ICT Infrastructure in Two Asian Giants: A Comparative Analysis of China and India[1]

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ABSTRACT

China and India are two of the leading and fastest growing telecommunications markets in the emerging markets world. China is ahead of India in terms of proliferation of telecommunications services and has been more successful in networking societies. The paper studies the current state of the telecommunications networks in both countries, taking into consideration not only technical, but also economical, political, educational and social factors. Based on a comparative, in-depth analysis it is found that China has a substantial lead over India in areas such as awareness, availability, and affordability.

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1. Introduction

India, an emerging world power with a rising economy, is comparable to China in terms of population, geographic size, and cultural vibrancy. Also, just like China, India is striving to become a leader in the global economy. China accounts for 5% of the world Gross Domestic Product (GDP) and 22% of world population; India accounts for 2% of world GDP and 18% of the world population. Together they account for 40% of the world's population. In recent years, both China and India have gained significant importance because of their growing role in the world economy. They have become the two fastest-growing developing economies; in the last three years especially, they witnessed a phenomenal growth rate. India's export of goods and services were 19% of the national GDP against China's 34% (WDI, 2006). In services, India's growth rate of 8.2% was almost equal to China's growth rate of 9.8% (WDI, 2006). This is one sector where India is equal to China in productivity and output.

Regarding telecommunications, their combined networks are among the worlds largest and most promising. Ovum predicts that India and China will account for 30% of the world's mobile phone users by 2010 (Burns, 2007). With a market of over one billion people (low-income and middle-income), according to the 2005 A.T. Kearney FDI Confidence Index, these two Asian giants are the most favored foreign direct investment (FDI) destinations in the world (Trinh, 2006). According to the 2005 World Investment Report, among the Asian countries, China attracted US$60.63 billion and India US$5.34 billion in FDI inflows (*India-Economic Survey*, 2005-2006). In the telecommunications industry alone, according to the 2006 World Development Indicators (WDI) released by World Bank, investments in the telecommunications industry with private participation, China attracted $8,495.9 million in contrast to India's $14,321.9 million (WDI, 2006). In the last five to six years, India's telecommunication market

has witnessed unparalleled growth. India has become the fifth-largest telephone network in the world after China, USA, Japan, and Germany.

India, a world power in terms of size and intellectual workforce, is striving to catch up with its close competitor in Asia, but is still not on par. With substantial progress in the area of the information and communication technologies (ICT) sector, China and India have gained significant global attention and importance in the last decade. Yet the differences between the two countries are profound. Is the underlying cause due to technology, economy, government, or the people?

2. State of ICT: Comparative Analysis of India and China

Although adoption and proliferation of the internet is growing rapidly in the two Asian giants, China is ahead in terms of the number of subscribers.

First, according to September 2006's, Telecom Regulatory Authority of India (TRAI) report, total internet subscribers in India stood at 8.10 million and total broadband (>256 Kbps) subscribers at 1.81 million. Compared to that, China has 137 million internet subscribers with 90.7 million broadband subscribers (as of January 2007) (CNNIC, 2007; TRAI, 2007a, b). Thus, it is clear that penetration in India is much slower than that of China. Breaking the subscribers down in terms of access methods and technologies, the gap widens further. In India, approximately 18,876 use leased lines as compared to 27.1 million in China. A vast majority of internet subscribers in India still use dial-up connections against China's 39 million; dial-up is the most favored method in India.

Second, the two countries differ in the number of internet hosts, i.e., computers that are directly connected to the worldwide internet network, measured in terms of country-specific

domain names registered; India (.IN) has 200,000 versus China (.CN)'s 1,803,393 (CNNIC, 2007; .IN Registry).

Third, India's recent phenomenal growth in the mobile industry has become one of the greatest success stories. This is evident from the fact that India's teledensity reached 18.26% at the end of February 2007, up from 1% in the late 1990s (TRAI, 2007). Furthermore, at the end of February 2007, India had a total of 202.74 million telephone subscribers (40.40 million fixed line users and 162.53 million wireless users) against China's 740 million phone users (350 million fixed line users and 390 million mobile users) at the end of 2005. The growth of main telephone lines in China between 2000 and 2005 has been 19.3% against India's 8.95% during the same period (WTD, 2006). In India, during the same period mobile subscribers grew at a rate of 90.6% against China's 35.8% (WTD, 2006).

Fourth, regarding competitiveness, the Indian mobile market is much more competitive than China's (TRAI Study Paper No. 1/2006).

