Working Paper
373

THE DRAGON VS. THE ELEPHANT COMPARATIVE ANALYSIS OF INNOVATION CAPABILITY IN THE TELECOMMUNICATIONS EQUIPMENT INDUSTRY IN CHINA AND INDIA

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I acknowledge, with the thanks, the support that I received from the United Nations University-Institute for New Technology towards preparing this paper. I am grateful to Robert Shaw and Shulin Gu for facilitating my field research in China. Kristine Clara and Narayan Ramachandran made available to me a number of useful and otherwise inaccessible publications on the telecommunications industry. Comments received during an open seminar at the Centre on June 3 and in particular to P. Mohanan Pillai and from an anonymous referee to an earlier draft were very useful. Thanks are also due to Ms Xue Han for her research assistance. The usual disclaimer holds good.

ABSTRACT

China and India have one of the largest telecommunications equipment markets in the world. The paper employs a sectoral system of innovation framework towards understanding the differential outcomes in innovation capability building in the industry achieved by China and India. The countries have pursued widely diverging strategies for developing their domestic innovation capability. India followed a very rigid policy of indigenous development of domestic technologies by establishing a stand-alone public laboratory that developed state-of-the-art switching technologies. These were then transferred to manufacturing enterprises in both public and private sectors. The enterprises themselves did not have any in-house R&D capability. The public laboratory was also not given any strategic direction, even though it was technologically speaking, very competent. Consequently the country, despite possessing good quality human resource was unable to keep pace with changes in the technology frontier and the equipment industry has now become essentially dominated by affiliates of MNCs. China, on the contrary, first depended on MNCs for her technology needs in this area. But subsequently encouraged the emergence of three national champions, two of which are erstwhile public laboratories. The country has built up considerable hardware capability in both fixed line and mobile communications technology and has also emerged as a major player in world markets. Although the sectoral system of innovation in both the countries were promoted and nurtured by the state through a variety of instruments, the quality of such interventionist strategy is found to be better in China. The final outcome proves this line of argument.

Key Words: Innovation capability, China, India, Telecommunications industry, Digital switching systems, Mobile telephony

JEL Classification: L630, O310, 0320, 0380

Introduction

The telecommunications industries in both China and India have much in common. The growth rates in the number of telecommunication lines (both fixed and mobile) have been growing quite significantly, teledensities have been steadily improving and the ratio of mobile to fixed communications has crossed unity in both the countries. The distribution of telecommunication services in both the countries have been reformed restructured and in some cases privatised. In addition to the distribution of telecommunications services, both the countries have a sizeable telecommunications equipment manufacturing industry. But there are important differences in the sectoral system of innovation for the telecom equipment industry. India has followed a policy of establishing a stand alone public laboratory, which was charged with the responsibility of developing a family of digital switching equipments and then transferring this generated technology to domestic public and private sector telecom equipment manufacturers. China has followed a different strategy. Although it had a public laboratory, much of the telecom technologies are actually developed by domestic private and public enterprises which had managed to build up tremendous innovation capability and have also acquired substantial capability to keep pace with changes in the world frontier for these technologies. The country has also used technology acquisition through the route of foreign-owned joint ventures rather successfully: it has managed, through public policies, to effect positive technology spillovers to local enterprises from the operation of these MNCs. Consequently although a much late-starter, Chinese telecom equipment manufacturing industry has become a forced to be reckoned with. It has managed to take advantage of the challenges posed by globalization, while the Indian industry, although much older has been less agile in terms of taking advantage of these challenges. The telecommunications industry is a good example of the fact while having cheap factor endowments is necessary for a country to establish its presence in the international market; ability to move up the innovation ladder is a sufficient condition for that to occur.

The paper is organised into five sections. The first section outlines the theoretical framework used in the study. The study employs a sectoral system of innovation**,** which specifies the boundaries of this system. The second section compares the present status of the telecommunications industry on both the countries by focusing more on the distribution of telecommunications services industry, as it is the main consumer of the equipments that are manufactured within the country. The segment, in both the countries, has been charecterised by a series of path breaking changes: deregulation and privatisation being the most important of these. The phenomenal growth of mobile communications is another important component of this change. The third section maps out the institutions and organizations that constitute the elements of the sectoral system of innovation in both the countries. The fourth section traces the efforts towards keeping pace with changes in the technology frontier adopted by the innovations systems of these countries. The important differences in both the Chinese and Indian strategies are brought out. An important difference is that China has placed the firm at the centre of its innovation system. State support for R&D and other technology generating activities were primarily targeted towards the firm. This made Chinese firms extremely research intensive. Cases of two of the leading Chinese telecom manufacturers, namely Huawei and ZTE, will be discussed. An interesting feature is that these Chinese telecom companies have considerable technology transactions with India: Huawei has set up an important R&D outfit in the Indian city of Bangalore to tap into the country's vast pool of telecom software engineers while ZTE has licensed its wireline technology to the leading Indian state-owned manufacturing firm, ITI. India's net imports of telecommunications equipments from China have been growing since the early part of the 1990s. India, on the contrary, placed a public laboratory at the nerve centre of its sectoral system of innovation. Although the laboratory was very competent technologically speaking, it lacked strategic direction. Not much emphasis was placed on in-house R&D centres within its telecom manufacturing enterprises. So the innovation system was unable to keep pace with changes in the technology frontier. In short with a much shorter research and manufacturing history, China has managed to build up a world-class telecommunications equipment industry. Despite possessing very many required ingredients India's innovation system has failed to take off. The fifth and final section distills out the policy implications that arise from this study.

I. Conceptual Framework

The paper adopts a sectoral system of innovation perspective introduced by Malerba (2004). An earlier version of this framework was applied to the specific case of mobile telecommunications by Edquist (2003). The framework involves mapping out the boundaries of the innovation system in terms of the specific agencies of the government dealing with telecommunications development, the policy framework, the equipment suppliers, the service providers and the regulatory agency and tracking the knowledge flows between these various actors within the system. According to Malerba (2004), every sectoral system of innovation has at least three blocks: (i) knowledge, technological domain, and boundaries; (ii) actors, relationships and networks; and (iii) institutions. These three blocks may be elaborated as follows. First, knowledge plays a central role in innovation. It has to be absorbed by firms through their differential abilities accumulated over time.

Knowledge differs across sectors in terms of domains. One knowledge domain refers to the specific scientific and technological fields at the base of innovative activities in a sector. The boundaries of sectoral systems are affected by knowledge base and technologies. Second, sectoral systems are composed of heterogeneous actors. Firms are the key actors in the generation, adoption, and use of new technologies. Actors also include users and suppliers who have different types of relationships with the innovating, producing or selling firms. Other types of agents in a sectoral system are non-firm organizations, government agencies, local authorities, and so on. In various ways, they support innovation, technological diffusion, and production by firms, but again their role greatly differs among sectoral systems. Third, in all sectoral systems, institutions play a major role in affecting the rate of technological change, the organization of innovative activity and performance. Innovation greatly differs across sectors in terms of sources, actors, features, boundaries and organization.

