more oligopolisttic and thereby increased its market power by a considerable measure.

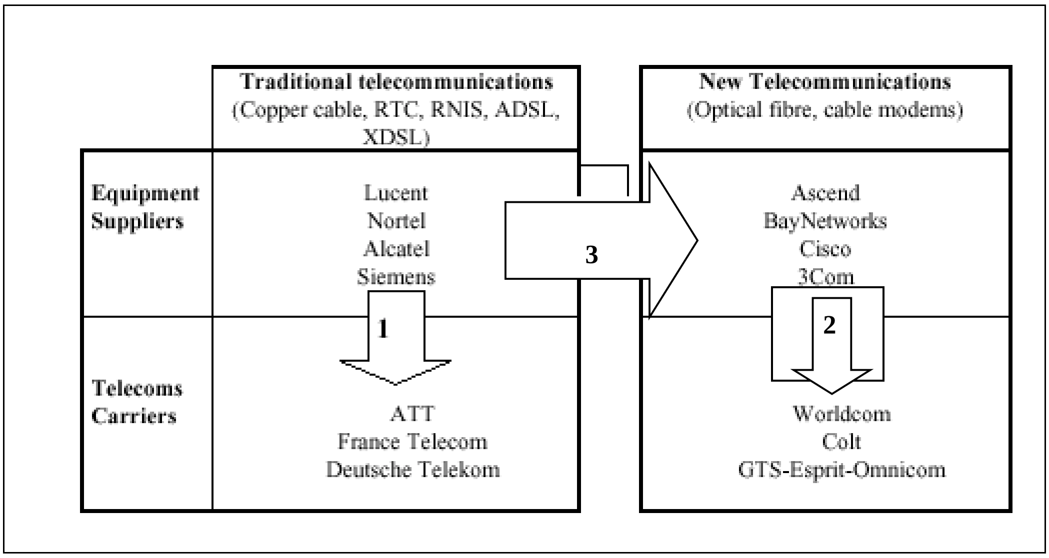


Figure 4: The characteristics and evolution of vertical structures in telecoms industry
Source: Gaffard and Krafft, http://www.wu-wien.ac.at/inst/vw1/gee/emaee/emaee0~1.pdf

[5] During this time both ATT and Lucent are the same company.

(b) Innovative activity in the World telecom equipment industry has increased significantly

Telecommunications equipment industry is one of the most research-intensive industries in the world. The research intensity of the sector has averaged over 7 per cent of the sales revenue per year[6]. I measure the innovative activity of the sector in terms of two standard indicators, namely an input indicator such as R&D expenditure (Table 3) and output indicator such as the performance of these companies with respect to patenting (Table 4). Both the indicators show that there has been significant increase across the board in the innovative activity of these enterprises especially during the period since the mid 1990s. An interesting feature is the fact that the increase in the number of patents secured by all the companies are better than their performance with respect to R&D investments.

Based on the data presented in the two tables, it could safely be concluded that the leading telecom equipment manufacturers have not only increased their share of the market but also of their control over the technology.

Table 3: R&D expenditure of leading world telecommunications equipment manufacturers.

<table>
<tr><th rowspan="2"></th><th colspan="3">Millions of US $</th><th rowspan="2"></th><th colspan="3">Millions of Euro</th></tr>
<tr><th>1997</th><th>1998</th><th>1999</th><th>1997</th><th>1998</th><th>1999</th></tr>
<tr><td>Lucent Technologies</td><td>3185(11.5)</td><td>3903(12.3)</td><td>4510(11.8)</td><td rowspan="2">Ericsson</td><td rowspan="2">2465(12.5)</td><td rowspan="2">2970(13.7)</td><td rowspan="2">3337(14)</td></tr>
<tr><td>Nortel Networks</td><td>2150(13.9)</td><td>2450(14)</td><td>2910(13.1)</td></tr>
<tr><td>NEC</td><td>3220(7)</td><td>3517(8)</td><td>3194(7)</td><td rowspan="2">Alcatel</td><td rowspan="2">1775(8.2)</td><td rowspan="2">1809(8.5)</td><td rowspan="2">2067(10.1)</td></tr>
<tr><td>CISCO</td><td>702(10.9)</td><td>1026(12.1)</td><td>1594(13.1)</td></tr>
</table>

Note: Figures in brackets indicate the research intensity in per cent.
Source: Gaffard and Krafft, http://www.wu-wien.ac.at/inst/vw1/gee/emaee/emaee0~1.pdf

[6] While the R&D-to-sales ratio reflect the relative tendency of companies within an industry to devote their own resources to R&D activities, they do not reflect the additional resources provided by governments that increase the actual amount of R&D performed. Such governmental support for R&D varies by industry to industry. But since telecommunications equipment industry has many dual applications, both in defence and civilian, situations, they are very likely to receive large doses of governmental funding. Therefore, any study of the broader question of how much total R&D is performed by industry would require supplemental data on governmental support which is very often difficult to obtain. I have obtained an average of 7 per cent by taking the average R&D to sales ratio of all the U.S communications equipment industry during the 11 year period 1986 through 1996. Given the fact that most of the telecommunications equipment firms are U.S based this is a very plausible assumption to be made. See National Science Foundation (1999).

Table 4: Patenting performance of international telecommunications companies, 1995-2000

Name of company (country)	Technological Strength[1]		Number of patents[2]		Current impact index[3]		Science linkage[4]		Technological cycle time[5]	
	2000	1995-99	2000	1995-99	2000	1995-99	2000	1995-99	2000	1995-99
1. Lucent Technologies (U.S)	2485	1701	1445	881	1.72	1.93	1.31	1.78	5.4	5.4
2. Motorolla (U.S)	2035	2148	1241	1193	1.64	1.80	0.63	0.76	9.4	5.5
3. Ericsson Telephone (Sweden)	1651	714	775	320	2.13	2.23	0.99	1.32	5.2	5.8
5. CISCO Systems (U.S)	911	123	133	25	6.85	4.94	1.15	0.90	5.8	4.9
7. Alcatel (France)	478	319	423	285	1.13	1.12	0.79	1.06	6.4	6.7
8. Qualcomm (U.S)	451	350	111	63	4.06	5.56	0.71	1.47	6.7	6.4
9. Cabletron systems (USA)	253	116	41	17	6.18	6.98	2.00	2.39	5.2	4.5
10. Ciena (U.S)	109	30	26	6	4.18	4.61	1.73	1.97	5.0	4.1
11. JDS Uniphase(U.S)	100	57	52	36	1.93	1.61	2.21	1.31	7.1	7.5
12. Qwest Communications International (U.S)	97	105	29	33	3.33	3.16	0.34	1.13	4.1	5.0

Notes: 1. This figure, the basis of the rankings, provides an overall assessment of a firm's intellectual property power. It is calculated by multiplying the number of a company's U.S patents by its Current Impact Index.
2. The total number of U.S. patents awarded excluding design and other special-case inventions.
3. This measure showcases the broader significance of a company's patents by examining how often its U.S. patents from the previous five years are cited as "prior art" in the current year's batch. A value of 1.0 represents average citation; so 1.4 would indicate a company's patents were cited 40 percent more often than average, and so on.
4. Patents sometimes cite scientific papers as prior art. This value shows the average number of science references listed in a company's U.S patents. A high figure indicates the company is closer to the cutting edge than its compatriots
5. An indicator of a firm's speed in turning leading-edge technology into intellectual property defined as the median age (in years) of the U.S patents cited as prior art in the company's art.

Source: MIT Technology Review (2001)

(c) Asia-Pacific region is the largest market for telecoms equipments

According to telecoms revenue forecasts by Pyramid Research (2002) based on analysis of telecoms markets in 85 countries, the global telecoms industry will grow by a compound annual growth rate of 6 per cent reaching US $ 1.3 trillion in revenues by 2007 from US$ 1 trillion in 2002. Further according to these forecasts, the emerging markets in the Asia-Pacific region a general and in particular China and

India are the fastest growing segments of the market. In fact the share of developed markets such as North America and Western Europe is expected to shrink from a whopping 65 per cent in 1999 to about 50 per cent in 2007 (Table 5). On the contrary, the share of developing country markets and more specifically those specifically in the Asia-Pacific regions show significant increase in shares. This means that one of the major impetus for the growth of the market for telecommunications equipments are to emerge from the developing economies of Asia. This means that the MNC telecom vendors are once again going to exert considerable pressure on domestic carrier companies in these countries. This tactics has received a fillip because consequent to the deregulation of the equipment sector a number of these MNC vendors have actually established manufacturing plants in India. This point will be analysed in some more detail in the second section on the structure of the equipment sector in India.

Table 5: Global telecoms revenue by region
(percentage shares)

Region	**1999**	**2007(*forecast*)**
Asia Pacific	23	35
Western Europe	29	19
North America	36	30
Latin America	6	7
Central and Eastern Europe	3	5
Africa and Middle East	3	4
Total	**100**	**100**

Source: Pyramid Research (2002)

Reforms in the Indian telecommunications carrier industry: Table 6 summarises the major reforms in the sector 1984 through March 2002.

Table 6: Chronology of reforms in the Indian telecommunications sector, 1984-2002

Time of change	Content of change
1984	Manufacturing of subscriber premises equipment to private sector
1985	The erstwhile Department of Posts and Telegraphs was bifurcated and the Department of Tecommunications was established with a separate Board
1986	Two separate corporations called Maha Nagar Telecom Nigam (MTNL) and Videsh Sanchar Nigam (VSNL) were established to distribute telecom services in Delhi and Bombay and overseas calls respectively
1988	The government introduces in-dialling scheme. PABX services only within a building, or in adjoining buildings
1989	Establishment of the Telecom Commission
1991	Telecom equipment manufacturing opened to private sector. Major international players like Alcatel, AT&T, Ericsson, Fujitsu and Siemens entered equipment manufacturing market
1992	Value-added services sector opened for private competition
1993	Private networks allowed in industrial areas
1994	Licenses for radio paging (27 cities) issued
May 1994	Announcement of the New Telecom Policy
September 1994	Broad guidelines for private sector entry into basic services announced
November 1994	Licenses for cellular mobiles for 4 metros issued
December 1994	Tenders floated for bids in cellular mobile services in 19 circles, excluding the four metros, on a duopoly basis
January 1995	Tenders floated for second operator in basic services on a circle basis.
July 1995	Cellular tender bid opened
August 1995	Basic service tender bid opened; the bids caused a lot of controversy. A majority of bids were considered low
December 1995	Letters of Intents(LOIs) issued to some operators for cellular mobile operations in circles
January 1996	Rebidding takes place for basic services in 13 circles. Poor response The Telecom Regulatory Authority of India (TRAI) formed by ordinance
October 1996	LOIs are issued for basic services
February 1997 March 1997	The TRAI begins functioning as a regulatory authority. Licence issued for basic telephone service in Gujarat circle
November 1998	New Policy on Internet Service Providers announced
March 1999	New Telecom Policy announced
March 2000	Telecom Regulatory Authority of India (Amendment) Bill 2000 was passed by the Parliament
August 2000	• National long distance services were opened to private operators. Four companies have been issued letter of intent for this service of which three licenses have been signed. • Internet Service Providers (ISPs) have been allowed to set up International Internet Gateways for both Satellite and Landing stations for submarine optical fibre cables. Thirteen ISP's have been given clearance for commissioning of international gateways for internet using satellite medium for 29 gateways. • Free right of way to lay fiber-optic cable networks along highways and roads allowed