Fifth, the Network Readiness Index (NRI) ranking that measures the propensity for countries to exploit the opportunities offered by ICT, based on the 2005 World Information Technology Report, ranked India at 40 whereas China was ranked at 50 (TRAI Study Paper No. 1/2006). This indicates more opportunities offered in India as compared to China. It is clear that in the recent past, the mobile market in India grew at a faster rate as compared to China; however, in the case of fixed services, China is still ahead.

Indian mobile market is expanding due to increase in household income and purchasing power, cheaper handsets, market innovations, value added services, choice of multiple service provider, and local manufacturing of handsets e.g., Nokia. It is said that with transparent, simple regulation and innovative operators, India's mobile market is expected to grow (Patel *et al.*

2007). With such a growth potential, along with world's biggest low-end market, there are more investment opportunities in India than ever before. If we impose these statistics for China and India to the S-curve of growth, India would be placed on the lower but faster growing portion of the curve whereas China would be placed at a more mature stage. Thus, India continues lagging behind China in terms of broadband penetration.

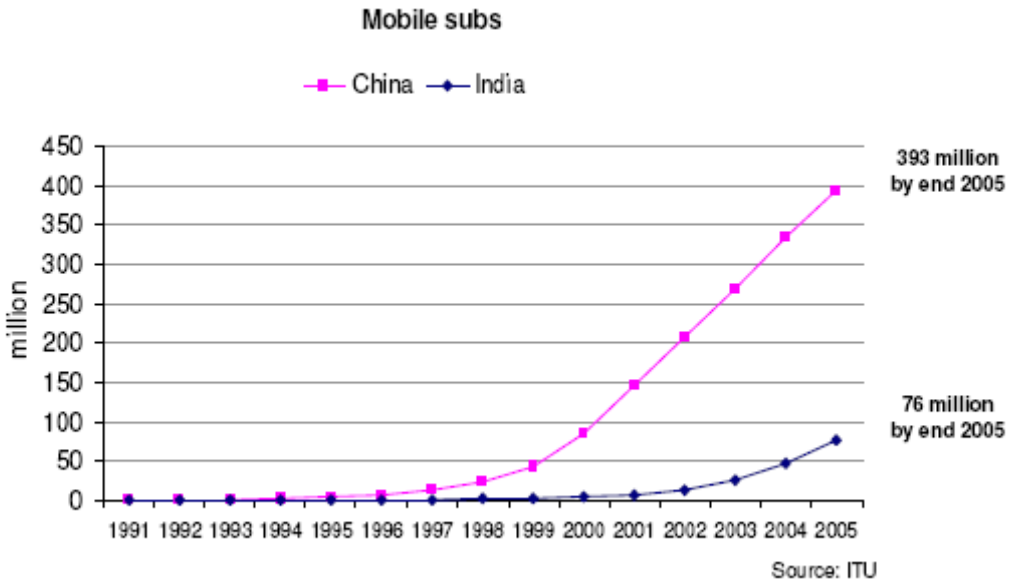

Figure 1 Mobile Subscriber: India and China

Source: PA Consulting Group (Patel *et al.* 2007)

This brings forth some fundamental research questions: why there is such a stark difference between India and China with regard to telecommunications services? Is it the affordability, availability, or the lack of awareness and knowledge? Does lack of knowledge play a part in the adoption of a technology? How significant is knowledge, or rather the lack of it, in the adoption of technology?

The use of information services in recent years has changed the way people connect, learn, share knowledge, and do business. Academics, consultants, and research organizations have argued over the years that development of infrastructure and its associated services has an

immense impact on individuals, societies, businesses, and the overall growth of the country. Infrastructure development (road, power, transportation, and telecommunications) helps improving the attractiveness, adoption, proliferation, and competitiveness of markets, businesses, and the workforce. Recent studies by Press *et al.* (2003); Kshetri, (2002), Dholakia, *et al.* (2003); Kshetri and Dholakia (2003); Bardhan (2006); Komandur (2004); Hong (2004); Tan (2004); Malik (2004); Indjikian and Siegel (2005); Tallon and Kraemer (1999), Hollifield and Donnermeyer (2003), Aizu (2002), Desai (2003), Wolcott and Goodman (2003), and Rai and Lal (2000) offer insights on the factors contributing to success. The authors argue that lack of knowledge has a significant impact on the effectiveness of the adoption and diffusion of technology. Factors such as *regulation and administration*, *awareness*, *availability*, and *affordability* will all have a different, yet relevant, impact on the penetration and acceptability of a technology. Note of caution the key factors and variables are interrelated and overlap; the idea is to highlight the individual factors that are critical in understanding the growth patterns in China and India.