II. Telecommunications Industry in China and India

China and India are normally considered to be the emerging technological giants from the developing world. Both the countries spent about one percent of their GDP on R&D and have a growing number of patents issued in the US to their local inventors. China has a perceived technological strength in the production of telecommunication equipments, mechanical engineering products and in the new and emerging areas of computer graphics and handwriting recognition, while India is an acknowledged powerhouse in embedded software, business software in general, chip designs and in pharmaceuticals. See Table 1 for a comparative picture of China and India in terms of their relative strengths.

The countries, because of their sheer size, have one of the largest telecommunications networks in the world. On five different standard indicators China compares better than India on all excepting bandwidth prices (Table 2).

Table 1: Relative Technological Strengths: China vs. India

Indicator	China		India	
Strengths	• Telecommunications • Mechanical engineering • Computer graphics • Handwriting recognition		• Embedded software • Drugs • Business software • Chip design	
	1993	**2003**	**1993**	**2003**
U.S Patents	60	366	30	354
R&D spending	1.2 per cent of GDP		1 per cent of GDP	
Science and Engineering graduates	337 thousand		316 thousand	

Source: Engardio (2004), p. 67.

Table 2: Broad Features of the Telecommunications Sector in China and India (c2003)

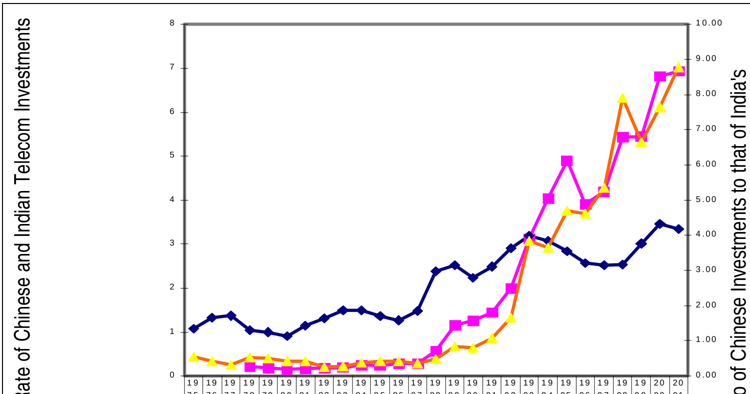
	China	India
1. Density of fixed telephones per 100 population	18.0	3.9
2. Density of mobile telephone per 100 population	18.3	2.6
3. Density of Internet users per 100 population	2.5	0.4
4. Density of broadband connections per 100 population	1.4	0.019
5. Charges for 20 hours of internet use per month (US $)	10.00	9.00

Source: National Bureau of Statistics of China (2004), Department of Telecommunications (2002-03), International Telecommunication Union (2003).

In the following I compare the telecommunications sector in both the countries according to: (i) investments in the telecom sector (ii) relative size of the telecommunications services market; (iii) privatisation and structure of the services market; (iv) size of the telecoms equipment sector; (v) the extent and direction of digital divide and; (vi) overall telecom development as judged through the scores obtained in the digital access index.

(i) Investments in the Telecom Sector

Two indicators are used here: (i) the rate of telecom investments in the two countries measured in terms of telecom investments as a percentage share of gross fixed capital formation (denoted as China RT and India RT respectively); and (ii) ratio of Chinese annual investments in telecommunications to that of India's. Figure 1 tracks these two indicators over a long period of time. Both the countries did not invest much in telecommunications sector until the 1990s. In fact both in the absolute and relative sense India invested much more than China during this earlier period. The situation changed dramatically since 1991. China's investment in the sector increased significantly during this latter period: ratio of Chinese investments in telecom to that of India's averaged around 0.46 during the early period, but increased to an average of 5.08 during the latter period. Similar is the case of the rate of investments (China RT and India RT). This was part of that country's strategy of improving her infrastructure primarily to attract foreign investments (Harwit, 1998). In fact some commentators have referred to an investment boom in the telecommunications sector as the Chinese authorities began to realise that telecommunications is an important contributor to national economic growth and, as economic activity increased, it was necessary to provide services to people of all walks of life and not just to the military and the elites as was the case before (Wu, 2004). In India too there was a similar realization that good telecommunications services was a necessary pre condition for the country's march towards supremacy in ceratin areas of high technology.



	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
China RT				0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.5	1.1	1.2	1.4	2.0	3.1	4.0	4.9	3.9	4.2	5.4	5.4	6.8	6.9
India RT	1.0	1.3	1.3	1.0	1.0	0.9	1.1	1.3	1.4	1.4	1.3	1.2	1.4	2.3	2.5	2.2	2.4	2.9	3.1	3.0	2.8	2.5	2.5	2.5	3.0	3.4	3.3
Ratio of China to India	0.5	0.4	0.3	0.5	0.5	0.4	0.4	0.2	0.2	0.3	0.4	0.4	0.3	0.4	0.8	0.7	1.0	1.6	3.8	3.6	4.7	4.6	5.3	7.9	6.6	7.6	8.7

Figure 1: Chinese and Indian Investments in Telecommunications, 1975- 2001

Source: International Telecommunication Union (2003)

(ii) Relative Size of the Telecommunications Services Market

The number of telecom connections (both fixed and mobile) has been growing in both the countries (Table 3). In both the countries, keeping with the international trend, the ratio of mobile to fixed telephones has crossed unity. But the sheer size of China's telecommunications services segment, over 500 million as against India's 100 million is something to write home about.

Table 3: Growth of Telecommunications Services Sector in China and India, 1990-2004

	India (number of subscribers in millions)			China (number of subscribers in millions		
	Fixed	Mobile	Ratio of mobile to fixed	Fixed	Mobile	Ratio of mobile to fixed
1990	2.15					
1991	5.07			8.45	.005	.01
1992	5.81			11.47	0.18	.02
1993	6.8			17.33	0.64	.04
1994	8.03			27.30	1.57	.06
1995	9.8			40.71	3.63	.09
1996	11.98			54.95	6.85	0.12
1997	14.54	0.34	0.02	70.31	13.23	0.19
1998	17.8	0.88	0.05	87.42	23.86	0.27
1999	21.59	1.20	0.06	108.72	43.30	0.40
2000	26.51	1.88	0.07	144.83	84.53	0.58
2001	32.44	3.58	0.11	180.37	145.22	0.81
2002	41.48	13.00	0.31	214.22	206.01	0.96
2003	42.58	33.58	0.79	262.75	269.95	1.03
2004	45.00	50.00	1.11			

Source : Economic Research Unit (2002), Telecom Regulatory Authority of India (2005), National Bureau of Statistics of China (2004).

However in terms of revenue in value, the Chinese market for telecom services is not only significantly higher (7 times the India market in 2003) but is also rising much faster than that of India's (Table 4).

Table 4: Growth of Telecoms Revenues in China and India, 1997-2003
(Value in billions of US $)

	China	India	Ratio of China to India
1998	25.3	6.3	4.02
1999	29.3	6.5	4.51
2000	38.5	7.1	5.42
2001	44.9	7.6	5.91
2002	51	8.2	6.22
2003	62	8.8	7.05

Source: World Markets Research Centre (2005)

This means that in both countries possess a large domestic market for telecommunications equipments and this market is growing very fast too.