October 2000	▪ The cap on foreign equity in telecom services up from the current 49 % to 74% ▪ As in the case of basic phone services, long distance and internet services, there will be no limit on the number of players in the cellular services ▪ The cabinet has approved a proposal to allow FDI of up to 100% in Internet Service Providers (ISPs) that do not have satellite or submarine landing stations ▪ Reduction in basic customs duties for several types of telecom equipments announced ▪ Corporatisation of the Department of Telecom Services (DTS) finally approved and a new company called Bharat Sanchar Nigam (BSNL) was e formed on October 1 with a paid up capital of Rs 50 billion and authorized capital of Rs 100 billion.
2001-2002	• Policy for Voice mail/Audiotex service was announced in July 2001 by incorporating a new service called "Unified Messaging Service" • Two categories of infrastructure providers have been allowed to provide end-to-end bandwidth and dark fibre, right of way, towers, duct space etc. • Fourth cellular operator, one each in four metros and thirteen circles have been permitted. In all, 80 licences(56 private and 22 to BSNL and 2 MTNL) have been issued; • Wireless in Local Loop (WILL) has been introduced for providing telephone connections in urban, semi-urban and rural areas promptly; • The Communications Convergence Bill 2001 was introduced in Lok Sabha on 31 August 2001 and it was referred to a standing committee; • Termination of monopoly of VSNL for International Long Distance (ILD) services has been preponed to March 31 2002 from March 31 2004. LOIs have been issued to five companies for ILDs of which one has been converted in to a licence; • Sanchar Sagar project being executed to meet the bandwidth demand of the IT sector; • VSNL has developed its capacity to provide international bandwidth on demand; • TRAI has given its recommendations for opening up of internet telephony in 2002 and these are under consideration of the government.

Sources: Mani (2002a), pp-122-3; and DoT (2002a), p.19

Contrary to popular impression, the reforms were initiated in the 1980s, much before the announcement of the new economic policy in 1991. Almost all the reforms were targeted at the carrier industry excepting for three, which were directed at the telecoms equipment industry[7]. However, most of the reforms in the carrier industry have important implications for the telecoms equipment industry as well. In a nutshell the reforms in the carrier industry and especially the opening up of basic and value added services have actually increased the size of the domestic market for these equipments in the country. In the following I focus on the effect of reforms on two important dimensions of the carrier industry, namely on (i) the basic services sector; and (ii) the value added sector.

[7] These are (i)deregulation of the manufacture of subscriber-premises equipment industry to the private sector in 1984; (ii) Opening up of the manufacture of telecoms equipment to private sector enterprises including foreign enterprises in 1991; and (iii) Announcement of the reduction of basic customs duties on various types of telecoms equipment in 2000.

(i) Basic services sector: The opening up of the basic telephone service in the country was initiated by the New Telecom Policy of 1999. The decision was to open up the sector without any restriction on the number of operators. The applicant must be an Indian company, registered under the Indian Companies Act of 1956. The entire country is divided into 18 circles and the Applicant Company can apply for license in more than one telecom circle subject to fulfillment

of the conditions of entry[8]. The total foreign equity in the applicant company must not exceed 49 per cent at any time during the entire license period. The licensed operator can provide all types of services except those for which a separate license is required. An important consequence of the entry of basic service operators is the introduction of Wireless in Local Loop (WILL) transmission technology[9]. Some indicators of the performance of basic services in the country are presented in Table 7.

Table 7: Performance indicators of the basic services segment of India's telecoms carrier industry

Indicator	2000	2001	2002
Number of licensees		31 + BSNL and MTNL	31 + BSNL and MTNL
Number of private carriers actually providing services		6	6
Number of Direct Exchange Lines (in million)	26.51	32.44	37.95
• Public (BSNL and MTNL)	negligible	0.27	0.58
• Private			0.0153
• Ratio of private to public DELs	NA	0.0083	2.24
Share of private sector in total revenues (in per cent)	negligible	NA	
Number of National Long distance service providers			BSNL + 4 (1)
Number of International long distance service providers			VSNL + 3 (3)

[8] Licenses shall be issued without any restriction on the number of entrants for provision of basic telephone service in a telecom Circle. The license for Basic Telecom Service Operator shall be issued on non-exclusive basis, for a period of 20 years, extendable by 10 years at one time, within the territorial jurisdiction of a licensed telecom circle.

[9] WiLL is a communication system that connects customers to the Public Switched Telephone Network (PSTN) using radio frequency signals as a substitute for conventional wires for all or part of the connection between the subscribers and the telephone exchange. There are at least two situations under which a wireless access network is very advantageous. First, wireless access promises quick deployment - an aspect particularly important to the new operator. Second, and perhaps more surprisingly, wireless access is proving to be more cost-effective than other access technologies as a permanent access network in mid-sized Indian towns and rural areas.

Note: Figures in parentheses indicate those with only a letter of intent and not yet converted that into a license.
Source: DoT, http://www.dotindia.com/plans/obj_ninth.htm

Admittedly the share of the private sector at the moment is quite low, though it is fast increasing: in fact the ratio of private sector to public sector in direct exchange lines has increased by as much as 59 per cent over the last two years (Table 6). But according to the demand forecasts for tenth five year plan (2002-2007) made by the DOT approximately 30 per cent of the additional capacity is to be met by the private sector. See Box 3 for the details. Given the fact that the private sector companies are new they are likely to offer a whole host of new services necessitating the use of state-of-the-art switching and

Box 3: Demand forecast: 2002-2007

Demand for telephone is dependent on various parameters like the economic growth of the country, tariff etc. As per the present trend of growth of telephone network over the period from 1991-97, the average growth rate is l6.5%. At this growth rate, to meet the objectives of providing telephone on demand, the additional demand during the period 1997 to 2007 comes to about 67.4 million. As the basic services are being opened to private sector, it is assumed that about 20.4 million of this additional demand will be met by the private sector. Based on this assumption the DOT will have to provide 40.7 million Direct Exchange lines during 1997 to 2007 to keep providing telephone on demand. At present telephone density is about 1.5 telephone per hundred population in the country. Assuming that the present GDP growth would continue to be maintained and also the population growth rate, the telephone density will reach around 3 per hundred in 2000, and 9 per hundred in 2007, In rural areas it may cross one per hundred population mark by the year 2007.

Source: DoT, http://www.dotindia.com/plans/perspective19972007.htm (accessed on 21/11/2002)

transmission equipments and this is likely to exert a pressure on the domestic manufacturers and R&D organisations to cater to these demanding customers. Also with the liberalisation of the market to both MNCs and imports, the domestic carrier industry does have a very wide choice and this is going to enhance the pressure on the domestic production and research sector.

(ii) **Value added services**: About six different types of value added telecom services have been introduced in the country (See Table 8) and all of them have been opened up to private sector participation.

Table 8: Structure of India's valued added telecoms carrier industry
(as on 30/06/2002)

Type of valued added service	Indicator of its size
• **Cellular mobile**	The country is divided into 24 circles. Hitherto about 80 licenses have been issued to 26 companies (including public sector carriers)*.
• **Total ISP Licensees**	410
Of which who have reported start of internet service	188
Number of ISPs to whom clearance for provisional commissioning of ISP gateways has been given	52
Number of ISPs who have been permitted to offer internet telephony service	49
• **Infrastructure Providers**	55
Number of Infrastructure Provider-I for whom Registration Certificates have been issued	49
Number of Infrastructure Provider-I for whom Registration Certificates have been issued	6
• **Very Small Aperture Terminal (VSAT) service providers**	Not Available
• **Radio Paging**	79 licenses issued to 15 companies
• A circle paging	8 licenses issued to 3 companies
• B circle paging	52 licenses have been issued to 15 companies to operate from 26 service areas
• **Public Mobile Radio Trunk Service**	Two companies are expected to sign the license agreement in terms of the LOI issued to them for GMPCS Service.
• **Global Mobile Personal Communications by Satellite (GMPCS)**	

Notes**: *** In terms of National Telecoms Policy-19999, cellular operators will be free to provide, within their area of operation, all types of mobile services including voice and non-voice messages, data services and PCOs utilising any type of network equipment, including circuit and/or package switches that meet the relevant International Telecommunication Union (ITU) /Telecom Engineering Centre (TEC) standards.
Source: DoT

Within the value-added services, it is cellular mobile that has registered significant growth (Figure 5) and this industry is almost entirely in the hands of the private sector.

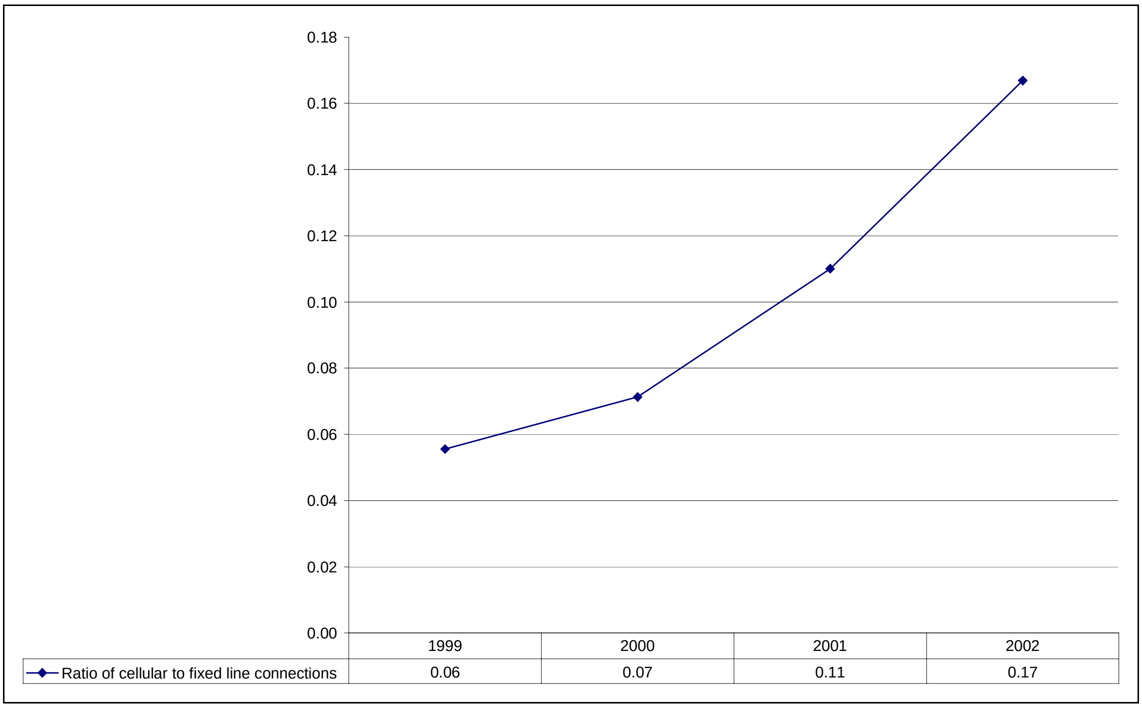


Figure 5: Ratio of cellular to fixed line connections in the Indian telecoms carrier industry
Source: ICRA (2002)

This shows that within a short period of time the breadth of telecom services in India has increased. Of all the value added services, the two most important ones are cellular mobile and the internet services segments, both of which, as seen earlier are poised for significant growth in the next five years or so. This spectacular growth of the segment is likely to increase both the breadth and depth of the market for telecom equipments and also in its complexity.