2.1. Liberalization of Telecommunications in India and China

Both India and China began with state-owned telecommunications monopolies that were inefficient and resisted new technologies (Press *et al.* 2003). Telecommunications infrastructure and operations in both countries were controlled by state run agencies. The Ministry of Posts and Telecommunications (MPT) and the Department of Telecommunications controlled nationwide infrastructure in China and India respectively (Loo, 2004; Gupta, 2003). At the end of 1994, China had 27 million fixed and 2 million mobile subscribers, against 8 million fixed subscribers in India (Mani, 2005).

1994-1997: In order to foster competition and growth, the Chinese government started breaking the monopoly of MPT. In 1994, MPT was divided into two state-owned enterprises, China Unicom (domestic competition) and China Telecom (controlled the only Fixed Telephone Network) (Loo, 2004; Dong and Li, 2004; Chang *et al.* 2005). Furthermore, due to the growing demand from people, education and research institutions, China Telecom offered the first public Internet services in 1994, through ChinaNet (Loo, 2004). During 1980s and 1990s the Chinese government invested heavily in the telecom sector (Kshetri, 2003). During this period, the strong growth in the telecom industry was a result of heavy investments: it grew at a rate of 25% per year during 1990s (Chang el. al., 2005). Also, FDI played a major role in the sudden change of the Chinese telecommunications industry. This is evident from the fact that during 1994-1997, FDI inflows in China averaged $39 billion per year (UNCTAD, 2006). By the end 1997, China had 70 million fixed and 13 million mobile subscribers and a digital divide (ratio of urban to rural density was) of 2.94 (Mani, 2005). The bolstered growth was a result of the government initiatives and the market pressure, although the regulation and operations were not separated.

In India on the other hand, technology advancement and market pressure forced the government to introduce competition in mobile and fixed services. The first major initiative was the introduction of the National Telecom Policy 1994 (NTP'94). NTP '94 allowed competition in mobile and fixed services, but failed in creating a competitive environment; therefore, problems still existed. Private companies were forced to compete with incumbent operators in all regions where they held license. Furthermore, companies faced hurdles in getting permission to build new facilities and sites. Similar to China, regulation and operations were not separated, rather controlled by the ministry and the Department of Telecommunications (DOT). Internet services in India in 1995 (like China) were offered by a government owned company, namely Videsh

Sanchar Nigam Limited. During this period, 1994-1997, FDI inflows in India average $2 billion per year (UNCTAD, 2006). The ratio of urban to rural tele-densities, i.e., the digital divide, was 16 (Mani, 2005). By 1997, India had only 15 million fixed subscribers and negligible mobile subscribers, even though mobile services were launched in 1995 (Mani, 2005).

1998-Present: In 1998 in China, the Ministry of Information Industry (MII) was formed by merging MPT and Ministry of Electronics Industry (MEI), marking the separation of regulation and operations in Chinese telecommunications industry (Loo, 2004; Dong and Li, 2004; Chang *et al.* 2005). MII encouraged competitions, by reorganizing the existing telecom companies into seven new enterprises. Furthermore, in 2000 and 2001 MII undertook one more change, by dividing China Telecom in two: north and south. All the reforms aimed to make the domestic market more competitive and sustain international competition (Dong and Li, 2004). In regards to investments, FDI inflow continued to rise, during 1998-2000 FDI inflow average at $42 billion per year and $57 billion during 2001-2005 (UNCTAD, 2006). At the end of 2003, the digital divide was 1.67. By 2005, total (mobile and fixed) subscribers crossed 600 million (Mani, 2005).

In India, at the pressure of setback, obstacles, and pressure from private companies to reform the telecommunications industry, the government decided to revisit NTP ’94 and introduce NTP’99: in literal sense, a pragmatic and forward looking policy. NTP’99 heralded the start of new era in the Indian telecommunications industry (Gupta, 2003). With new goals and objectives, the Indian government realized the important relation between telecommunications services and economic growth. In 1998, an internet policy was introduced. Competition was introduced in cellular services (with more than three operators competing in a given market), fixed services, and national long distance (Gupta, 2003). In 2000, the TRAI Act of 1997 was