(iii) Privatisation and Structure of the Services Market:

The distribution of both the fixed and mobile services in both the countries are deregulated and opened to private competition although the state-owned incumbents in both the countries (China Telecom and BSNL) have not been privatised as such. A direct comparison is difficult. Also the state of competition is different in fixed and mobile communications. In India the market is divided into different operating circles (which roughly correspond to a state within the country's federal establishment) and in each circle there is the state incumbent and a select number of private service providers. The extent of competition between the state incumbent and the private providers is very intense in the case of mobile communication services while it is much less in the case of fixed line services. On the contrary in China, both in the case of fixed and mobile services the competition is very partial and between state-owned carriers, although some dilution of the state equity has taken place. Finally India has a relatively more independent regulator in the form of Telecom Regulatory Authority of India (TRAI)[1] . Since China's accession to the WTO in December 2001, the country has tightened up its telecom regulatory framework although the Ministry of Information Industry (MII) continues to be the regulator as well and is there is no independent regulatory agency (Pangestu and Mrongowius, 2004). The main implications of these changes are slightly different for fixed line and mobile services and that too for China and India. In China, the equipment vendors will have to deal with dominant buyers in both fixed and mobile services while India the vendors will have to deal with one dominant buyer in the case of fixed telephony equipment while they have to deal with a large number of mobile service providers for mobile communications equipments.

(iv) Size of Telecom Equipment Sector: It is difficult to find data on the value of telecom equipment production in China. The National Bureau of Statistics of China (2004) report production of certain telecom equipments in physical terms[2] and that too the data are available for just one or two years. India, on the contrary, report the total value of all telecom equipments produced in value terms especially over the 1990s[3]. The only comparable data for the two countries that are easily available is the data on exports and imports of telecom equipments[4]. Although not a perfect measure, the ratio of Chinese exports and imports to that of

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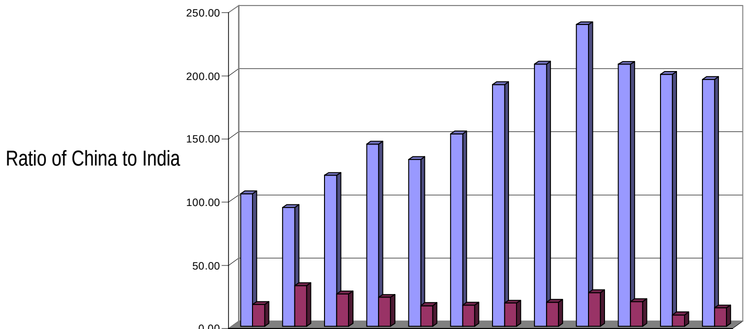
1 In an absolute sense, TRAI has not been that effective. See Mani (2002).

2 The equipments are telephone sets, fax machines, carrier wave communication equipment, mobile phones, mobile communication equipment for base stations.

3 This is available in Department of Telecommunications (2002-03), p. 7. The source reports the data on domestic output during the period 1993-94 through 2001-02.

4 This is available from the UN Comtrade Statistics. I have used the Standards International Trade Classification (SITC) Revision 3 classification system.

India provides us with a quantitative picture of the relative size of the market for telecom equipment in both the countries. See Figure 2.



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Ratio Chinese Exports to Indian Exports	105.07	94.04	119.59	144.16	132.10	152.30	191.40	207.50	238.89	207.41	199.53	195.34
Ratio of Chinese Imports to Indian	17.29	32.26	25.62	22.97	16.37	16.84	18.43	19.11	26.69	19.50	9.06	14.67

Figure 2: Relative Size of the Market for Telecom Equipments, 1992-2003

Source: Computed from UN Comtrade

This shows an interesting picture. While the quantum of Chinese exports is significantly higher than that of India's, the same is not the case on the imports front. The Chinese domestic market is thus considerably higher than that of India's and the country, relatively speaking, is more self sufficient in the production of telecom equipments. This point will be examined in some more detail in one of the following sections dealing with innovation capability.

(v) Extent and Direction of Digital Divide: This is defined in terms of the broad rural- urban divide in the access to telecoms. Although the number of telecom subscribers has increased in both the countries and the divide has tended to come down, India has a much higher digital divide (Table 5). Even though the divide in China increased significantly since 1978, it has also been drastically brought down since 1994. This shows that China has a more successful universal service obligation strategy in place. India has issued guidelines for implementing the Universal Service Obligation, although the Universal Service Fund is yet to be made functional[5] .

Table 5: Extent of Digital Divide in China and India, 1978-2003

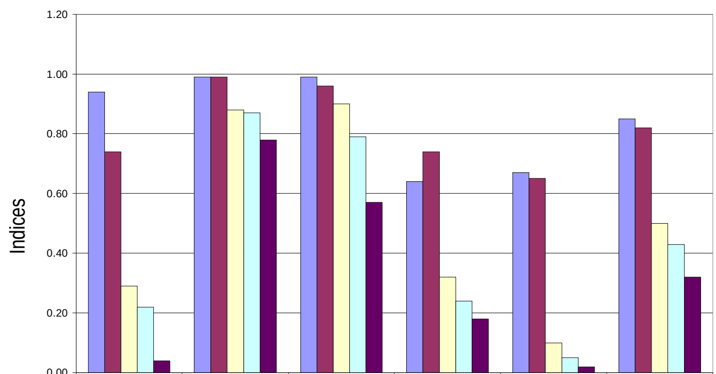
	China	**India**
1978	1.62	
1980	1.68	
1985	2.35	
1990	3.67	
1991	3.85	
1992	4.07	
1993	4.32	
1994	4.65	
1996	3.52	13.33
1997	2.94	16.00
1998	2.52	14.50
1999	2.19	13.80
2000	1.80	11.71
2002	1.73	10.17
2003	1.67	9.53

Source: Economic Research Unit (2002), Telecom Regulatory Authority of India (2005), Department of Telecommunications (2002-03), National Bureau of Statistics of China (2004).

(vi) Overall Telecom Development: I measure this in terms of the Digital Access Index (DAI) introduced for the first time by the International Telecommunications Union (2003). The DAI is an inclusive index that measures the overall ability of individuals in a country to

5 See Department of Telecommunications (2002-03), p. VI

access and use telecommunications and ICT's in general. It is composed five parts: infrastructure, affordability, knowledge, quality and usage[6]. A single index value is computed for each of the five DAI categories and the values range from 0 to 1: the closer it is to 1 the better it is. The values obtained by China and India in each of the five categories are presented in Figure 3. Of the 178 countries for which the DAI is computed China ranks 84th while India is at 119. However with the increase in teledensity (which enters the calculation of the infrastructure variable) and improvements in both quality and affordability, both India and China



	Infrastructure	Affordability	Knowledge	Quality	Usage	DAI
Sweden	0.94	0.99	0.99	0.64	0.67	0.85
Korea	0.74	0.99	0.96	0.74	0.65	0.82
Brazil	0.29	0.88	0.90	0.32	0.10	0.50
China	0.22	0.87	0.79	0.24	0.05	0.43
India	0.04	0.78	0.57	0.18	0.02	0.32

Figure 3: Digital Access Index: China and India, 2002

Source: International Telecommunications Union (2003)

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6 The indicators used to construct the DAI are: infrastructure (measured in terms of density of fixed and mobile cellular subscribers), affordability (measured in terms of internet access as percentage of Gross National Income per capita), knowledge (adult literacy and combined primary, secondary and tertiary school enrolment levels), quality (international internet bandwidth per capita and broadband subscribers per 100 inhabitants) and usage (internet users per 100 inhabitants). Source: International Telecommunications Union (2003).

are expected to better their respective scores although India is still expected to lag behind China in terms of overall telecommunications development.