II. MEASURING INNOVATION CAPABILITY OF THE INDIAN TELECOMS SECTOR:

At the outset it is necessary to map out the structure of the innovation system for the telecoms sector. See Figure 6. The telecommunications innovation system of the country consists of three major components[10]: the government (namely the DoT), the technology generating sector (the most important of which is C-DOT) and finally the production sector (consisting of both state-owned and private sector enterprises).

R&D projects in the area of telecommunications are conducted by several organisations in the country (Figure 8). In 1999 the DoT constituted the 'The Telecom R&D Council' with a view to facilitate co-ordination of R&D efforts that are being made in various research centres and universities throughout the country. In other words, the council was a way of defining the national system of innovation for telecom research within the country. 18 different organisations were represented in the council. According to a survey made by this council there were 142 R&D projects organised in seven different types of organisations (Table 9).

But there is no information on what is the level of co-ordination[11] or output of these R&D projects. Based on the discussions that I had with officials of the DoT and with one of the largest telecommunications equipment manufacturers, it is very clear that the council is not functioning at all. In fact no meetings of this so called council has taken place since its first meeting in 1999. Further no budget too was attached to this council rendering it ineffective.

[10] Very recently, the Telecommunications Equipment Manufacturers Association (TEMA) has proposed that a part of Centre for Development of Telematics (C-DOT) be hived off and dedicated to developing technologies suggested by them. The equipment manufacturers would fund the activities of this new division. But nothing more is known about this proposal. See Economic Times (October 4, 2002), http://economictimes.indiatimes.com/cms.dll/html/comp/articleshow?artid=24100018&sType=1

[11] The Steering Committee (Chairman: N K Singh) on Communications and Information (of the Telecoms Working Group) of the Indian Planning Commission has sought to consolidate the national system of innovation of the telecommunications sector. In specific terms the committee made the following three recommendations: (I) Setting up of a communications research council as the apex body to prioritse plans and finance R&D projects. The council should basically be industry financed and governed body in which the government provides a one-time corpus fund; (ii) The present infrastructure available with C-DOT, being of very high quality, can be converted into a national research organisation. The industry shall be fully associated with financing and managing this organisation; and (iii) The companies in the organised sector of the telecoms industry must earmark a percent of their turnover for R&D activities.

Table 9: Survey of telecommunications R&D projects in India

Sl No	Institution	Field of research	Number of R&D projects
1	Indian Space Research Organisation	Satellite systems	21
2	BEL	Communications equipment	9
		Raiders as system	21
		Components and Devices	9
		Telecommunications	13
3	Tata Institute of Fundamental Research	Electronic Commerce	4
		Computer Network Packet switches	1
			1
4	VSNL	Internet Telephony	4
5	DST funded projects in Academic institutes	IT	3
	and universities throughout the country	Telecommunications	25
6	C-DOT	Switching	4
		Transmission	7
7	ITI		20
	Total		142

Source: Telecommunications Engineering Centre

An important measure of success of these projects is the actual use of these products in the Indian telecommunications network. Based on these criteria, I choose three major projects for my measurement of innovation capability. Based on this criteria, it is seen that the country has built up considerable innovation capability in three different areas: (i) digital switching systems; (ii) Wireless in local loop (WLL)-based access technologies for fixed line connectivity; and (iii) telecoms software An important feature of the innovation system is the recent growth of the telecom software segment and this segment is expected to be the fastest growing and most profitable segment of the software industry in India (Indiatel, 2002). In fact it is argued that the growth of the telecom software sector itself has been stimulated by domestic R&D projects.

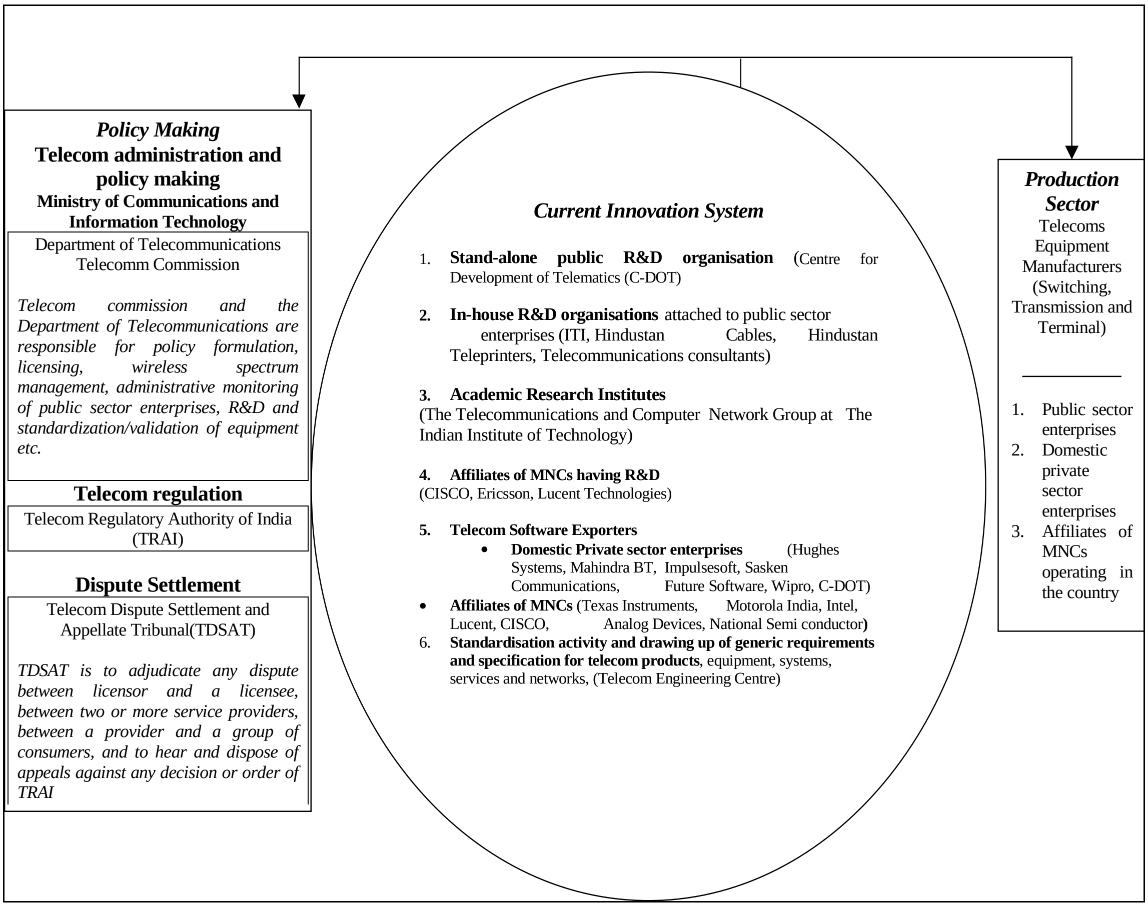
First of all, I will discuss each of the three cases briefly and then will go on to measuring the revealed capability of each of these actors with the aid of some quantitative indicators that reflect the definition of innovation capability that I outlined above.

(a) C-DOT and innovation capability in switching equipments:

C-DOT was established as a stand-alone public R&D organisation by the central government in 1984[12]. It was charged with the responsibility of developing a family of digital switching systems that were

[12] For a detailed history of the centre up to the early mid 1990s, see Mani (1992) and Mani (1995). In the past many attempts were made to pare down the research activities or even close down the activities of C-DOT supposedly on time overruns in their R&D projects. Mani (1995) has attempted to show that these attempts could largely be attributed to the 'machinations of MNCs' whose market in the country was challenged by C-DOT. It is surprising to note that the Centre has survived these attempts very admirably only to face such an attempt once again in the last few months of 2002.

suitable to the Indian usage pattern and conditions. Its scope has now been broadened to include transmission and access products as well. Over time, C-DOT has developed a wide range of switching and transmission products both for the rural and urban applications. It is claimed that while the C-DOT main exchange can also function as Mobile Switching Centre for GSM Cellular Service, the Small Rural Automatic exchanges developed for rural environment can work without air-conditioning. They come complete with SS7 Intelligent Network signaling systems13**.** In addition ISDN facilities are also available; what is unique is that these switches have been designed to operate without air- conditioning in harsh environments. About 45,000 exchanges totaling about 23 million telephone lines have been installed in India (As on December 31, 2001). This means that approximately 50 per cent of the equipped capacity in the country is based on C-DOT designed switches. Exports in bulk have been to about 22 countries such as Vietnam, Bangladesh, Nepal, Ethiopia, Nepal, Ghana, and Uganda. And this systematic vendor development shows that there have been considerable technology spillovers to downstream industries as well. It has a R & D centre in Bangalore with complete test equipments such as ,



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[13] These are the systems that are used to find out if a number is busy or available and involve a separate system that checks up the data bases of phone numbers ; also they provide toll-free services; in this way a the main telephone network does not get overloaded ; these systems are also used to interconnect Mobile and land based telephone numbers.

Figure 6: Current (2002) structure of the National Innovation System of the Indian telecommunications sector
Source: Own compilation

microprocessor development systems, CASE Tools, Object- Oriented methodologies, software metrics, along with V5.1, V 5.2 interface, SS7 signaling systems complete with the SSP, SCP and SMP systems. In fact C-DOT with a total manpower of 1300 employees has one of the fastest development cycle for digital switching systems any where in the world (Mani, 1995). C-DOT also claims to be having retrofitting capabilities- that is it has the capability to redesign some of the older switches that it has already developed and is currently being used in the network comply with more recent technological changes. This is achieved by making the necessary software changes. I have of course been not able to secure an independent confirmation of this capability.

I now turn my attention to measure quantitatively the innovation capability of C-DOT. Towards this direction, I consider two separate indicators of this capability. First is a summary measure of innovation capability based on production of C-DOT designed switches.. Second is a series of evidences to show the spillover effects of the technologies developed at C-DOT.

Indicator of innovation capability

There are two variants of this index. The first variant of this index is based on the relative market share of domestically designed (namely C-DOT designed and ITI-manufactured Main Automatic Local Exchanges (in terms of number of lines)) and foreign-designed but domestically manufactured (namely Alcatel-designed and ITI manufactured).[14] On technical grounds, both the technologies are considered to be equal. In very specific terms the index is defined as follows:

$$\text{Index of innovation capability} = \frac{\text{Production of C-DOT designed exchanges at ITI}}{\text{Production of Alcatel-designed OCB-283 exchanges at ITI}} * 100$$

[14] Currently the Indian telecoms carrier industry employs eight different types of switching technologies like C-DOT, E-10B and OCB-283 (Alcatel), 5ESS (Lucent technologies), EWSD (Siemens), FETEX-150L (Fujitsu) and NEAX 61E(NEC). Of all these 8 technologies, C-DOT is the single largest with a market share of 50 per cent.