amended with a view to strengthen the regulator and the Telecom Dispute Settlement; also, the Appellate Tribunal (TDSAT) was formed for dispute settlement in telecom sector (Gupta, 2003). In 2002, state run ISP VSNL was privatized, by selling the major holding percentage to Tata Group. However, the biggest success story in India's telecommunication industry in recent years (or since the introduction of NTP '99) was in the mobile industry. During 1999-2005, the mobile industry grew at compounded average growth rate of 89%. Part of the reason for this tremendous growth was due to reforms in licensing, reduction of interconnection charges, revenue sharing practice instead of a one time licensing fee, market innovation, and by allowing more than two operators to compete in fixed and mobile services. The results of liberalization, reforms, and adoption of new technologies undertaken in the last last decade are seen now (Patel *et al.* 2007). At the end of 2003, digital divide was reduced to 9.53 from 16.00 in 1997. At the end of 2005, total (mobile and fixed) subscribers in Indian telecommunications industry passed 100 million (Mani, 2005); 200 plus million at the end of March 2007; however, even today, growth in fixed services remains a bottleneck. Developments in recent past have shown that the Indian telecommunications industry has come a long way despite failures. In spite of all these developments, the concept of encouraging FDI still eludes India. Singh's (2005) critical analysis of FDI in India from the license-raj era to the period of liberalization, reveals that even today, neither the very definition and importance of FDI nor its impact on the economic growth is fully understood. This was due to the unbalanced political situations during the last two to three decades: that was the main factor in the late beginning of FDI. Sectoral analysis reveals that in recent years FDI has become the staple for growth. There is a sense of understanding of the relationship between infrastructure and investments. Telecommunications and power sector are the two main reasons of growth in FDI influx in recent time; however, unevenness still remains.

For instance, FDI inflows in India averaged $2.7 billion per year (1998-2000) and $5.5 billion during 2001-2005 (UNCTAD, 2006).

Overall, China and India have pursued different paths of reforms and competitiveness. They have tasted success in reforming their telecommunications sector. Over the last two decades, the two countries have regularly tried to break away from a monopolistic state, by introducing competition. Apart from reforms and promoting competition, the differentiating factors have been the FDI inflows and China's self reliance on home grown products (Kshetri, 2003). Consider for example, a comparison of annual R&D expenditure between two largest telecom manufacturers: Huawei, China invested $385 million (2003) in R&D against 0.94 million (2003) by Indian Telephone Industries Limited (ITI), India. Furthermore, China's success in reforming telecommunications industry can be attributed to the overall economic performance and aggressive investing in modernizing telecommunication infrastructure. In the case of India, in recent years, the Indian government has been aggressively promoting market liberalization and reforms. However, it is the failure of the first round of reforms (NTP '94) and political debacles that resulted to its slow growth.

2.2. Awareness:

In order to foster the adoption on ICT services a simple requirement is the creation of manpower to use and covey the benefits associated with connectivity. Research in "Social networks" is used to convey the importance of being connected. The elementary examples of social networks we come across in daily life are for example, group of friends, NGOs, associations, societies, and the government. Common to all is that they communicate verbally but within themselves or within their small network and rarely with other social groups. Some of the reasons that contribute to this weak link are the overall objectives, information flow, education, and availability of physical

infrastructure. If technology is introduced, one can observe the differences in the organization and communication of these societies which were once connected verbally. The first and the foremost question would be whether technology can help them to learn, communicate, and share knowledge. There are certain rules and requirements such as: education, knowledge of how to use it, and the purpose of its usage. With the use of technology, the communication has improved but only within a society.

India and China are rivals in IT and IT-related services. China is ahead in terms of proliferation of internet services. China is known for being the production house of the world, while India is recognized for its service industry, i.e., Information Technology Enabled Services (ITES). In China, it is the availability of a well-developed and disciplined physical infrastructure which contributes to the growth; In India, it is the availability of millions of low-cost English-speaking professionals.

The prime factor that contributes to the adoption of technology is education. To put things in perspective, India's biggest advantage is the availability of skilled labor and qualified engineers. But availability of such a work force is a problem. Illiteracy rates in India exceed 35%, while only 4.9% in China. India has a significantly higher dropout rate. According to the National Sample Survey Organization (NSSO), India, at least 26% of rural families in India and 8% of urban families have no literate member over the age of 15 (Hindustan Time, April 17, 2007). There is a considerable difference between the two countries when one looks at the gross enrollment ratio (% of relevant age group). Furthermore, looking at the secondary and tertiary gross enrollment ratios, the difference is prominent as shown in Table 1. It is evident from the 2006 Human Development Report that India's public expenditure on education (as a proportion of total expenditure) has dropped from 12.2% in 1991 to 10.7% in 2004. China ranks higher than

India in terms of the Gender Development Index (GDI): this shows higher gender disparities in India than in China (a GDI of 1 indicates parity exists between sexes). The female literacy rate in China (87%), is much higher compared to India's (48%). According to the United Nations Development Program (UNDP's), the global 2006 Human Development Report (HDR) ranked India 126th while China as 81st in terms of a composite Human Development Index (HDI) (see Table 1). Finally, looking at the labour force participation in the two countries the margin has narrowed over the years. However, low work force participation, especially for women, in India is a dominant factor. According to Trinh (2006), India's labor market is Asia's most inflexible.