I. Sectoral System of Innovation

In this, I map out the sectoral system of innovation of the telecoms sector in both the countries in terms of four components: management and policy support, structure of the telecom services segment, structure of manufacturing segment, and organization of the research segment. The section ends with some discussion of the relative quality of the innovation system although its performance in terms of a specified set of indicators is mapped out in the next section. The sectoral systems of China and India are mapped out in Figures 4 and 5 respectively.

A comparison of the two sectoral systems yield the following results:

China:

- Relatively speaking the country's innovation system is much stronger and appears to be more closely knit. This is because some of the state laboratories have been converted into production enterprises. In other words, the distinction between research and production segments is increasingly hazy. This implies that telecom equipment manufacturing companies have a strong research base while the laboratories have acquired both manufacturing and marketing capabilities;

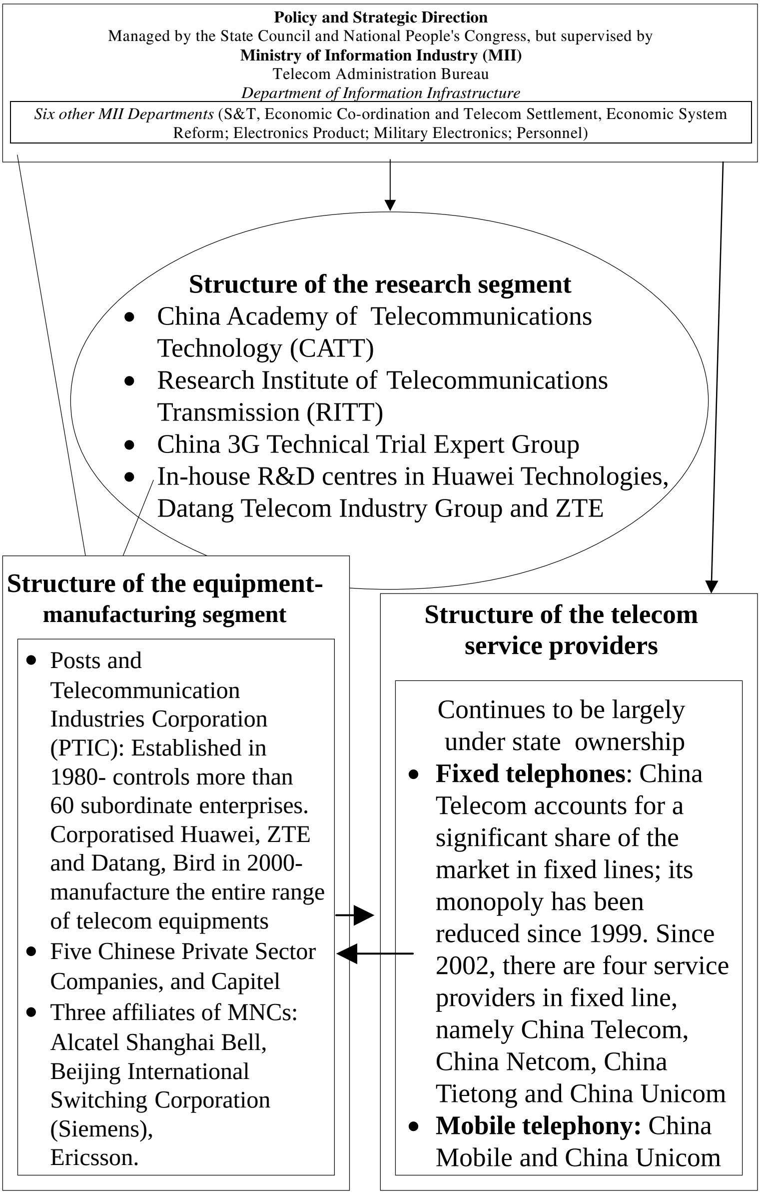

Figure 4: Sectoral System of Innovation of the Chinese Telecommunications Equipment Industry (c2003)

Source: Own compilation

Policy and Strategic Direction

- **Managed** by the *Department of Telecommunications (DOT)* within the Ministry of Communication and Information Technology. **Governed** by the National Telecoms Policy of 1999- wants to make India a major manufacturing base for telecom equipments. Telecom Commission and the DOT are responsible for policy formulation, licensing, wireless spectrum management, administrative monitoring of public sector enterprises.
- **Regulated** by the Telecommunications Regulatory Authority of India (TRAI)
- **Disputes settlement:** Telecom Dispute Settlement and Apellate Tribunal (TDSAT) is to adjudicate any dispute between licensor and a licensee, between two or more service providers, between a provider and a group of consumers, and to hear and dispose of appeals against any decision or orders of TRAI.

Structure of the research segment

- Centre for Development of Telematics (C-DOT)
- Telecommunication Engineering Centre (TEC)
- Indian Institute of Technology-Madras
- In-house R&D Centres of ITI and Hindustan Cables
- Contract Research Organisations, who does R&D outsourcing deals for MNCs like Wipro Technologies
- Telecom software manufacturing companies in the private sector

Structure of the equipment-manufacturing segment

- A total of nearly 150 large, small and medium domestic and foreign companies
- State-owned undertaking such as ITI. Hindustan Cables
- Private sector C-DOT technology licensees
- Affiliates of MNCs: Alcatel, Ericsson, Fujitsu, Huawei, Lucent, Motorola, NEC, Nokia, Nortel Networks, Qualcomm, Siemens, ZTE etc

Structure of the telecom service providers

Continues to be largely under state-ownership

- **Fixed telephones**: 91 per cent of the fixed lines are still under the public sector entities, BSNL and MTNL. but the share of private sector has been increasing,
- **Mobile telephony**: is largely in the private sector, but the share of the public sector enterprise has been increasing and is now about 21 per cent.

Figure 5: Sectoral System of Innovation of the Indian Telecommunications Equipment Industry (c2003)

Source: Own compilation

- As a corollary of the above, the manufacturing enterprises are highly research- intensive and two of them have emerged as leading MNCs in their own right competing very successfully with Western established telecom giants in both developing and developed country markets as well (See Annexure 1 for a profile of these enterprises). This strong rivalry between the domestic manufacturers, on one hand, and with western MNCs on the other hand has made the domestic manufacturers to strengthen their innovation capability and also to keep pace with changes in the technology frontier.