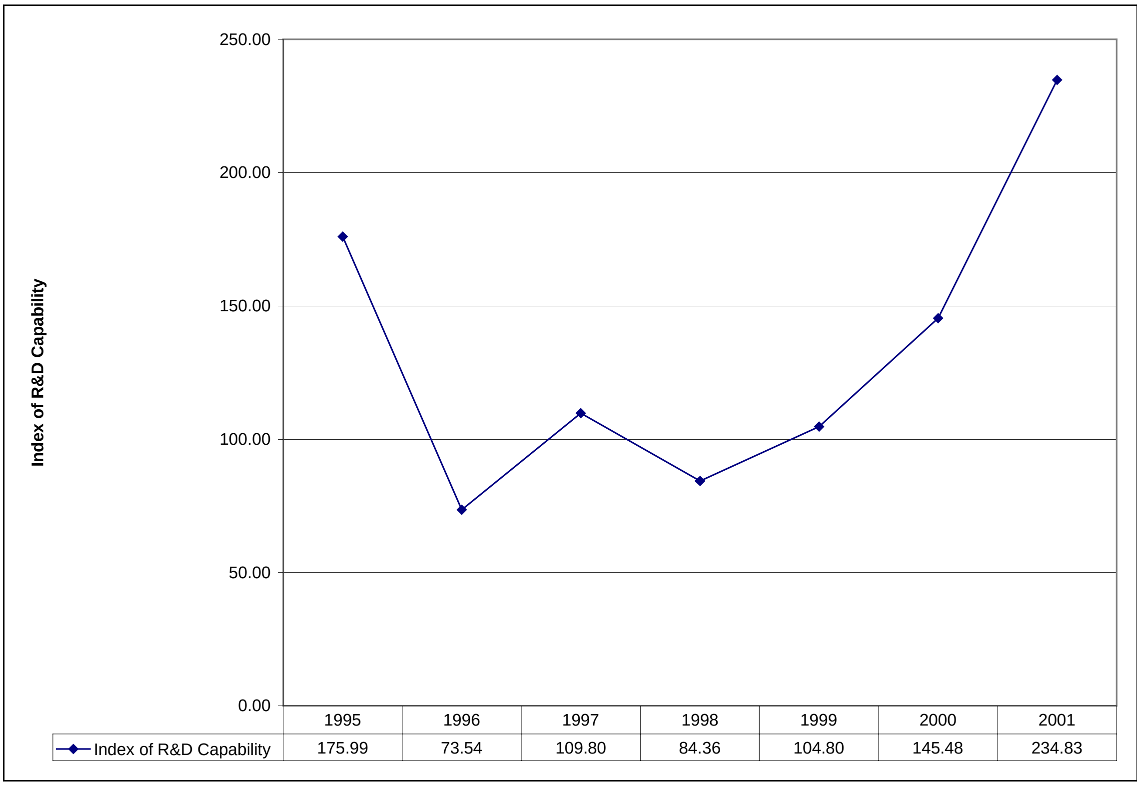

Figure 7: Index of innovation capability in Switching Equipments, 1995-2001
Source: ITI (various issues)

If the index is greater than 100 and increasing over time, one can say that the innovation capability of the domestic research sector is increasing over time. A major limitation of the index is that it is rather difficult to interpret short-term movements in the index. A second limitation is the fact that the index is defined in terms of production figures, and not in terms of number of working connections. But I argue that this will only affect the level of the index and not its direction of movement. This is because the share of C-DOT designed exchanges have been rising over time Based on the data during the period 1995 through 2001, the index has been computed and it is presented in Figure 7. Excepting for the initial year, the index shows that it has been showing a continuous rise over time implying a rising capability. This is quite significant as this has been happening at a time when the industry was going through a flux: the carrier industry was getting deregulated and MNCs were entering the equipment industry. So despite these factors which can militate against the usage of domestically designed switches one sees a systematic and continuous increase in its market share. As seen before this could be largely explained by the public procurement policy of the main consumer, the DoT .

The second variant is based on the number of lines of a switching technology actually commissioned within the network of the two main public telecoms service providers, namely within the DoT and the MTNL networks during a year. This variant is thus more of an index of market share of the various technologies and it is measured by the share of C-DOT designed switches in the total number of lines commissioned each year (Table 10). This variant thus captures the effect of liberalization. In fact the index shows that despite public technology procurement, the share of C-DOT designed switches have continuously fallen all through the period. This of course proves that public technology procurement in the Indian does not afford any protection to domestically designed switches. This proposition could be further explained as follows.

Table 10: Share of C-DOT designed switches in the total number of lines commissioned in DOT and MTNL Network, 1994-1997

Type of switching technology	1993-94	1994-95	1995-96	1996-97
1. AXE-10	74000	169704	128300	113060
2. EWSD	107000	203500	297328	249544
3. 5ESS	10000	4000	132000	40648
4. FETEX-150	160000	93000	113200	93280
5. NEAX-61	Nil	10000	Nil	Nil
6. E-10B	766327	957330	1119994	523854
7. OCB-283	79500	311000	405720	490578
Total foreign technology (1+2+3+4+5+6+7)	1196827	1748534	2196542	1510964
8. Domestic technology *Of which:*	966583	1198516	112519	661905
• C-DOT: Large Exchange*	148500	186020	328625	206166
• C-DOT: Extra Large Exchange**	Nil	Nil	18800	11200
• C-DOT: Small Exchange***	818083	1012496	774094	444539
Share of Domestic technology in the total number of lines commissioned (in per cent)	44.68	40.67	33.80	30.46

Notes: * Small and medium exchanges are those having up to 3000 lines; ** Large exchanges are those between 3000 and 10, 000; and *** Extra large are those having more than 10, 000 lines.

Source: Rajya Sabha, Unstarred Question No: 1171, http://164.100.24.219/rsq/quest.asp?qref=32199

(i) The Table tracks only the share of foreign and domestic technologies in the total annual flow of exchange lines commissioned. C-DOT's share in the total stock of exchange lines in the country is high at about 50 per cent with remaining 50 per cent shared by the other eight technologies;

(ii) C-DOT is specialising in small and medium exchanges, while the imported technologies are used essentially in large and extra large exchanges. It also a fact that C-DOT's capability is largely in small and medium exchanges, though it also has claims of capabilities in designing large and extra large switches;

(iii) It is also clear from an answer to an unstarred question in the upper house of the Indian parliament that the DoT procured almost five times the tendered quantity of switching equipments during the same period, supposedly for modernising the network with ISDN facility15. But the number of subscribers using ISDN in the whole country was just 309[16]. So it

[15] See Rajya Sabha Unstarred Question No: 4125 , http://164.100.24.219/rsq/quest.asp?qref=21560. According to the answer given by the Ministry of Communications, the DoT has actually ordered 0.91 million lines of digital switching equipments in response to a tender for just 0.2 million lines.

is clear that DoT appears to have purchased these 'overspecified ' equipments far in excess of its actual requirement and this 'excess purchase' appears to have eroded the market share of C-DOT;

(iv) Further the Comptroller and Auditor General of India (2000) found number of other irregularities with this tendering process. For instance, although most of the components of these switching equipments were imported by the suppliers, DoT assumed the import content as low as 23 per cent while working out reduction on rates on account of fall in customs duty in the 1995-96 budget. This inaccurate assumption by DoT led to excess payment of Rs 405 million to the suppliers with corresponding loss to the government exchequer. DoT also had to make an avoidable expenditure of Rs 639 million in the procurement of these exchanges against 1997-99 tender due to failure of the Tender Evaluation Committee (TEC) to submit its report within the bid validity period. TEC took 190 days in finalisation of its report against the prescribed limit of 42 days; and

(v) Despite this fall in market share, C-DOT designed switches continue to occupy the single largest share .

(vi) In the light of the above comments, it would not be correct to interpret the fall in the overall market share of C-DOT designed switches to mean a fall in its innovation capability[17].

Spillover effects of C-DOT

Over the last two decades of its existence, C-DOT has made a number of important contributions both in money and in giving a fillip to domestic technology development in this area of high technology. These could be enumerated as follows:

(i) Since its inception in 1984, C-DOT has recouped approximately 25 per cent of the amount that its has received in the form of parliamentary grants through the sale of its generated technologies. This rate of self generation has increased significantly to more than two thirds in the very recent past (Figure 8). This is a remarkable achievement as elsewhere in India, the network of laboratories coming under the purview of the Council of Scientific and Industrial Research (CSIR) has record of generating only about 10 per cent of their total income through self generation (Mani, 2002b).

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[16] See response to the same question no: 4125. From the same response it is also clear that the number of ISDN subscribers even in developed countries range from 0.5 million in the USA to just 40, 000 in Italy.

[17] According to some commentators the functioning of C-DOT throughout the 1990s was charecterised by a lack of proper direction as far as the type of research projects that it undertook. For instance according to a recent newspaper report, '… While the rest of the telecom world moved on to wireless and IP (Internet Protocol)-based technologies, C-DoT rested on past laurels earned from its wonderfully robust small-port RAXs (rural automatic exchanges). Throughout the 1990s, it made small incremental steps to a MAX (main automatic exchange); came up with an IN (intelligent network) platform; an ATM (asynchronous transfer mode) switch; some ISDN (integrated services digital network) boxes and satellite products',. See Josey Puliyenthuruthel (2002), 'Sanchar Bhavan's no Mecca any more' Business Standard, December 18 2002, http://www.business-standard.com/archives/2002/dec/50181202.077.asp).

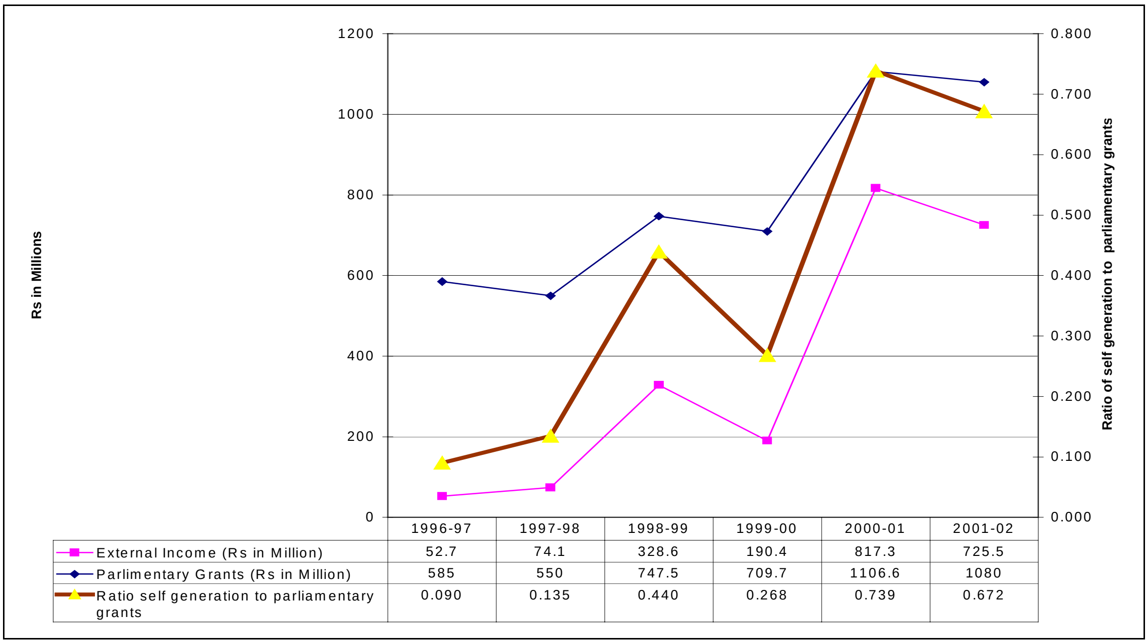


Figure 7: Ratio of self-generation through sale of technology to total parliamentary grants

Source: C-DOT (Various issues)

(ii) C-DOT 's technological innovations have contributed to a substantial reduction in the price of switching equipments sold in the country (Figure 8). In fact over the last one decade prices have fallen by as much as 75 per cent. This fall in prices have enabled the country to increase the supply of direct exchange lines.