The next important dimension is the use of technology in the education system. Tallon and Kraemer (1999)'s study suggests that it is not enough to attract investments in building infrastructure; it is the creation of awareness and development of the education system which is tailored to the needs of industry and encourages its use. This leads to an interesting question: how many schools and universities are connected to the internet? In China and India, an initiative to connect schools and universities to the worldwide web was launched by their respective governments. However, differences still exist. In the case of India, the government launched the Education and Research Network (ERNET) in 1986 with the objective of providing state-of-the-art infrastructure and service to academics and research institutions. The ERNET backbone is a mix of terrestrial- and satellite-based wide area networks. Other initiatives launched through ERNET are: Vidya Vahini (IT in education), launched in seven districts in six states, now has 167 schools enrolled into the program; Gyan Vahini (computer-aided techniques into learning environment); ICAR-Net (Indian Council for Agriculture Research–Net), 274 institutions have been connected through VSAT and terrestrial link; and AICTE–Net, 48 institutions have been connected so far, and UGC-Infonet.

In the case of China, the China Education and Research Network (CERNET) established in 1994, supports "1500 universities and institutions connected and about 20 million end users." In terms of international connectivity, ERNET's global connectivity is far less, compared to CERNET's (see Table 1).

In short, China has been successful in networking universities, institutes, schools, and other organizations serving professors, researchers, and students. Rajeev Malik, economist at JPMorgan, Singapore points out "everyone talks about this demographic dividend in India, which is a valid point, but you need to make sure the people coming out are able to do something useful and not become a deadweight on the economy" (Leahy, 2007). Shortage of skilled workers is an indicator of failing to raise education standards to meet industry needs. These indicators are important to differentiate between availability of skilled and qualified engineers in India and China.

Table 1

Awareness

	India	**China**
Education Index		
Literacy Rate	64.84% (according to 2001 census)	95.1%
Expenditure on education as a proportion of GDP	2.78 (as of 2003-04)	NA
Expenditure per student, primary (% of GDP per capita)	9.1 (as of 2005)	NA
Public expenditure on education (% of total government expenditure)	12.2 (1991) 10.7 (2004)	12.7 (1991) NA
Gross Enrollment Ratio		
Secondary	52%	70%
Tertiary	11%	15%
Gender Disparity		
Gender Parity Index (GPI), gross enrollment in tertiary education	0.66 (as of 2004)	0.85 (as of 2004)
Labour Force Participation		
Female Labour Force Participation (as of 2005)	45%	79%
Skilled Labour		

Engineers		
Development Index		
Human Development Index (HDI)	126 (as of 2004)	81 (as of 2004)
Gender Development Index (GDI)	98 (as of 2003)	64 (as of 2003)
Academic Internet Backbone		
International capacity	6.64Mbps (ERNET)	800Mbps (CERNET)
Traffic generated	20GB (ERNET)	800GB (CERNET)

Source: UNDP, Human Development Report, 2006, World Development Indicators 2006, International Telecommunications Union (ITU), and India Budget (2005-06)

2.3. Affordability:

Affordability measured in terms of income and cost of a service (internet, mobile phone, fixed line) is a good indicator of the adoption and diffusion of a technology. According to the 2006 Human Development Report, India's GDP per capita (PPP, US$) is $3,139 compared to China's $5,896 (see table 2). China's per capita income is almost twice that of India's. When compared in terms of the price basket for a residential fixed line, mobile phone, and internet services, i.e., dollar per month, the difference is negligible in case of fixed line and mobile phone services, whereas in the case of internet services it is cheaper in India than in China (see table 2). Aforementioned India's mobile market has seen steady growth in recent years. In the long run, that growth could reach a stabilizing point or perhaps slowdown, if government, regulator, and operators fail to address semi-urban and rural markets. The size of middle class in India who can afford services is growing, but is not as big as compared to the semi-urban and rural markets. Lower return on investment and slower uptake are some of the reasons that private operators in India are concerned.

Table 2

Affordability

	India	**China**
Cost of Service ($ per month)		
Price basket for residential fixed line	$3.2	$3.6
Price basket for mobile	$3.2	$3.7

Price basket for internet	$8.7	$10.1
Income		
GDP per capita (PPP, US$)	$3,139	$5,896

Source: 2006 World Development Indicators

2.4. Availability:

Availability of services such as fixed and mobile phones, personal computers (PCs), and internet are just as important as awareness and affordability.