- During the period up to 2001, China depended more on affiliates of MNCs. See Figure 6. The two European manufacturers, Alcatel and Siemens have been successful largely because they have managed to transform their local switching manufacturing operations into de facto Chinese companies. Siemens has removed the German parent's name from the company literature of its local subsidiary BISC, and although Alcatel has reclaimed its prestigious Shanghai Bell operations through a recent share buyout, it still enjoys local status (Pyramid Research, 2002). But slowly over time China has managed to create three world class domestic manufacturers (namely Huawei, ZTE and Datang);

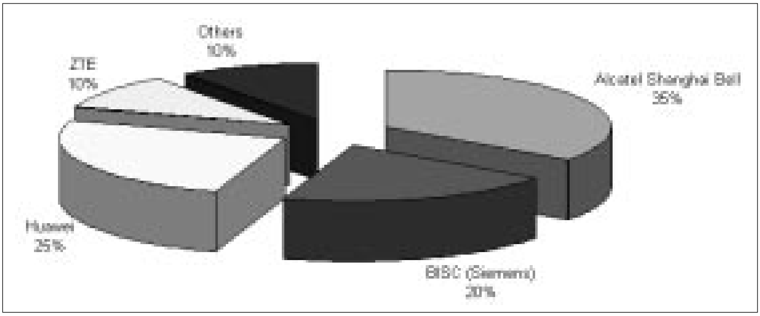

Figure 6: Switching Equipment Market Share by Suppliers, Cumulative till 2001

Source: Pyramid Research (2002), p. 126l

- The state has provided strong and effective strategic direction to the manufacturers and the research segments. In 1986, State High-Tech Research and Development Plan, sometimes referred to as the 863 Plan, the first intermediate- and long-term plan combining military and civilian production in China was announced. Telecommunications were brought into the ambit of this plan in 1992. Under the plan, about US $ 200 billion was to be spent on information and communications technologies, of which US $ 150 billion was earmarked for telecommunications. This strong support from the state has enabled Chinese manufacturers to embark on a number off state-of-the-art R&D projects including the prestigious third generation mobile technology (3G) project in mobile telephony. The innovation system has thus acquired capabilities not only in the more recent developments in packet switching as far as fixed telephony is concerned, but also in the more recent vintages in mobile telephony technology as well.

India

- On the whole, India's sectoral system of innovation is very weak and fragmented. While the research segment, especially the dedicated public laboratory C-DOT, is very strong in terms of its capability to do successful R&D projects, there have been several attempts in the past to weaken its functioning (Mani 1995 and 2006, forthcoming). Compared to the Chinese, the strategic direction from the state has been virtually absent[7]. Given the fact that the country was demonstrating a growing capability in computer software efforts should have been made to have a strong

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7 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 of the report on telecommunications one finds that the study did not anticipate at all the phenomenal growth of mobile telecommunications in the country.

presence in telecoms software. This was, of course, accomplished subsequently in some measure by the private sector enterprises but with little or no state support;

- The most distinguishing aspect of India's sectoral system for innovation is the central role that it assigned to the public laboratory, C-DOT. While the lab was successful in not just generating technologies that were quite suited to Indian conditions, it was able to effectively transfer the generated technology to a host of public and private sector enterprises. At the very same time it assiduously built up a growing number of component suppliers. In short, the laboratory is credited with establishing a modern telecommunications equipment industry in the country (Mani, 2006 forthcoming);

- The drawback of this strategy was that the firms did not have their own in-house R&D centres and were dependent entirely on the technologies that they received from the public laboratory. The lab, as mentioned earlier, continued to focus on fixed telephony and that too on circuit switching technology, when packet switching was becoming the state-of-the-art. Further, it failed to take cognizance of the future in mobile communications (just like its counterpart in Brazil, the CPqD, but unlike its Korean counterpart, the ETRI [8]). The net result is that the licensing firms have become too complacent with respect to their own capability building. This is unlike the Chinese strategy where the firms have built up considerable innovation capability on their own through their in-house R&D centres and have in addition acquired considerable production and marketing capabilities and has within a short span pf about 10 years emerged as internationally competitive;

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8 Mani (2006, *forthcoming*) has the details.

- During the period up to and including the 1990s, domestic Indian companies dominated India's telecom equipment industry. For instance, despite having a public technology procurement policy, which did not favour domestic equipment manufacturers, the share of indigenously designed and manufactured equipments accounted for over 50 per cent of market (Mani, 2006 forthcoming). However the country just did not have a strategy in place to make its leading state-owned equipment manufacturer, ITI, a national champion in sharp contrast to the strategy pursued by the Chinese. This will be evident when one makes a comparison of two leading telecommunications equipment manufacturers from China and India (Annexure 2): despite being an early starter, on every single indicator, the leading Chinese firm outperforms the leading Indian firm;

- India has been a recipient of substantial FDI in telecommunications, although much of it is in the distribution of mobile communications services. Many MNCs including two of the leading Chinese telecom equipment manufacturers, Huawei and ZTE have established or are in the process of establishing manufacturing ventures in the country[9]. The Department of

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9 The Ministry of Communications and Information Technology (the parent ministry of DoT) has been actively promoting FDI in telecom equipment manufacturing. Very recently two Finnish companies (Nokia and Elcoteq) have established or announced establishing manufacturing facilities in the country for mobile phones. Further, two Chinese companies have announced their entry into telecom equipment manufacturing within the country. Huawei Technologies, which already has a software development center in Bangalore, is planning to set up a telecommunications manufacturing facility in India. According to a Reuters report from New Delhi quoting a Huawei executive, the telecom company plans to invest about a $100 million in the manufacturing facility. Operations are expected to begin by 2007, and production will focus on the Indian telecom market, the report said. See Reuters India, http://www.reuters.co.in/locales/c_newsArticle.jsp?type=businessNews&localeKey=en_IN&storyID=8132428 (accessed on April 26 2005). Another Chinese rival ZTE Corporation has built a factory in India to make telecom equipment for sale within the country and for export. Located in Haryana State, the facility can make CDMA system equipment of 3 million lines and other equipment for GSM, DSL, NGN, etc Earlier in

Telecommunications (DoT) has set a target of attracting about $ 800 million in foreign direct investments in telecom manufacturing by March 2006. Cumulatively over the period 1991 through 2004, the country has attracted FDI in telecommunications to the tune of US $ 7.14 billion and this works out to about 18 per cent of the total approved FDI the country has received as a whole. As a result of these high foreign investments, the complexion of India's telecom equipment industry is fast undergoing a change with foreign affiliates and imports accounting or going to account for a significant share of the domestic market for telecom equipments.

- In fact a recent study by the Department of Telecommunications (2004) found that currently (c2004) most of the domestic telecom equipment manufacturers and even the state-owned undertaking, ITI which till recently was the major equipment manufacturer, have merely become a "trader" by importing the equipment and supplying it to the service providers[10]. The deregulation of India's telecom equipment industry had an extremely destablising effect on the operations of ITI (Subramanian, 2004) and its very existence was now in danger[11].

2005, ZTE won a contract worth more than US$20 million from Atlas International Pvt Ltd, India's largest Internet Protocol Television (IPTV) operator, to build a broadband IPTV network. For a detailed write up on the entry of foreign telecom companies to India, see Puliyenthuruthel (2005).

10 The study even states that 'in order to take advantage of lower customs duty, a separate procedure of "high –sea sale" is being followed. Even reservation quotas of PSUs are being used for trading goods manufactured abroad and without any commitment of transfer of technology". See Department of Telecommunications (2004), p. 4.

11 Recently the Prime Minister Manmohan Singh has sanctioned Rs 10.32 billion for the revival ITI and IT has entered into a technical tie-up with Alcatel for manufacture of three million telephone lines. An announcement to this effect was made in the upper house of Indian parliament on March 24, 2005. See Economic Times, http://economictimes.indiatimes.com/articleshow/1061839.cms (accessed on April 28 2005).

- An important development in the country's sectoral system of innovation is the growth of R&D outsourcing deals between foreign MNCs and Indian contract research organizations in the area of telecom R&D. As this is a growing phenomenon, there are no precise estimates[12]. Even C-DOT, the nerve centre of the sector's innovation system, has recently entered into a contractual agreement with Alcatel to set up a global R&D centre for broadband wireless products[13].