(iii) C-DOT has transferred eight different types of technologies to very nearly 74 manufacturers in the country (Table 11). These 74 companies have their own suppliers of components and spare parts numbering over 600 enterprises. C-DOT has thus effectively contributed to the creation of an indigenous telecommunications equipment industry in the country. More details of the industry are analysed in one of the subsequent sections.

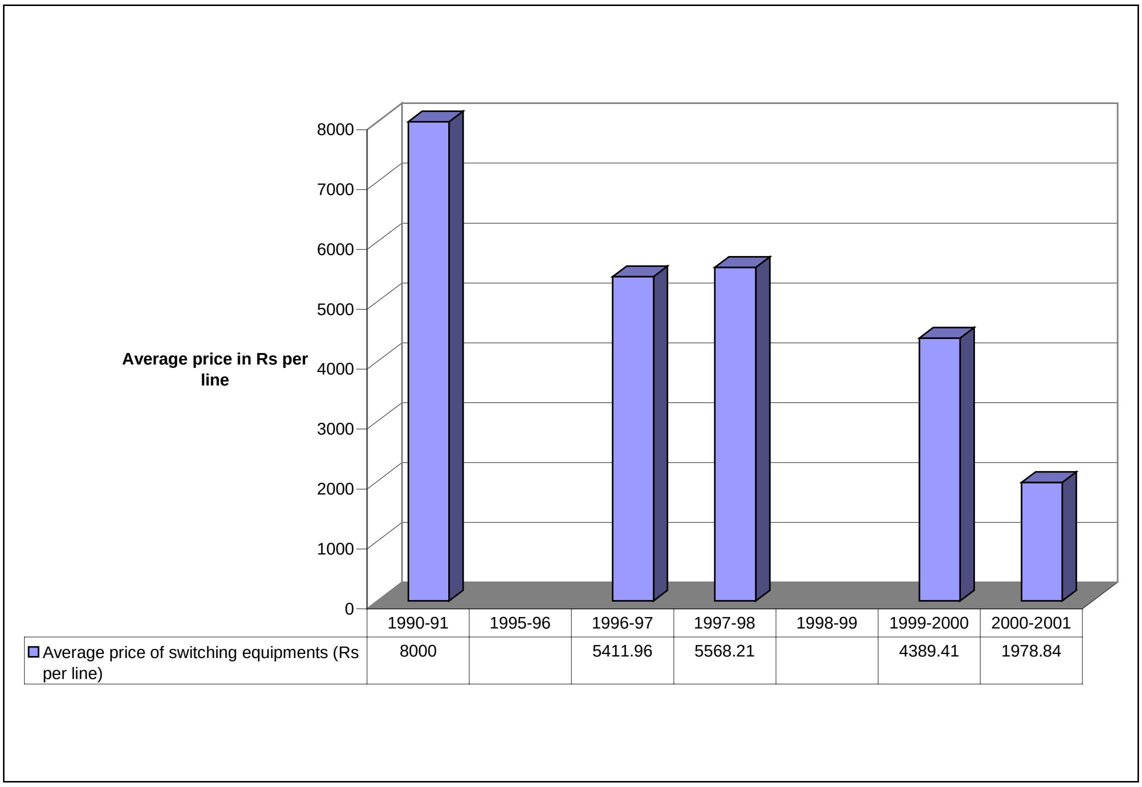


Figure 8: Average price of switching equipments, 1990-1 through 2000-01

Source: Department of Telecommunications (2002b)

Table 11: Technology transfer by C-DOT (Completed technologies)

Type of technology	Number of manufacturers
256 P RAX	14
SBM RAX	14
DSS MAX	13
IVRS	10
DMX-8	9
DMX-34	3
TDMA-PMP	6
OLTE-8	5
Total	74

Source: C-DOT (various issues)

(iii) C-DOT has pioneered the telecoms software industry in the country. Every year approximately 80 engineers (out of a total of about 1200) leave the centre. Since the development of modern digital switches are largely software based, this has given these engineers a strong background in the development of telecom software. The growth of the telecoms software sector is analysed separately.

While C-DOT has considerable capability in the design of fixed line switches, there is some doubt about its ability to design mobile switches. In fact my discussions at both the DoT, the TEC and with C-DOT revealed that C-DOT does not have , as of now , any real capability in the design of mobile switches. In fact no state agencies in India (including the Technology Information and Forecasting Assessment Council[18]) has done a detailed technology foresight exercise for the telecoms sector so much to say that C-DOT , despite possessing the potential has been totally unprepared for this change over. This is going to be a serious short coming for C-DOT in the future, as the growth of mobile phones is likely to be faster than that of fixed lines (Table 12). MNCs such as Lucent, Motorolla and Siemens have already established themselves as suppliers of state-of-the-art mobile switching centres to the cellular service providers. The problem is so severe that according the CEO[19] of ITI Ltd. (the largest telecoms equipment manufacturer in India), it had no orders for switching equipments for fixed lines from the largest telecom service provider in the country (namely BSNL) for the year 2003. Already there are reports of most of the licensees (switching equipment) of C-DOT having to close their manufacturing activities or scaling it down for lack of sufficient orders.

[18] The TIFAC did a major technology foresight exercise covering nearly 17 different areas including the telecommunications sector. Known as the 'Vision 2020' reports, these were published in 1996. Going through the list of seven major recommendations (and specifically recommendations iii through vi) of the report on telecommunications one finds that the study did not anticipate at all the phenomenal growth of mobile telecommunications in the country.

i. Extensive deployment of optical fibre in the existing network as well as for the network to be laid in coming years to support new broadband services is stressed to be more important;
ii. Taking necessary steps to ensure sufficient use of radio frequency spectrum, ensuring maximum economic benefit &effective wireless technologies are also considered to play significant role;
iii. Targeting R&D activity to strategic areas to work on specific socially relevant applications and efforts to raise funding through collaborative R&D in strategic alliances and regional initiatives should be pursued in the field of R&D;
iv. Orientation of Indian telecommunications industry from being technology, equipment & product focused to being services focused is brought out as an immediate specific action;
v. Introduction of new technologies in the network, to accelerate the development of telecommunications infrastructure in rural and remote areas also requires an immediate action;
vi. Upgradation of quality of human resources in telecommunications industry, and strengthening of India's core competence in software & design are stressed to be important; and
vii. Appropriate modifications of rules and procedures to ensure the above stated recommendations to be implementable are also discussed so that urgent attention may be given to these aspects as well.

Source: TIFAC website (http://tifac.org.in/)

[19] Private communication with the present author at Bangalore on March 7 2003.

Table 12: Actual and projected growth of fixed Vs mobile lines in the Indian telecommunications network

(Value in millions of lines; Actual data up to 2002; Data from 2003-2007 are projections)

	Number of fixed lines	**Number of mobile lines**	**Ratio of mobile to fixed**	**Rate of growth of fixed lines (%)**	**Rate of growth of mobile (%)**
1981	2.15				
1991	5.07				
1992	5.81				
1993	6.80				
1994	8.03				
1995	9.80				
1996	11.98				
1997	14.54	0.34	0.02		
1997	17.80	0.88	0.05	22.42	158.82
1998	21.59	1.20	0.06	21.29	36.36
1999	26.51	1.88	0.07	22.79	56.67
2001	32.44	3.58	0.11	22.37	90.43
2002	48.99	9.73	0.20	51.02	171.79
2003	56.86	12.27	0.22	16.06	26.10
2004	65.31	16.6	0.25	14.86	35.29
2005	75.33	22.27	0.30	15.34	34.16
2006	86.29	30.56	0.35	14.55	37.22
2007	99.15	41.28	0.42	14.90	35.08

Source: Department of Telecommunications (2002a); Department of Telecommunications (2002b)

The C-DOT case thus shows that , despite possessing the requisite potential, lack of strategic direction for the laboratory is likely to see its eventual closure. Also, it emerged from my discussions that several attempts to co-ordinate the research activities of both C-DOT and the in-house R&D centre of ITI has not been successful. Unless C-DOT diversify itself into other areas such as telecom software for instance, it's continued existence as an R&D organisation will be questioned.

Innovation capability in a new Wireless in Local Loop access technology the case of corDECT

In most countries the telecoms boom left an oversupply of fibre-optic cable along trunk routes, but this links directly only to the largest customers. Homes and small offices that want high-speed internet access usually subscribe to either a digital subscriber line (DSL) or a cable-television service. Both are far from ideal: the phone wires used by DSL and the television cables tend to be owned by monopolies, and neither was designed for surfing the web. Retrofitting a 1950s telephone line for broadband takes a lot of work, making cheap DSL hard to supply profitably. In principle, the new wireless in local loop (WLL) has no such drawbacks. Indeed, many see it as an ideal solution to the local access problem as it is based on radio waves. Of course, most WLL systems require their own dedicated radio frequencies, but regulators have been fairly generous with these-selling enough licences to competing WLL operators at a fraction of the prices paid by mobile-phone operators. Some can even use the same free, unlicensed frequencies in the 2.4 and 5 gigahertz bands. In the real world, wireless has so far lagged behind both cable and DSL.

CorDECT is a WLL access technology developed by two Indian research organisations namely IIT Chennai, Midas Communication Technologies, Chennai and a US semiconductor manufacturer. The project started towards the end of 1993 and was completed in 1994. The innovation system for this technology consisted of three different types of entities, namely (a) Indian Institute of Technology, Madras and Midas Communications; (b) Four private manufacturers who funded the project through advanced licences; and (c) Semi conductor manufacturer which included a MNC from the U S. Royalty from their equipment sales goes to IIT, Chennai. The total development cost of the project was Rs 750 million financed mainly through, as mentioned before, advanced licensing. Currently between the four manufacturers there is an installed capacity to manufacture 1 million lines per annum. This technology offers relatively low cost and rapid installation of telecom services in areas with even high subscriber density environments. This system relies on a modest bandwidth of 20 MHz for the entire country and is very useful for rural areas where subscriber density is low and laying of cable is not economical.. The following description of this technology helps one to understand the significance and utility of this technology[20].