India has only 12.67 total telephone subscribers per 100 inhabitants against China's 56.53 (World Telecommunications Development Report (WTD), 2006). Breaking it down, in case of fixed line services, India has 4.5 main telephone lines per 100 inhabitants against China's 26.63 (WTD, 2006). The difference is also visible in the case of mobile phones: India has 8.16 cellular mobile subscribers per 100 inhabitants against China's 29.90 (WTD, 2006). In terms of coverage, 41% of the population[3] in India is covered by mobile telephony against China's 73% (2006 World Bank, WDI report). Rural coverage telephone services are available in 97% of villages in China against 87% in India. In order to increase the coverage area, operators can opt for combination of low cost technologies.

As far as information technology is concerned, access to and availability of PCs is also critical, as PCs enable access to the internet. China has the lead in PCs, according to the ITU WTD 2006 report: as of 2005, China had approximately 53 million PCs versus 17 million in India, and the similarly Computer Industry Almanac estimates approximately 64 million PCs in China and 17 million in India. Thus, the two industry group estimates are different in terms of China's number of PCs, but the fact remains: not only is the gap already wide, but also it is widening. According to NASSCOM report on Internet users, subscribers, and PC sales in India as of

[3] Is the percentage of people within range of mobile cellular signal regardless of whether they are subscribers or not.

Mar 2005, India had approximately 12 personal computers (PC) per 1000 people. In case of user to subscriber ratio, as of Mar 2005, there were 13 users per businesses (48 million users), 1.5 users per household (4.4 million users), totaling to approximately 53 million subscribers. The ratios are of Mar 2005, but considering India's more than one billion population, the ratios are not good indicators of computer awareness. Compelling reasons are the lack of availability of locally-manufactured computers and cost.

In regards to international connectivity, i.e., international internet bandwidth for transmitting internet traffic between countries, China overwhelms India by five times. India invests 4% of its GDP back into infrastructure development against China's 9%. Regarding ICT expenditure (which includes computer hardware, software, services, and wired and wireless communications equipment), China spends 4.4% of GDP as compared to India's 3.8%; also, when compared in US dollars spent per capita, China spends more than India (WDI, 2006). This contributes to China having superior access and services as compared to India. China is not only well-positioned in terms of telecommunication infrastructure, but it also has a huge availability of hardware (PCs, phones, etc) due to strong local manufacturing base.

Table 3

Availability

	India	**China**
Telephone Lines		
Total telephone lines /100 inhabitants	12.67	56.53
Main telephone lines/100 inhabitants	4.51	26.63
Mobile subscribers/100 inhabitants	8.16	29.90
Information Age		
Personal Computer (as of 2005) (in millions)	17	53
International Internet bandwidth bits per capita (2004)	11	57
Information and communications technology expenditure		
% of GDP (2004)	3.8	4.4

Per capita $ (2004)	24	66
Television		
Households with television (%) (as of 2005)	37	91

Source: 2006, World Development Indicators 2006, International Telecommunications Union

Thus, China has a substantial lead over India in the development of infrastructure and the subsequent creation of its awareness.

The International Telecommunication Union (ITU)'s Digital Access Index (DAI) takes into account factors such as infrastructure (availability), affordability, knowledge, and quality in classifying countries as high, upper, medium, and low ICT access. Based on ITU's DAI[4] results, China and India are listed under countries with medium level ICT access. Overall, China's performance (.43) is better than India's (.32) (WTD Report, 2003). The Economist Intelligence Unit (EIU)'s e-readiness rankings capture variables such as connectivity, citizens' ability to utilize technology skillfully, transparency of business and legal systems, and the extent to which governments encourage the use of digital technologies. Based on the 2006 e-readiness rankings, India (53) ranks higher than China (57). India's performance is better as compared to China, due to better corporate governance, companies that are more commercially driven, growing IT service industry industry, and openness to trade and investments. The key learning for both countries is that in spite of making considerable progress, the two countries will fall behind leaders, unless their policies are revised to check diffusion of ICT services. The two indices show a different picture; what remain common are the bottlenecks with technology infrastructure and access to ICT.

2.5. Other Factors:

[4] 178 economies, on a scale of 0 to 1 where 1 = higher access.

Moving on from the information age to other physical infrastructures which indirectly contribute to the growth of the society, China enjoys a much better physical infrastructure compared to India (see table 4). The problem with infrastructure in India is that the infrastructure deficit continues to impede its progress. According to the recent article, "The Trouble with India" in BusinessWeek, 2007, it is said that India is where China was a decade ago (Hamm, 2007). According to T.V. Mohandas Pai, Director of Human Resources for Infosys, "India has underinvested in infrastructure for 60 years, and we're behind what we need by 10 to 12 years (Hamm, 2007)." This is clearly visible when someone compares the two giants in terms of road networks; as of 2006, India has 3,700 miles of national highways against China's 25,000. With the road networks in disarray, India's woes about power production and consumption are continuing (see table 4). It is not surprising that international companies choose China over India when setting up manufacturing plants. According to new estimates, India needs to invest about $500bn on infrastructure in the next five years in power plants, roads, ports, and airports (Leahy, 2007).