If this is to extend, there will be considerable innovation capability remaining in the country but targeted more at the foreign markets.

IV. Innovation Capability

This is defined as the ability to conceptualise, design, manufacture and sell internationally competitive telecom equipments and also at the same time keep pace with changes in the technology frontier of these equipments. There is no one single indicator that can capture this dimension adequately. I employ four different types of indicators, namely,

(i) Traditional indicators: (a) R&D investments; and (b) Patents;
(ii) Competitiveness in exports;
(iii) Capability in hardware design;
(iv) Capability in telecoms software

However no effort is made to combine them into a single indicator.

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12 According to one of the leading consultancy organizations the R&D outsourcing market for IT in India is estimated to grow more than $8 billion by 2010 from $1.3 billion in 2003, at a CAGR of 30 per cent. There have been a number of high profile R&D outsourcing deals between Western MNCs and Indian enterprises, for instance the WIPRO-Ericsson deal, the Sasken-Nortel deal are two of three high profile deals in this area.

13 The project is to develop WiMAX (Worldwide Interoperability for Microwave Access) broadband technology. WiMax is a lot like WiFi, the short-range wireless technology that allows Web surfers to connect to the Internet at so-called hot spots. But unlike WiFi's 50-metre range, WiMax has a reach of one to 10 miles, offering a way to bring the Internet to entire communities without having to invest billions of dollars to install phone or cable networks.

(i) Traditional Indicators

(a) R&D Expenditure: Even though there is some underestimation[14] of both the Chinese and Indian data on R&D expenditure on telecommunications, the ratio of Chinese to Indian R&D investments are significantly higher than unity and increasing over time (Figure 7). The difference between the two countries is even more dramatic when we consider the R&D personnel (Table 6).

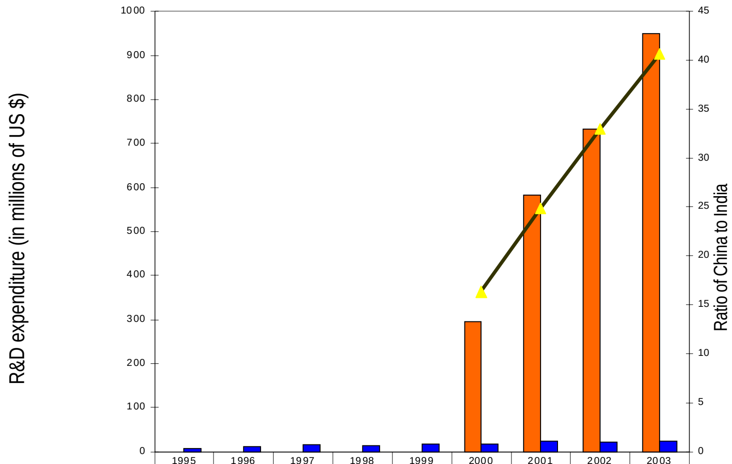
Table 6: Human Resource Devoted to Telecom R&D in China and India (Number of R&D scientists and engineers)

	Huawei	ZTE	Datang	Ning Bo Bird	Beijing Capital	Total China	C-DOT (India)
1999	5138	4794				9932	
2000	6061	6240				12301	
2001	7996	7020		400		15416	
2002	9662	9010		435	300	19407	1109
2003	10000	9900	1840	612	360	22712	1045

Note: In India, besides C-DOT there are a few scientists and engineers engaged in telecoms R&D within the in-house R&D centre of ITI. But many of these engineers left the rolls of ITI during the 1990s and are therefore not counted here.

Source: Mani (2006, forthcoming), Field survey notes

14 The Chinese data refers only to manufacturing enterprises and the amount of R&D expended by the state sector (especially those by the CITT and the RITT) is not available. In the Indian case, on the contrary, the data refers only to those expended by the public laboratory, C-DOT, is taken into consideration as the R&D expenditure by the enterprises are not available.



	1995	1996	1997	1998	1999	2000	2001	2002	2003
China						294.48	583.56	733.7	950.11
India	8.63	11.29	16.11	13.33	17.36	18.02	23.45	22.22	23.36
Ratio of China to India						16.34	24.89	33.02	40.67

Figure 7: Ratio of Chinese to Indian Investments in Telecom R&D, 2000-2003

Source: Mani (2006, forthcoming), Field survey notes

The most striking aspect of this is that in all the three Chinese equipment manufacturers, the number of R&D scientists and engineers work out to almost 50 per cent of the total manpower strength of these enterprises. In other words, the in house R&D departments of these companies are very strong. Given the proximity between production and research in these enterprises, their ability to service changing market needs has been much easier. Another interesting aspect of the country comparison is that fact that the Chinese R&D expenditure is not only higher, but kept on increasing during the period under consideration, while India's R&D investments in the sector have virtually remained stagnant. Thus based on this very traditional indicator, China's innovation capability has been increasing much faster compared to that of India's. I pursue this further by examining the patenting behaviour of both the countries.

(b) Patenting Behaviour: Detailed data on patents applied for and granted in telecommunications technologies are not readily available for either of the countries. Based on the fragmentary evidence that is available the following picture emerges. The leading Chinese manufacturer, Huawei has applied for 641 (cumulative till 2004) patents in the US and 4628 patents in China. C-DOT has started its patenting activities only very recently[15]. The US Patent and Trademark office has granted C-DoT a patent for Asynchronous Transfer Mode (ATM) switch fabric implementation, which enables higher speed data transmission through a new method of routing information packets. The lab was granted a further two patents within India during 2003-04. So based on this indicator, given the paucity of data, all that one can say is that both the Chinese and the Indians have started appreciating the need for and importance of patenting their innovations.

(ii) Competitiveness of Exports: Ability to continuously sell products designed and manufactured locally in markets abroad, where they have to face fierce competition from other manufacturers can be taken as a reasonably good indicator of a country's ability to innovate in a particular technology. A better measure than the absolute value of exports is some indicator of the competitiveness of these exports. There are a variety of indicators to measure export competitiveness, but Revealed Comparative Advantages (RCA)[16] -which is a quantity based ex post measure-is the one that is commonly used. I have computed RCA indices for both Chinese and Indian exports of telecommunications and this is presented in Table 7.

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15 In fact according to its latest Annual Report 2003-04, C-DOT has constituted an IPR cell within it and a series of workshops have been conducted to sensitise the scientists and engineers to the need for and importance of protecting their intellectual property rights on their process and product innovations.

16 This is computed by dividing China (or India's) share of telecom exports in the world by their share of total world exports.

Table 7: Competitiveness of Telecom Exports, 1992-2003
(Based on Revealed Comparative Advantage Indices)

	China	India
1992	1.06	0.04
1993	1.02	0.05
1994	1.20	0.05
1995	1.30	0.04
1996	1.50	0.05
1997	1.41	0.05
1998	1.54	0.04
1999	1.70	0.04
2000	1.64	0.04
2001	1.96	0.60
2002	2.26	0.07
2003	2.35	0.08

Source: Computed from UN Comtrade Statistics

China is a highly competitive in the international market, while India is not competitive at all. In fact China now accounts for about 15 per cent of the total world exports of telecom equipments. With a relatively speaking shorter manufacturing history, the country is now becoming an important force to be reckoned with in the technologically speaking complex market for telecom equipments. Although uncompetitive, India's RCA has been showing some growth over the last three years.