The corDECT system contains three subsystems- the DECT Interface Unit (DIU), compact base stations (CBS), and subscriber access units that could be either fixed wallsets or portable handsets. The DIU is at the heart of the corDECT system. Each DIU is connected to a maximum of 20 CBS and each CBS itself serves between 30 and 70 subscribers, depending on the traffic. The CBS is a small, pole-mounted or wall mounted electronic unit that provides 12 simultaneous speech channels. The CBS is connected to the DIU through standard twisted copper pair links that carry data in the ISDN format. The CBS installed without the need for frequency planning is equipped with antenna for 'talking' to the subscriber wallsets or handsets. The wallset is a subscriber-premises equipment that provides the radio interface for PSTN connectivity. It is powered by an AC mains adapter and includes in-built battery backup and has very low power consumption. The wallset is an intelligent device that continuously looks for access to the strongest base station among many and locks on to the quietest channel. A wall set can be used three -kilometers from a CBS while a handset can be operated up to 200 meters from a CBS depending on the obstacles. The wall set can be connected to a standard fax machine or modem. CorDECT has been designed to be a modular system. It is stated that while the basic unit provides services to up to 1000 subscribers, multiple corDECT systems can be connected together using a transit switch. Compared to other substitute technologies like Code Division Multiple Access (CDMA), the corDECT has a number of advantages (Table 13)..

[20] This description is largely based on the information contained in Asian Technology Information Program (1997), Jayaraman (2002) and James (2003).

Table 13: Comparison of corDECT with CDMA

Parameters	DECT	CDMA
Frequency planning	Not required	Required
Power planning	No power planning	Power planning is complex
Voice quality	32kbps	9.6-13 kbps
Subscriber density	Very high	Low
Services supported	Voice/fax/data/N-ISDN	Limited data handling

Source: Asian Technology Information Program (1997)

In very simple terms, corDECT technology will reduce significantly the access cost of telecom service especially in rural areas. This will hasten the diffusion of internet services in the country and especially in the rural areas[21] and is also eminently suited to other developing countries as well. The system has also been exported to fourteen different countries namely Madagascar, Kenya, Fiji, Iran, Nigeria, Argentina, Singapore, Brazil, Tunisia, Egypt, Nepal, USA, South Africa and Angola. But there is very little quantitative data on its actual diffusion within the Indian network: about 100, 000 lines are said to be in operation within the country (Table 14).

Table 14: WLL technologies in use within the Indian telecommunications carrier industry

System Standard	Start-up date	Subscriber lines	System operator	System supplier
CDMA	May 1997	1,000	MTNL - Delhi	Qualcomm
CDMA	1997	unknown	Bharti Telenet	Motorola
corDECT	unknown	trial	DoT	IIT Madras/Midas/Analog Devices
PACS	unknown	trial (250)	MTNL	Hughes Network Systems
unknown	1998	unknown	Maharastra	Hughes Network Systems
CDMA	unknown	unknown	DoT	Qualcomm
CDMA	unknown	unknown	DoT	Samsung
DRA 1900	unknown	unknown	DoT	Ericsson
CT2	unknown	unknown	DoT	Dassault
TACS	unknown	unknown	DoT	Motorola
DECTLink	unknown	unknown	DoT	Siemens
PHS	unknown	unknown	DoT	Array Comm
cor-DECT	unknown	unknown	DoT	Analogue Devices
cor-DECT	unknown	unknown	DoT	Shyam
E-TDMA	unknown	unknown	Hughes Ispat	Hughes
cor-DECT	unknown	unknown	MTNL	Compton Greaves
cor-DECT	unknown	unknown	MTNL	Shyam
CDMA	unknown	unknown	Tata Teleservice	Lucent
CDMA	unknown	unknown	Telelink	Qualcomm
A 9800	unknown	trial	DoT	Alcatel
DECT	unknown	trial	DoT	C.Dot/NSC
PACS	unknown	trial	MTNL	Hughes
CT2	unknown	trial	DoT	Dassault

[21] CorDECT technology effectively and inexpensively addresses the problems of distance and lack of infrastructure in rural areas. Installing a fixed wireless local loop does not require expensive digging, and the system consists of only 4 major components. Because the central base station/ direct interface unit (CBS/DIU) handles traffic from 200-1000 subscribers, it works ideally in small, dispersed markets and does not require the large subscriber base that traditional landline or cellular systems require for profitability. This low infrastructure investment, combined with low usage costs, makes the proposition affordable both for suppliers and customers in capital-constrained economies. See World Resources Institite, Digital Dividend, http://www.digitaldividend.org/action_agenda/action_agenda_01_nlogue.htm

Source: Office of telecommunications technologies, U.S Department of Commerce.

However its diffusion within the domestic sector has received a major fillip in 2002 when one of the recent private entrants namely Reliance Infocomm[22] (which is building one of the largest broadband networks in India) decided to use corDECT to roll out its network in rural areas. However the same company has chosen a rival foreign technology, namely CDMA 2000 1X[23] to provide services in especially urban residential areas. CorDECT has thus an uphill task against this imported technology for two reasons. First, the owner of this technology also has an equity position in one of the largest telecoms operators in the country and this is likely to influence the technology purchase decisions of the latter. Second, the leading vendors of the CDMA technology (Table 15) are all MNCs and they are able to give deferred credit facilities to the operators while the vendors of corDECT which are all domestic companies are not in a position to do so. Thus corDECT is yet another instance of the country demonstrating its innovation capability despite severe competition from MNCs.

(c) Growth of telecom software exports

India's software exports have been showing some spectacular performance during the 1990s. But oft repeated complaint is that much of the software exports from India is of low technology. But over time, the enterprises involved in this effort has been attempting to move up the value chain. A clear anifestation of this effort is the emergence of telecom software exports from the country. It is generally believed that the impetus for this originated from C-DOT. This fledgling sector of the software industry consists of three different types of firms:

- Indian companies (some with foreign collaboration) focused only on telecoms software. Examples of this would be Hughes Software Systems, Future Software, Sasken, Mahindra-BT etc
- Information Technology companies (domestic) working on telecom software. For example WIPRO, Infosys, HCL Technologies, Satyam Computer, Tata Consultancy Services etc.,

[22] Reliance Infocomm is part of a large Indian conglomerate namely Reliance Industries. About 4 per cent of the shares of Reliance Infocomm are held by the American telecoms company, Qualcomm which pioneered the CDMA technology. Qualcomm makes money from royalties every time a chipset is inserted into CDMA phones and other network equipment as well as from license fees. Further based on my discussions with Midas Communications, it could be seen that the order from Reliance Infocomm has led to a large quantum of orders from both elsewhere within the country and from abroad. For instance, following test-run with 25,000 CorDect systems in 24 cities across nine states for over an year, Bharat Sanchar Nigam Limited (BSNL) has recently awarded a contract for over 0.6 million CorDect lines. The BSNL contract is worth around Rs 7 billion and is divided among Himachal Futuristic Communications Ltd (HFCL), Indian Telephone Industries Ltd (ITI), Electronic Corporation of India (ECI), Shyam Telecom and Hindustan Teleprinters Ltd (HTL) The BSNL contract for CorDect systems is mainly for smaller towns and rural areas in these states, according to Midas Communications director Shirish B Purohit.

23 According to reliable sources, CDMA 2000 1X has a much faster data transferring capacity at 144 kbps as against coDECT's capacity of 35-70 kbps. See India Bandwidth, http://www.indiabandwidth.com/dir1/wireless8.html

Table 15: Diffusion of CDMA WLL technology in India, 2002

	Operator	2G/3G	Type of System	Status	Infrastructure Vendor(s)	CDMA Coverage
1	Bharat Sanchar Nigam Limited (BSNL)	3G - CDMA 2000 1X	WLL, 800 MHz	Launch 2Q 2003	ZTE	Karnataka, Kerala, Mahrashtra
2	Bharti Telenet, Ltd.	2G - IS-95A	WLL, 800 MHz	Commercial	Motorola	Madhya, Pradesh
3	HFCL Infotel	2G - IS-95A	WLL, 800 MHz	Commercial	Lucent	Chandigarh, Ludhiana, Punjab
4	Mahangar Telephone Nigam Ltd. (MTNL)	2G - IS-95A	WLL, 800 MHz	Commercial	Motorola	Delhi
5	Reliance Infocomm Limited	3G - CDMA 2000 1X	WLL, 800 MHz	Commercial	Lucent	Nationwide
6	Shyam Telelink Limited	2G - IS-95A	WLL, 800 MHz	Commercial	Lucent	Jaipur, Rajasthan region
7	Tata Teleservices Limited	3G - CDMA 2000 1X	WLL, 800 MHz	Commercial	Lucent	Delhi
8	Tata Teleservices Limited	3G - CDMA 2000 1X	WLL, 800 MHz	Deployment	Motorola	Goa, Maharashtra, Mumbai
9	Tata Teleservices Limited	2G - IS-95A	WLL, 800 MHz	Commercial	Lucent	Eluru, Guntur, Hyderabad, Nellore in Andra Pradesh Circle, Rajahmundry, Vijayawada, Vizag
10	Tata Teleservices Limited	2G - IS-95A	WLL, 800 MHz	Deployment	Lucent	Delhi Circle, Gujaret Circle, Karnataka Circle, Tamil Nadu Circle

Source: CDMA Development Group, http://www.cdg.org/worldwide/index.asp#result

- Subsidiaries of MNCs. Examples of this would be Alcatel, Cisco systems, Lucent technologies etc.

Telecoms software fall into three areas: (I) embedded software (ii) system software; and (iii) application software that are used by service providers. A wide variety of telecoms software such as SDH, DWDM and optical networking, soft switches and intelligent networking, VoIP, ATM and SS7 gateways, Wireless networking, Broadband, home gateways and access network solutions, operations support systems etc are being developed. According to the Telecommunications Equipment Manufacturers Association (2002), the total size of the telecom software industry in India is about Rs 41 billion. This includes export of telecom software as well as domestic sales. While the export revenue includes embedded systems software, domestic sales refers only to the software that is sold to Indian service providers like OSS/BSS and network management. An indirect evidence to show that much of these exports are in the value added segment is given by the fact that over 94 per cent of the exports of telecoms software are meant for telecoms equipment manufacturers and only about 6 per cent are meant for telecoms carrier industry[24].

Consistent time series data on telecom software exports from India are not available: it is estimated that over 97 per cent of the output of this sector is exported25. However available data from industry- sources (Table 16) shows that telecoms software exports form about 14 per cent of total software exports from the country and have also registered more or less the same rate of growth. It is of course projected to touch about 20 per cent of India's software exports by 2003.

Table 16: Telecoms software exports from India (Millions of US $)

	Software exports from India	Estimated telecoms software exports from India
1998-99	2626	262.60 (10)
1999-2000	4015	461.73 (11.5)
2000-01	6341	883.09(14)
2001-02	7174	993.83 (14)

Note: Figures in parentheses indicate percentage share of total software exports
Source: Reserve Bank of India (2002), Indiatel (2002)

Thus our discussion of the above shows that country has built up considerable innovation capability in the area of both telecom hardware and indeed in software too.

Another important dimension of India's capability in the telecoms software industry is the fact that a number of MNC telecom companies have established their software development centres in India. Of late some of them have closed down their own R&D centres in India, but have outsourced their telecoms R&D to Indian software companies. The first such initiative was the recent deal between Ericsson and Wipro. See Box 4 the details

Box 4: Innovation capability in India's telecom software industry: case of the Ericsson-Wipro deal in outsourcing of R&D

According to the letter of intent that Wipro has signed, the deal will involve Wipro picking up assets, including personnel, of Ericsson’s R&D centres in Bangalore, Hyderabad and New Delhi. Around 300 software professionals who were part of Ericsson’s units would now be on Wipro’s payroll. This would take Wipro’s overall Ericsson-related team size close to 400 software professionals, as the software major already has around 100 people working on Ericsson’s projects. While the financial terms of the agreement are yet to be worked out, the deal does throw up interesting pointers on what Indian companies can do to gain a competitive edge.

