Information Technology as an Engine of Broad-Based Growth in India*

Nirvikar Singh
Professor of Economics
University of California, Santa Cruz
Santa Cruz, CA 95064, USA

February 2002

Abstract

In this paper, we survey some of the developments in India's IT sector, and prospects for broad-based growth led by this sector. We examine the IT sector, discussing the role of software versus hardware, the growth pattern of the software industry and software exports, and the potential problems in IT labor supply to support future growth. We focus on a current bottleneck for the IT sector, namely the telecommunications infrastructure. Issues considered include the basic driver of technological convergence across voice and data communications, problems with current infrastructure, innovations that have the potential to dramatically alter the economics of access to telecoms, and the evolving structure of the telecoms industry. We also examine the policy environment more closely, arguing that government policy is better focused on removing labor market distortions and infrastructure constraints, rather than providing output or export subsidies to the software industry. We discuss the appropriateness of specific policy goals such as universal access, as well as issues of implementation of more general objectives of broader telecoms access. Finally, we map out the possibilities for broad-based IT-led growth, including increasing value-added, using better telecom links to capture more benefits domestically through offshore development for industrial country firms, greater spillovers to the local economy, broadening the IT industry with production of telecom access devices, improving the functioning of the economy through a more extensive and denser communications network, and improving governance.

Keywords: information technology, software, complementarities, telecommunications
JEL Classification: M21, L63, O12, O3

* This paper has been prepared for a volume on the future of India and Indian business, edited by Parthasarathi Banerjee and Frank-Jürgen Richter. I am grateful to Yale Braunstein, Ashok Desai, Atanu Dey, Rafiq Dossani, Kyle Eischen, P.D. Kaushik and Vini Mahajan for helpful comments and discussions. None of them is responsible for any remaining shortcomings. I have learned about aspects of this topic from numerous people, in addition to the ones named. I have tried to reference their works as much as possible, and regret any inadvertent omissions.

1. Introduction

Nothing has captured the imagination of India's policymakers quite like information technology (IT). Indians have proved themselves to be world class in IT. Indians (or people of Indian origin) are becoming not just contributors but leaders of the IT revolution in the United States. India's software industry appeared to be growing so rapidly that it would forever solve India's balance of payments problems, and make India an IT "super power".

At the same time, some have decried India's IT boom as just another version of global sweatshop production, with lines of code replacing garments. A related concern is that the growth will peter out as these labor-intensive software tasks reach their limits, or even become automated. More worrying, perhaps, is the concern that IT in India will become an enclave similar to natural resource enclaves, controlled directly or indirectly by multinationals, with a small elite of workers, no productive spillovers to the local economy, and greatly increased inequality. Some of the different concerns are mutually exclusive, but either possibility, rapidly diminishing returns or very narrowly focused benefits, is inconsistent with a golden future for India's IT sector and its broader economy.

In this paper, we survey some of the developments in India's IT sector, and prospects for broad-based growth led by this sector. We try to identify some areas where policy changes and current innovations can together lead to realization of the more optimistic scenario, and avoidance of some of the pitfalls that analysts have identified. Section 2 provides a brief overview of the Indian economy, including its structure and recent reforms. Section 3 examines the IT sector, discussing the role of software versus hardware, the growth pattern of the software industry and software exports, and the potential problems in IT labor supply to support future

growth. Section 4 examines a current bottleneck for the IT sector, namely the telecommunications infrastructure. Issues considered include the basic driver of technological convergence across voice and data communications, problems with current infrastructure, innovations that have the potential to dramatically alter the economics of access to telecoms, and the evolving structure of the telecoms industry.

While policy issues crop up throughout the paper, Section 5 examines the policy environment more closely, arguing that government policy is better focused on removing labor market distortions and infrastructure constraints, rather than providing output or export subsidies to the software industry. The latter are not only costly, but will lead to narrower development of the IT sector. We discuss the appropriateness of specific policy goals such as universal access, as well as issues of implementation of more general objectives of broader telecoms access.

Section 6 builds on earlier arguments in the paper, to map out the possibilities for broad-based IT-led growth, including increasing value-added, using better telecom links to capture more benefits domestically through offshore development for industrial country firms, greater spillovers to the local economy, broadening the IT industry with production of telecom access devices, improving the functioning of the economy through a more extensive and denser communications network, and improving governance. Section 7 provides a summary conclusion.