(iii) Capability in Hardware Design

Telecom system equipments may be roughly divided into three categories: switching, transmission and terminal equipments. During the initial period, both the countries relied on foreign sources of technology for all the three kinds of telecom hardware and especially for the former two. However slowly over time considerable innovation capability has been built up in hardware design and manufacture in both the countries, although the Chinese have been more successful in keeping up with changes in the world technology frontier. I first discuss the Chinese case and then the Indian one.

China

Within a very short period of time, China has built up considerable capability not only in circuit switching, but also in packet switching and indeed in mobile communications. According to a recent survey done by the market research firm, Heavy Reading[17] Huawei- the leading Chinese telecom equipment manufacturer-in the course of the twelve months since the last survey in 2003, had increased its ranking among global wireline-equipment providers from 18th to 8th. Not only that, Huawei ranked fourth in the world in terms of service and support. The report calls Huawei's ascendancy "astounding" and says it has already surpassed several incumbent vendors in perceived market leadership. See Box 1 for some additional supporting evidence for this statement:

17 2005 Wireline Telecom Equipment Market Perception Study by Heavy Reading did a detailed look at how manufacturers of telecommunications equipment are faring in their efforts to capture the attention (and thus the capital spending) of their service provider customers. For this study, *Heavy Reading* invited service provider employees from around the world to identify which vendors they perceive as the market leaders in 17 different wireline product categories. The survey drew responses from 160 carrier professionals representing more than 100 different network operators worldwide. See Economist (2005).

Box 1: Huawei- the Chinese Innovator and a force to be reckoned with

- The aggressive push into international markets by Huawei, China's leading telecoms-equipment manufacturer appears to be bearing fruit. In December 2004, Huawei won an estimated $100m contract to build a third-generation (3G) wireless network for Telfort, a Dutch operator that has always used gear from Ericsson, the world's largest telecoms-equipment firm. In January 2005, Huawei won a $187m order for another 3G network, in Thailand, beating Ericsson and Motorola with a bid 46% below the operator's original estimate.

- Initially, Huawei concentrated on developing countries, but it is now gaining traction in the developed world, in Europe in particular. Last week it was named a key supplier by COLT, a British operator, and also won a $100m broadband contract from Optus, an Australian firm. Huawei has yet to win the endorsement of a first-tier operator, but its gear is being evaluated by BT, and by Vodafone, the world's largest mobile operator. BT is expected to announce the suppliers for its new "21st Century Network" soon, and Huawei is on the short list.

- Mr Bill Owens, the Chief Executive Officer of Nortel, a Canadian equipment-manufacturer, says the Chinese vendors are "quality competitors". Nortel already outsources all its manufacturing, and has just formed a joint-venture with China Putian to develop 3G gear.

Source: Economist (2005)

An area of hardware design where the Chinese have excelled is the design of 3G Mobile technologies[18]. There are essentially three different types of 3G[19] technologies that are developed across the world: WCDMA, CDMA2000, and TD-SCDMA.

Although most countries that have licensed 3G mobile technologies have opted for the European WCDMA, the Chinese have taken the risk to develop their own 3G technology in the form of Time Division-Synchronous Code Division Multiple Access (TD-SCDMA). It is a competitor for the U.S. CDMA2000 system, backed by Qualcomm Inc, and Europe‘s WCDMA, supported by Ericsson and Nokia. The technology was jointly developed by Chinese Academy of Telecommunications Technology (CATT), Datang and Siemens and proposed by the China Wireless Telecommunication Standard group (CWTS) to the International Telecommunications Union (ITU) in 1998. In 2000, it was approved by the ITU as one of the candidate standards for 3G-radio communication, and in 2001, TD-SCDMA was accepted by the Third Generation Partnership Project (3GPP) as a part of Universal Mobile Telecommunications System (UMTS) release 4. According to press reports, a full commercial launch of this technology in the Chinese market is to take place in June 2005, although it is not entirely clear whether the Chinese government is indeed going to adopt the home-grown TD-SCDMA as the 3G standard for the country.

18 Term used to describe mobile systems evolved from the first and second generation of mobile communications networks. 3G systems feature higher data transmission speeds, advanced services and typically make use of new allocations of radio spectrum not available to operators of 2G networks. The data speeds are typically 2Mbps in fixed or in-building environments, 384 Kbps in pedestrian or urban environments and 144 Kbps in wide area mobile environments.

19 Worldwide there are about 160 million subscribers using this technology. NTT DoCoMo of Japan first introduced 3G in October 2001; most other countries have introduced it only during 2004.

India: The country has demonstrated significant innovation capability in two kinds of hardware. The first one is in small and large electronic digital switching systems, known popularly as the C-DOT digital switches and the second one is in a Wirless in Local Loop (WLL) access technology known as CorDECT. The C-DOT switches were designed and developed by the public laboratory, C-DOT. A detailed analysis of its development and subsequent manufacture could be found in Mani (2006, *forthcoming*).

(a) Digital Switching Systems: C-DOT has developed technologies for the manufacture of three different kinds of digital switches that are consistent with the usage patterns and climatic requirements of the Indian telecom network. They are: (i) Small capacity rural automatic switches with up to 256 terminations or ports. Popularly these switches are known as Rural Automatic Switches (RAX) as it is ideal for rural applications since it provides immediate basic telephone connections with practically no infrastructure. It is an easy to install and fault tolerant system with inbuilt redundancy. Besides requiring no air-conditioning, it withstands wide temperature fluctuations (-20^{o} C to 50^{o}C) and humidity. Moreover, it consumes very little power. A distinguishing feature of the C-DOT RAX is its simple and flexible connectivity through a wide range of transmission systems such as UHF, VHF, radio and satellite. As it is program-controlled, it can be easily adapted to different network requirements through software changes; (ii) The C-DOT Digital Switching System Main Automatic Exchange (MAX) is a family of digital switching systems which offers a total switching solution for national telecom networks. The C-DOT DSS MAX products have the proven ability to serve as local, toll, transit and Integrated Local-cum-Transit (ILT) switches. Starting from a switch that supports a few hundred lines for rural applications, to the 40,000-line main switch for central office applications the modular architecture of the C-DOT DSS MAX is capable of serving the needs of the entire range of customers. The modular architecture of the C-DOT DSS MAX ensures cost-effectiveness and protection of investment as the demand in a service area grows. It is possible to begin with a small switch in a potentially high growth area and to increase exchange capacity as the demand grows, simply by adding more modules to the existing exchange. The C-DOT DSS MAX products are packaged using standard cabinets, frames and cards. Due to minimum cabling required across cabinets the C-DOT DSS MAX products can be installed quickly and easily.

In addition the lab has successfully developed and transferred a number of other switching and transmission technologies. There are two ways of measuring C-DOT's capability in digital switching technologies. First, despite strong competition from imports and the not-so-favourable public technology procurement policies of its own parent, namely the Department of Telecommunications (DoT), C-DOT designed switches account for about a half of the switching network in India. See Table 8. Second, the royalties from technologies licensed to manufacturing enterprises contribute increasingly over three quarters of C-DOT's annual budget.