Rather than term this deal as an acquisition, Wipro is calling it an ‘outsourcing deal’. Wipro intends to run the centres in the form of an outsourcing contract, wherein it will undertake the entire responsibility for all the R&D work of the Swedish firm done in India by taking over assets and people.
While MNCs have been outsourcing R&D requirements for a long time to Indian software companies, the current competitive scenario has changed things a bit. At present, the R&D outsourcing services market is

24 See Laishram (2002), pp. 74-5.

[25] See Laishram, *op. cit*, pp. 74-5.

taking on a hue similar to the IT services scenario. For instance, when companies first began outsourcing their R&D services to India, the billing rates quoted were premium rates. But as more and more Indian companies ventured into this market, billing rates fell drastically and MNCs started dividing their work between their own Indian R&D centres and a handful of Indian software companies .Due to the turmoil in the global telecom industry these MNCs have been looking at the best way to cut costs without compromising on R&D. For instance, a year ago Ericsson had announced that it wanted to increase investments in its Indian R&D arms. The telecom giant had plans of scaling up manpower in these centres even though it cut manpower requirements massively in other centres. But in the light of the massive slowdown in the telecom sector, Ericsson thought it prudent to write off its assets in the Indian centres, while still retaining its competitive advantage by selling the centres and the people working there to its partner, Wipro. As a result the deal has created a win-win situation for both companies, or so it seems.

Source: Srikanth R P (2002) Express Computer,
http://www.expresscomputeronline.com/20021111/cover.shtml

III. DETERMINANTS OF INNOVATION CAPABILITY IN THE EQUIPMENT SECTOR

It was seen earlier that the country has a sizeable domestic manufacturing industry. Although in value terms the domestic output has virtually doubled itself during the period under consideration, its rate of growth has actually come down over time (Figure 10). But according to the DoT (2002), this fall in the rate of growth is entirely due to fall in prices and not in quantity. This fall in price realisation is the combined effect of two factors: namely due to technological innovation and due to competitive bidding by vendors This is a direct evidence to show that the public procurement policy of the DoT (to be discussed in detail) based on the price performance ratio of equipments is really a competitive process. Another interesting inference that can be drawn from the above figure is the fact that there appears to be direct relationship between the rate of growth of domestic production and imports. This is perfectly understandable as: (i)imports of externally assembled switching equipments are not encouraged by the public procurement policy which I discussed earlier; and (ii) domestically manufactured switching equipments, especially have an import component of very nearly 45-50 per cent[26] and the import content is directionally proportional to the capacity of the switch.

The normal practice in the literature is to identify certain input factors such as investments in R&D, availability of requisite quantum of scientists and engineers etc as the factors that determine innovation capability. However in my view while these factors are a necessary condition, they are not sufficient enough. So in the present, I undertake a survey of those factors, which I think are important. In fact all the three factors that I consider have important implications for domestically designed and manufactured equipments and hence on the building up of domestic research capability. These are considered in turn:

[26] Swaminathan (1998). According to him, these imports of components will continue for several years because of uneconomic production volumes, higher start up costs, and fast changing technology deter entrepreneurs from choosing to locally manufacture telecom components. The central government owned Semiconductor Complex produces a limited range of small scale, and medium scale integrated circuits. Large scale and very large-scale integrated circuits are essentially imported.

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gowth Rate in Production (%)		34.85	27.15	3.93	0.91	14.64	-11.32	4.47	8.18
Growth Rate in Imports (%)	34.90	32.77	16.85	-12.99	75.34				
Production (Millions of US $)	1300.16	1753.27	2229.30	2316.89	2338.03	2680.30	2376.99	2483.27	2686.30

Figure 10: Rate of growth of production and imports, 1993-2001
Sources: DoT (2002a), Mani (2000a)

(i) Public technology procurement policy: As seen earlier, technology procurement policy is an indirect incentive to R&D activities by domestic firms[27]. Korea is one developing country which has used this policy very successfully as a way of encouraging private sector enterprises to commit more resources to local technology generating activities. While several developed countries such as Sweden, France etc have used this specifically in the realm of digital switching systems. In fact I argue that it is the procurement policy of the DoT which has to a large extent promoted domestic innovation capability in the sector[28]. The DoT purchases switching equipments only from local manufacturers and does not allow

[27] The WTO already has the Government Procurement Agreement (GPA), with detailed rules on procurement. However, this agreement only binds 26 parties out of the 135 WTO Members. For this reason the WTO has pursued a work programme on transparency in government procurement (TGP). The aim is to draw up an agreement to which all WTO Members will be party. In principle the agreement does not seek to eliminate preferences to domestic suppliers, it simply aims to make these preferences transparent.

[28] The procurement policy of the main telecom consumer, namely the DoT (or the BSNL) needs to be distinguished from the procurement policy of other government departments. In the former case the telecoms products are selected on the basis of price-performance ratios (or the rate performance contract) while in the latter cases it is very often through a fiat. The procurement policy of the DoT (or the BSNL) especially for non-switching telecoms equipments have drawn some flak in recent times. Owing to pressure from the Parliamentary Standing Committee, BSNL constituted a committee — *Shift in Procurement Policy of BSNL* —, which is to submit its report soon (in late 2002). On a more general note, following the Singapore Ministerial Meeting of the WTO, the Central Government constituted an Inter-Ministerial Working Group on Transparency in Government Procurement at the level of additional secretaries and headed by the Additional Secretary (Commerce).

imports of finished switching products[29]. This really does not afford any protection to domestically assembled switches, but in fact quite the contrary. There are two types of evidences for this. First, imported equipments attract a customs duty of 15 per cent ad valorem(2002-03). At the same time the imported components for domestically assembled switches also attract customs duties and given the nearly fifty per cent import content of domestically assembled switches, the procurement policy does not afford any specific protection to domestically assembled or manufactured switches. Second, as noted earlier in Figure 8, the fall in price realisation of domestically manufactured equipments signal increased competitive pressures. Further in the past the rate of rejection of indigenously manufactured switching equipments by the DoT has been as high as 25 per cent in the early 1980s[30].

It has a decentalised telecom switches procurement policy. In order to simplify the procurement process, the department receives tenders and sets a fixed rate through a tendering process commonly known as "rate contract"[31] after which the Chief General Managers of the various telecom circles are authorized to purchase their requirements from approved vendors. The Telecommunications Engineering Centre (TEC)[32]within the department sets the technical standards of all telecom products including switches. Thirty per cent of the total requirement of switching equipments are reserved for the public sector enterprise. However the price at which this thirty per cent is procured is at the lowest price quotation received for the remaining seventy per cent for which an open tender is invited. This reservation price is referred to as the L1 price. It is thus seen that the public sector producer of switching equipments have actually to bid for thirty per cent of the switching requirements without actually knowing the price at which the bid is going to be made. Thus it is clear that the public procurement process followed in the case of switching equipments does not afford any protection to the public sector producer which in this case is ITI Ltd. at Bangalore. The price-performance ratio is thus the main criteria for selection and not other non-technical considerations such as deferred credit facilities. At least for some more years, given the near monopoly position of the government carriers) public procurement policy will be an effective instrument for stimulating local R&D activities. However with the growth of private service providers

[29] It must of course be added that the new private entrants are not governed by this stipulation and are free to import switching equipments.

[30] See Mani (1992), p. 97.

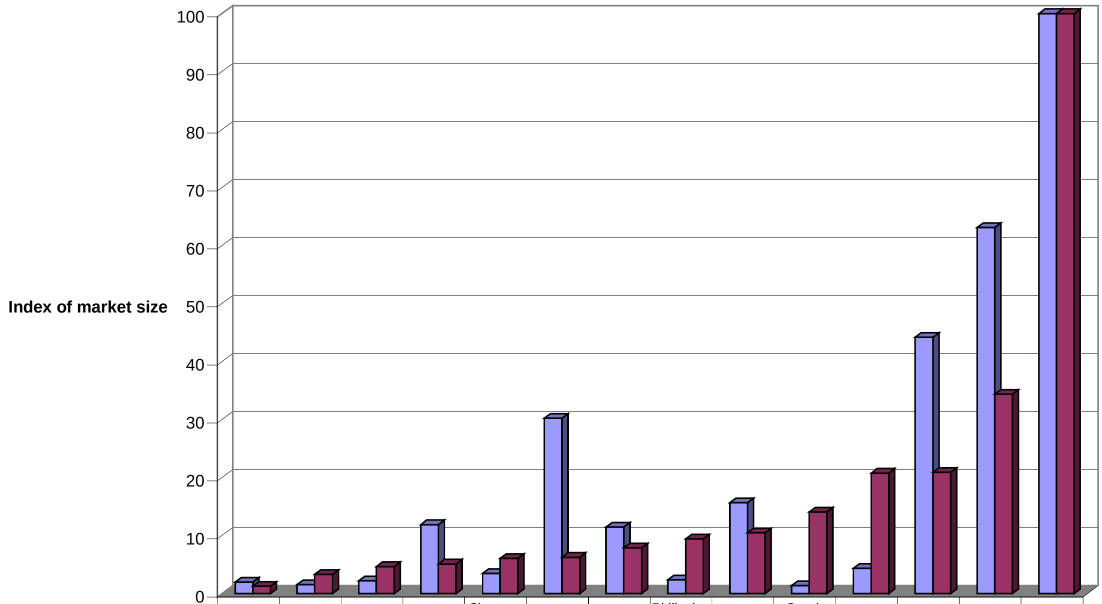
[31] The DoT receives and evaluates bids from domestic firms (including affiliates of MNCs) and awards rate contracts based on price and performance.

[32] TEC through its core group is responsible for drawing up the Standards' and Generic Requirements (GR's) for networks, systems, equipment and products to be used in the Indian telecommunications network. The Centre through its regional offices is also responsible for co-ordinating and evaluating these products, equipment and systems. TEC also provides advice to the DoT in respect of products and networks used by DoT. Switching division of TEC is responsible for all activities related to the switching products either working in the DoT’s network or inter working with the DoT’s network. This includes preparation of specifications of state-of-the-art digital switching systems, validation of switching systems to be inducted in the DoT’s network, interface testing of PABX and switches for GSM and basic service, testing of hardware and software upgradation of various switching systems, providing software maintenance support and field support to switching systems working in the DoT’s network.

this will be less effective, especially when the private sector providers, who are in the initial years of establishment, would also tale into account deferred credit facilities which only the MNC vendors can offer.

(ii) Expected growth in the size of the market for telecom equipments in the country: From the above discussion, it is clear that the market for telecommunications equipments is bound to increase significantly in the next 10 years or so and the market is considered to be very large not only by developing country standards but by developed country standards as well. This is based on an estimate of the market for various countries by the Office of telecommunications technologies, International trade administration of the US Department of Commerce. The size of the market given in value terms have been converted into an index against the size of the market for telecoms equipment and services revenue in Japan: Japan is chosen as the reference country as it had the largest size in both equipments and services segments in the sample of countries for which such data are available. See Figure 11. As discussed before the plan for raising India's tele density to 7 by 2005 and 15 by 2010 will require 75 million telephone connections by 2005 and 175 million by 2010. At current prices, this translates into additional investments of $36 billion by 2005 and $69 billion in the following five years[33]. The investment potential is not limited to basic telephony, but is spread across a wide range of services and technologies, including cellular, Internet, radio trunking, GMPCs and other value added services. But as seen earlier, the main area of growth is in cellular switching equipments and the capability for manufacturing these sort of equipments are largely only with private foreign manufacturers. This increase in the size and breadth of the market is likely to have important implications for the domestic equipment manufacturing industry.