Table 4

Other Infrastructure

Other	India	China
Roads Network, Paved (% of total roads) (as of 2001)	46%	91%
National Expressways (thousands of miles) (Hamm, 2007)	3.7	25 (data for 05)
Electric Power (Consumption/capita kwh) (as of 2001)	365	893
Electric Power Production**Error! Bookmark not defined.** (bn KWH)	654	2,500

3. Summary and Discussion

Today, India's huge pool of low-cost English-speaking professionals is attracting business process outsourcing services. However, high illiteracy rates and a dearth of qualified engineers

could hinder India's growth in the long-run. Analysis shows that huge gaps exist in the education system of the two countries. Due to lack of enthusiasm from part of the government to invest in the education system, would lead to work force imbalance. Access to education needs to be improved in India. Usage of technology in the education system needs to be stressed. Along with this usage, schools and universities should be provided with broadband coverage, enabling them to interact and share knowledge. Furthermore, India needs to focus on delivering customized educational content in local languages via ICT.

China's self-dependence on home-grown hardware, superior infrastructure, and availability of higher regional and international bandwidth, makes the country more attractive for FDI as opposed to India. Furthermore, China's higher per capita income coupled with superior access to infrastructure, help in driving telephone (fixed and mobile) and broadband penetration levels.

In order for India to reach the same levels, it needs to push its manufacturing base to offset its dependence on importing hardware: increase network coverage and user acceptability, which, in turn, will help creating jobs. Apart from investing in telecommunications, large investments are needed in the power sector as well as road development, which indirectly impact the level of foreign investment and attractiveness.

References

.IN Registry: India's official .IN Domain Name Registry, from http://www.registry.in/.

Aizu, I. (2002). A Comparative Study of Broadband in Asia: Deployment and Policy. *Asia Network Research*, 1-25, 2002

Bardhan, P. (2006). Awakening Giants, Feet of Clay: A Brief Assessment of the Rise of China and India. *Journal of South Asian Development,* April 2006.

Burns S. (2007). China and India poised for stellar mobile growth. VNU Business Publications, from http://www.vnunet.com/articles/print/2174261, accessed on April 12, 2007.

CERNET: China Education and Research Network, http://www.edu.cn/.

Chang, J., Fang, X., & Yen, D. C. (2005). China's telecommunication market for international investors: opportunities, challenges, and strategies. *Journal of Technology in Society*, 27, 105-121.

China Internet Network Information Center (2007). The 19th Survey Report, from http://www.cnnic.net.cn/en/index/0O/index.htm

Desai, M. (2003). India and China: An Essay in Comparative Political Economy. *Paper for IMF Conference on India/China, November*, 2003, Delhi, India.

Dholakia, N., Dholakia, R. R., & Kshetri, N. (2003). Internet Diffusion. Working paper, from http://ritim.cba.uri.edu/wp2003/pdf_format/Wiley-Encycl-Internet-Diffusion-v12.pdf

Dong, Y., & Li, M. (2004). Mobile communications in China. *International Journal of Mobile Communications*, 2(4), 395-404.

ERNET: Education and Research Network, India, http://www.ernet.in/index.htm.

Gupta, R. (2003). Assessing the Effects of Liberalization on India's Telecommunications Industry. Working Paper.

Hamm, S. (2007). The Trouble with India. BusinessWeek, March 19, 2007, 48-58.

Hindustan Times (2007). No literate adult among 26 percent rural families. available from http://www.hindustantimes.com/StoryPage/Print.aspx?Id=67049cca-0141-401c-a987-e5be023229ca, accessed on April 17, 2007.

Hollifield, Ann C., & Donnermeyer F. J. (2003). Creating demand: influencing information technology diffusion in rural communities. *Government Information Quarterly*, 20, 135-150.

Hong W. (2004). An Empirical Study on Telecommunications Development in the Rural Areas of China's Western Provinces. *Proc. of the International Telecommunications Society 15th Biennial Conference*, Berlin, Germany.

Indjikian, R., & Siegel, S. D. (2005). The Impact of Investment in IT on Economic Performance: Implications for Developing Countries. *World Development*, 33(5), 681-700.

International Telecommunication Union, World Telecommunication Development Indicators 2006, from http://www.itu.int/ITU-D/ict/statistics/.