Both these evidences confirm the proposition that C-DOT has considerable innovation capability in circuit switching technology. But the lab has failed to move up the chain in terms of mobile technology. My field research inquiries reveal that this itself does not signify any lack of innovation capability, but as mentioned earlier a catastrophic failure in strategically directing the lab at the right moment.

(b) Wireless in Local Loop Access Technology: 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.

Table 8: Share of C-DOT Designed Switches in India's Telecom Network (As on March 31, 2004)

	Number of exchanges	Number of equipped lines (in millions)
Rural automatic exchanges/ access network rural automatic exchanges	32,993	5.25
Single base module-rural automatic exchange	9971	9.40
Main automatic exchange	2117	10.78
Total	45081	25.43 (57*)

Note: * Figure in parenthesis indicate percentage share of the total network

Source: C-DOT Website, http://www.cdot.com/ (accessed on May 10 2005)

CorDECT is a WLL access technology developed by two Indian research organisations namely Indian Institute of Technology (IIT-M), 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) IIIT-M, 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 .

The corDECT system contains three subsystems- the DECT Interface Unit (DIU), compact base stations (CBS), and subscriber access units that could be either fixed wall sets 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 wall sets or handsets. The wall set is 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 wall set 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 (Mani, 2006 *forthcoming*)

In very simple terms, corDECT technology will reduce significantly the access cost of telecom service especially in rural areas. This may hasten the diffusion of Internet services in the country and especially in the rural areas[20] 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

However its diffusion within the domestic sector has received a major fillip only since 2002 when one of the recent private entrants

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20 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 Institute, Digital Dividend, http://www.digitaldividend.org/action_agenda/action_agenda_01_nlogue.htm

namely Reliance Infocomm[21] (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[22] 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 are all MNCs and they are able to give deferred credit facilities to the service providers 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.

(iv) Capability in Telecoms Software: This is an area where India has some comparative advantage over the Chinese in view of India's growing technological maturity in the design and production

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21 Reliance Infocomm is part of a large Indian conglomerate namely Reliance Industries. The American telecoms company, Qualcomm that pioneered the CDMA technology, holds about 4 per cent of the shares of Reliance Infocomm. 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.

22 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

of computer software. In fact the Chinese too have taken advantage of this by setting up telecom software development centres in India: the leading Chinese company, Huawei has such a facility in the Indian city of Bangalore and also by inviting and encouraging Indian software companies to operate from China as well. Therefore in this section I focus more on India's capability in telecom software and this capability is also one of the reasons as to why India is able to secure a growing number of R&D outsourcing deals in telecommunications especially in the recent past.

India's software exports have been showing some spectacular performance during the 1990s. But the 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 have been attempting to move up the value chain. A clear manifestation 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.,

- 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 Operating Support Systems (OSS)/Business Support Systems (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.

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 exported. However available data from industry- sources (Table 9) 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 2006.

Thus our discussion of the above shows that country has built up considerable innovation capability in the areas 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.

Table 9: Telecoms Software Exports from India (Millions of US $)

	Software exports from India	Estimated telecoms software exports from India
1998-99	2626	262.60 (10)
1999-00	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)

V. Conclusions

China and India have one of the largest domestic markets for telecommunications equipments in the world. Both the countries have pursued widely divergent strategies towards acquiring and maintaining innovation capability in the telecommunications equipment industry. China has followed a strategy of promoting manufacturing enterprises having strong in –house R&D capability. Also the country has sought to keep pace changes with movements in the technology frontier. For instance, she has built up considerable capability in the design and manufacture of mobile telephones (base stations, switching centers and handsets). Consequently, the country has now emerged as one of the largest manufacturers of telecommunications equipments in the world. China depended initially on MNCs for their technology needs, but has subsequently built up considerable local capability. In short the country's sectoral innovation system has effectively made the transition from a foreign dominated to a local dominated one. The Indian sectoral system of innovation has shown exactly the opposite. India, on the contrary, has had a much longer manufacturing and research history in this industry. However its sectoral system of innovation is very weak. Although she has managed to build up considerable innovation capability in conventional circuit switches the laboratory was not given the strategic direction to build up capability in mobile communications. Further, the in-house R&D efforts of the manufacturing enterprises were very weak as they depended entirely on the public laboratory for their technology needs. This strategy did indeed bring large amounts of royalty to the public laboratory, but at the very same time did not make the manufacturers stand on their own feet as far as their technology needs are concerned. The laboratory itself was subject to a fair amount of destabilizing shocks from the bureaucracy and the polity that its own continuation is now under great threat. However a number of private sector manufacturers, have developed fair amount of innovation capability in telecommunications software and this has spawned a growing telecoms software industry in the country and this industry has managed to win a number of R&D outsourcing contracts from especially Western and indeed even Chinese telecoms manufacturers. Of late the government has been promoting FDI in telecommunications equipment and therefore the industry is now in the process of being transformed from one dominated by domestic technology to one dominated by foreign technology and manufacturers.

The telecommunications industry is thus an example of an industry in which the Chinese are able to compete in the world markets not just based on the country's possession of cheap labour but on its innovation prowess. It also brings to the fore the importance of the quality of strategic direction to be provided by state agencies if a late starting developing country were to become an important manufacturer of high technology products[23]. Mere possession of research capability while necessary is

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23 In this way, the findings of this study are at variance with Saha (2004). According to this study the Chinese manufacturers have done better owing to a number of financial and fiscal support these companies have received from the Chinese state. But there is precious little discussion in his study about specific instruments of state support for R&D. The study also refers to the meteoric rise of Huawei, but is very silent about the channel or processes through which such a spectacular performance was achieved.

not sufficient enough for a country to emerge as an important producer of high technology products.

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ANNEXURE : 1

Profile of Chinese Telecommunications Equipment Manufacturers, 2003

	Huawei	ZTE	Datang
• Telecommunications revenue (millions of US Dollars in 2003)	3830.12	1937	213.1
• Annual R&D expenditure (millions of US Dollars in 2003)	385	213.07	32
• Number of scientists and engineers in 2003	10000	9010	1840
• Exports of telecom products (millions of US Dollars in 2003)	1050	42.65	na
• Customer base	87 telecom operators in 31 countries	na	na
• Partners	Microsoft, 3Com, Siemens and Qualcomm	na	Siemens
• New technologies	3G Phones, next generation telecom networks, and internet gear.	na	na

Source: Field survey notes

ANNEXURE : 2

Comparison between the Largest Chinese Telecom Equipment Manufacturer vs. the Largest Indian manufacturer

		Huawei (China)	ITI (India)
1.	Year of commencement of commercial operation	1988	1950
2.	Total turnover (Millions of US $ in 2003)	3830.12 (Exports:1050)	26.07
3.	Annual R&D expenditure (Millions of US $ in 2003)	385	0.94
4.	Number of scientists and engineers engaged in R&D in 2003	10000	Approximately 100
5.	Customer base countries	87 telecom operators in 33	2 state-owned telecom operators in India
6.	New technologies developed	3G Phones, Next Generation Networks, and internet gear	Hardly anything. Continue to depend on foreign sources of technology

Source: On Huawei: http://www.huawei.com/was/wps/portal (accessed on June 3 2005) and Field Survey Notes, On ITI: Department of Public Enterprise (2004) .

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