[33] It must be mentioned that there are various estimates of these likely investments. The present ones are based on the estimates by the Office of telecommunications technologies of the US Department of Commerce (http://www.telecom.ita.doc.gov/).



	Indonesia	Hungary	Thailand	Argentina	Singapore	Brazil	Taiwan	Philippines	Mexico	Czech Republic	India	China	UK	Japan
Telecoms services index	2	2	2	12	3	30	11	2	16	1	4	44	63	100
Equipment market index	1	3	5	5	6	6	8	9	10	14	21	21	34	100

Figure 11: Relative size of India's market for telecom equipments and telecom services during 1998-2001
Source: Office of Telecommunications Technologies, http://www.telecom.ita.doc.gov/ (accessed on 25/11/02)

(iii) **Entry of MNCs in the telecoms industry**: This is yet another factor that has important implications for the equipment sector In terms of FDI approvals the telecoms sector has received one of the highest FDI inflows- 20 per cent of all FDI approvals during the period 1991 through 2002[34]. The actual inflow of investments over the period 1993-2001 is plotted in Figure 12. It shows essentially two peaks- the first one in 1998 and then in 2001. It is interesting to note that the highest actual inflow of FDI into the sector was in 2001- a year after the crisis in the world telecoms industry. Another interesting feature is the fact that India has actually received more foreign private investment than domestic private investment in the telecommunications sector: the ratio of proposed foreign private investment to domestic private investment works out to 2.26 (during the period 1994-2000). Analysis of the industry-wise distribution within the telecoms sector (Table 14) shows that carrier industry and within that the cellular mobile segments have received the maximum share: all the so called holding companies too are in the mobile telephone carrier industry. Nevertheless the entry of MNCs either in the equipment or the carrier industry will have serious implications for the demand for domestically designed and manufactured equipments.

[34] Maximum FDI approvals were however in fuels (power and oil refining). See DoT, http://www.investindiatelecom.com/Investment%20Policy/FDI%20Approved.htm (accessed on 24/11/02).

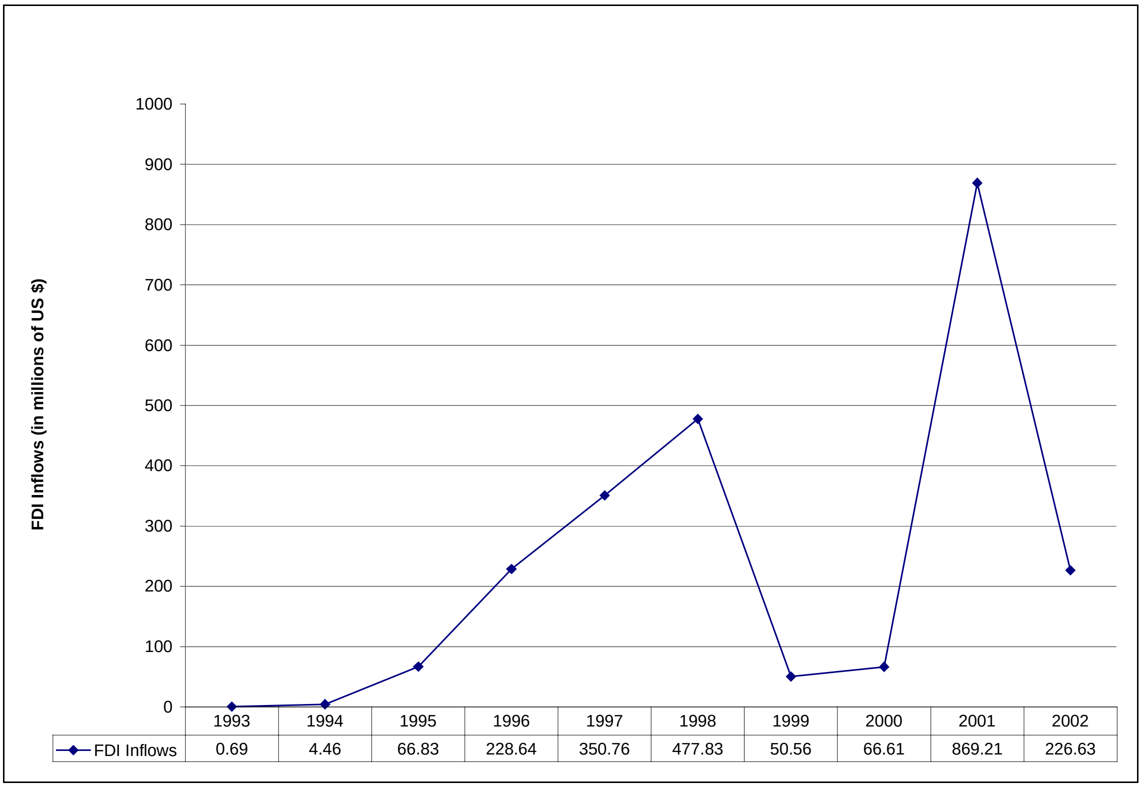


Figure 12: Actual inflow of FDI in the Indian telecommunications sector, 1993-2002
Source: DoT (http://www.investindiatelecom.com/Investment%20Policy/FDI%20Approved.htm (accessed on 24/11/02).

Table 17: Industry-wise distribution of actual inflows of FDI in Indian Telecoms Sector (Cumulative for August 1991 through December 2002)

Industry	Percentage shares
Basic telephone service	4.12
Cellular mobile telephone service	24.41
Holding companies	50.34
Radio paging	0.91
E-mail	0.72
VSAT	0.29
Cable TV Network + Internet	1.68
Satellite telephone service	0.50
Radio trunking	0.07
Other value added services	0.10
Manufacturing and consultancy	16.51
Automatic route	0.31
Total	100

Source: Department of telecommunications, (http://www.investindiatelecom.com/Investment%20Policy/FDI%20Approved.htm (accessed on 24/11/02).

As seen earlier in Table 6, the telecom switching equipment industry was thrown open to FDI in 1991. The present policy on FDI in the sector is summarised in Box 5.

Box 5: Present FDI policy of Government of India in the Telecommunications Industry

1. In basic, Cellular Mobile, paging and Value Added service, and Global Mobile Personal Communications by Satellite, FDI is limited to 49% (under automatic route) subject to grant of license from DoT and adherence by the companies (who are investing and the companies in which investment is being made) to the license conditions for foreign equity cap and lock in period for transfer and addition of equity and other license provision.

2. Foreign direct investment upto 74% permitted, subject to licensing and security requirements for the following:-

(i) Internet Service (with gateways)
(ii) Infrastructure Providers (category-II)
(iii) Radio Paging Service

3. FDI upto 100% permitted in respect of the following telecom services: -

(i) ISPs not providing gateways (both for satellite and submarine cables);
(ii) Infrastructure Providers providing dark fibre (IP Category I);
(iii) Electronic Mail; and
(iv) Voice Mail

The above would be subject to the following conditions: -

(i) FDI up to 100% is allowed subject to the conditions that such companies would divest 26% of their equity in favour of Indian public in 5 years, if these companies are listed in other parts of the world.
(ii) The above services would be subject to licensing and security requirements, wherever required.
(iii) Proposals for FDI beyond 49% shall be considered by FIPB on case to case basis.

4. In manufacturing sector 100% FDI is permitted under automatic route.

5. Foreign Direct Investment up to 49% is also permitted in an investment company, set up for making investment in the telecom companies licensed to operate telecom services. Investment by these investment companies in a telecom service company is treated as part of domestic equity and is not set of against the foreign equity cap.

Source: DoT

Consequent to this, there are now five of the leading MNCs having manufacturing facilities in the country[35]. Most of these firms have actually commenced manufacturing operations only in the last two years or so. Alcatel, the French major in telecommunication equipment, maintains a joint venture with Government-owned ITI, manufacturing large capacity switches. Alcatel also has a second collaboration in India - in collaboration with the Modi group. The U.S. major Lucent technologies assembles switches in its Bangalore manufacturing facility. Its modern state-of-the art ISO 14001 certified plant employs just 310 employees. The plant is responsible for the manufacture and sale of 5ESS Central Office Digital Switching products. Ericsson is active in almost every area of Indian telecommunication- switching, wireless, business communication, and trunking. It has a good presence in India through its large and medium switches which are used by DoT. Ericsson in collaboration with Ericsson India Limited (an existing Ericsson collaboration which manufactures electronics connectors) has established a manufacturing facility in Jaipur in 1994. The factory assembles AXE Digital Switching System such as Local Exchange for the use in the Indian network, as well as for export to international markets. Siemens manufactures large capacity switches and supplies to both DOT, and MTNL. Fujitsu of Japan in association with Punjab Electronics Limited has a facility in Punjab to manufacture large digital switches. Some of these companies and specifically both Lucent and Ericsson have R&D facilities in the country. One of the reasons as to why the MNCs have entered the Indian market with manufacturing and research facilities have got to do with the public procurement policy of the hitherto main consumer, namely the Department of Telecommunication or since October 2000, the Bharat Sanchar Nigam Ltd..

[35] The information for this section is largely based on the data contained Swaminathan (1998).

IV. CONCLUSIONS

The study was primarily concerned with measuring the innovation capability of the domestic telecommunications equipment sector and to provide an explanation of for its determinants. The study was conducted against the backdrop of the world telecommunications equipment industry becoming not only more concentrated but also increasing its innovative activity by a significant fashion. Another feature has been the deregulation of not only the equipment market but also the telecommunications carrier industry to private sector participation. India has a sizeable and growing market for telecommunications equipments. The country has assiduously built up considerable capability in the design, manufacture and sale of digital switching equipments. The domestically designed switches have managed to corner considerable market share in the domestic network. A major explanation for this needs to be found in the public technology procurement policy of the government. However it was also seen that the procurement policy while helping the sustenance of this capability has at times worked against it too. The DoT's exaggerated purchases during the mid-1990s is a case in point. The future growth of the telecoms equipment market is likely to be in mobile switches and the domestic research sectors does not appear to have any capability in this specific area. This lack of capability building can be attributed to lack of proper technology forecasting. In fact the absence of a credible innovation policy for the equipment sector is thus clearly brought out. In addition capability has also been built up in certain WLL access technology and also in telecoms software. But the ability of the research organisations to sustain this capability especially in the switching equipment area will crucially depend on the procurement policy of the state. Thus it is interesting to note that unlike in the case of Brazil (Szapiro, 2000), deregulation and the entry of MNCs is yet to have a perceptible deleterious effect on the domestic innovation capability in the Indian context[36]. However, whether it will continue to be so, especially when public technology procurement will become less effective, is a moot point.

[36] In the larger project we intend comparing the efforts of the three research organisations in the developing world, namely the C-DOT in India, the CPqD in Brazil and the Electronics and Telecommunications Research Institute (ETRI) in Korea towards creating domestic innovation capabilities in the telecommunications equipment industry in each of three countries.

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