International Telecommunication Union, World Telecommunications Development Report 2003: Access Indicators for Information Society, Executive Summary, from http://www.itu.int/ITU-D/ict/publications/wtdr_03/index.html.

Kshetri N., & Dholakia, N. (2003). Broadband Potential in Asian Giants: A Comparison of China and India. Working paper, from http://ritim.cba.uri.edu/wp2003/pdf_format/PTC-2003-Broadband-Kshetri-Dholakia-Final-v2.pdf.

Kshetri, N. (2002). What determines Internet diffusion loci in developing countries: Evidence from China and India. *Pacific Telecommunications Review*, 23(3), 25-34.

Leahy, J. (2007). India wants building workers back. Financial Times, December 10, 2007, from http://www.ft.com/cms/s/0/1030c602-a73a-11dc-a25a-0000779fd2ac,dwp_uuid=4c17109c-9c81-11da-8762-0000779e2340.html, accessed on December 11, 2007.

Loo, B. P. Y. (2004). Telecommunications reform in China: towards an analytical framework. *Journal of Telecommunications Policy*, 28, 697-714.

Malik P. (2004). Indian Telecommunications Policy and Regulation: Impact on Investment and Market Structure. Working Paper, from http://regulateonline.org.

Mani, S. (2005). The Dragon vs. Elephant: Comparative Analysis of Innovation Capability in the Telecom Industry of China and India. *Economic and Political Weekly*, 4271-4283, from http://cds.edu/EPW%20Dragon%20and%20Elephant.pdf

Patel, V., Kam, J., & Cheung, C. (2007). India's Evolving Mobile Market and Comparisons with China. *Proc. of the Pacific Telecommunications Council 2007 Conference*, from www.ptc07.org/program/papers/T13_ViratPatel.pdf.

Press L., Foster W., Wolcott P., & McHenry W. (2003). The Internet in India and China, *Information Technologies and International Development*, 1(1), 41-60.

Rai, P. L., & Lal, K. (2000). Indicators of the information revolution. *Journal of Technology in Society*, 22, 221-235.

Singh, K. (2005). Foreign Direct Investment in India: A Critical Analysis of FDI from1991-2005. From http://unpan1.un.org/intradoc/groups/public/

Tallon, P. P., & Kraemer, L. K. (1999). The Impact of Technology on Ireland's Economic Growth and Development: Lessons for Developing Countries. *Conference on System Sciences, 1999. HICSS-32, Proceedings of the 32nd Annual Hawaii International*, from http://ieeexplore.ieee.org/servlet/opac?punumber=6293.

Tan, Z. (2004). China's March into Broadband Internet. Proc. of the International Telecommunications Society 15th Biennial Conference, Berlin, Germany.

Telecom Regulatory Authority of India (2006). Study Paper on Financial Analysis of Telecom Industry of China and India. Study Paper No. 1/2006, 1-13, from http://www.trai.gov.in/StudyPapers_list_year.asp.

Telecom Regulatory Authority of India (2007), Telecom subscribers growth during February 2007. TRAI press release, from http://www.trai.gov.in/trai/upload/PressReleases/443/pr16mar07no29.pdf.

Telecom Regulatory Authority of India (2007a). Press Release: Telecom subscribers growth during February 2007. March 16th, 2007, from http://www.trai.gov.in/pressreleases_list_year.asp.

Telecom Regulatory Authority of India (2007b). The Indian Telecom Services Performance Indicators Report for the quarter ending December 2006. Performance Indicators Report, from http://www.trai.gov.in/Reports_list_year.asp.

The Economist (2006). The Economist Intelligence Unit 2006 e-readiness rankings. From http://www.eiu.com/site_info.asp?info_name=eiu_2006_e_readiness_rankings.

The World Bank Group, World Development Indicators 2006, from http://devdata.worldbank.org/wdi2006/contents/home.htm.

Trinh, S. (2006). India a study in contrast. *Deutsche Bank Research*, from http://www.dbresearch.com/.

United Nations Conference on Trade and Development (UNCTD), 2006 Foreign Direct Investment Database, from http://www.unctad.org/Templates/Page.asp?intItemID=1923&lang=1.

United Nations Development Programme (2006). The 2006 Human Development Report, from http://hdr.undp.org/hdr2006/.

Wolcott, P., & Goodman, S. (2003). Global Diffusion of the Internet - I India: Is the Elephant Learning to Dance? *Communications of the Association for Information Systems*, 11, 560-646.

Xia, J & Lu, Ting-Jie (2005). Universal Service Policy in China: Building Digital Bridge for Rural Community. *Proceedings of the 33rd Telecommunications Policy Research Conference*, George Mason University, Arlington, Virginia, USA.

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