2. Economy Overview

India has made considerable economic progress since independence, but it has not grown as rapidly as the East Asian "miracle" economies. Economic policy emphasized state-led

industrialization until the 1990s, though there was some shift away from this in the 1980s. Growth accelerated somewhat in the 1980s, and even more in the 1990s, in which GDP growth has averaged around six percent. The recent sectoral distribution of GDP is shown in Table 1, which also illustrates that the level of GDP remains quite low, at about $300 per capita. Poverty rates have fallen gradually over time, and somewhat more rapidly in the last decade, but they remain quite high, at close to 30% of the population. Human development indicators such as literacy and life expectancy have also tended to lag behind targets, with adult literacy being only 65% according to the latest census (even with a very minimal criterion being applied).

Table 1: India's GDP (Rs. billion) at Factor Cost by Industry of Origin 1993-94 to1999-2000 at 1993-94 prices

Year	Agriculture, forestry and logging, fishing, mining and quarrying	Manufacturing, construction, electricity, gas and water supply	Transport, communication and trade	Banking and insurance, real estate, dwellings and business services	Public administration and defense and other services	Gross domestic product at factor cost
1993-94	2620.6 (33.5)	1850.7 (23.7)	1505.0 (19.3)	900.8 (11.5)	936.3 (12.0)	7813.5
1994-95	2760.5 (32.9)	2040.9 (24.4)	1661.3 (19.8)	950.9 (11.3)	966.7 (11.5)	8380.3
1995-96	2751.5 (30.6)	2291.0 (25.5)	1881.7 (20.9)	1028.5 (11.4)	1043.0 (11.6)	8995.6
1996-97	2994.6 (30.9)	2468.5 (25.4)	2029.4 (20.9)	1099.9 (11.3)	1108.4 (11.4)	9700.8
1997-98	2950.5 (29.0)	2561.1 (25.2)	2185.1 (21.5)	1227.8 (12.1)	1238.2 (12.2)	10162.7
1998-99	3144.0 (29.0)	2654.3 (24.5)	2340.2 (21.6)	1331.3 (12.3)	1360.7 (12.6)	10830.5
1999-2000	3167.8 (27.5)	2837.2 (24.6)	2528.3 (21.9)	1465.5 (12.7)	1521.2 (13.2)	11519.9

Source: http://www.finmin.nic.in/fecosur.htm
Notes: 1999-2000 figures are estimates. Numbers in parentheses are percentages of total GDP.

Table 1 illustrates that agriculture remains an important part of the economy, contributing close to 30% of GDP, and still ahead of manufacturing. Agriculture's share of employment is considerably higher. Services of all kinds and the public sector are the other two sectors of the economy. While the public sector is, by its nature, "organized", much of the service sector, like

agriculture, is "informal" in nature. Thus India preserves the classic "dual" nature of a developing economy.

The single most important change that was introduced in the early 1990s was a drastic paring down of the longstanding regime of government controls on private industrial investment. The combination of this relaxation of the "license-permit *raj*" and substantial reductions in trade barriers (as well as moving from quantitative restrictions to tariffs) arguably contributed to the faster growth that India has seen in the past decade. Foreign investment was also liberalized. Liberalization of previously very severe controls was easier to accomplish, in some respects, than deeper institutional reforms, which include privatization of parts of the economy that have had substantial government presence, and the development of a set of modern laws and regulatory institutions to provide a framework within which the private sector can operate effectively.

Both political obstacles in the form of vested interests, and difficulties in learning how to create and manage new institutions in an environment of simultaneous rapid globalization and technological change, have slowed the progress of fundamental reforms of laws and institutions. Some of the greatest difficulties have arisen in sectors where private enterprise has traditionally been viewed as subject to market failure problems, due to cost structures that supported natural monopolies (i.e., large scale economies), or the existence of externalities or public good characteristics (i.e., non-rivalry or shareability, and non-excludability). The technical difficulties of efficient economic organization of production in such areas have been compounded by political resistance to change, even though the existing organization is grossly inefficient.

Two key sectors that stand out in this respect are electric power and telecommunications (telecoms). Along with roads and ports, power and telecoms are essential infrastructure for any

economy, and they represent the worst bottlenecks that currently prevent India from achieving higher growth rates. If one has to pick one of these sectors, electric power is the area where the problems and the benefits to improvement are arguably the greatest, but in this paper we take this as given, and focus on telecoms in the context of information technology more generally.

3. The IT Sector

Information technology essentially refers to the digital processing, storage and communication of information of all kinds[1]. Therefore, information technology (IT) can potentially be used in every sector of the economy. The true impact of IT on growth and productivity continues to be a matter of debate, even in the United States, which has been the leader and largest adopter of IT. However, there is no doubt that the IT sector has been a dynamic one in many developed countries, and India has stood out as a developing country where IT, in the guise of software exports, has grown dramatically, despite the country's relatively low level of income and development.

Software vs. Hardware

The basic distinction in IT is between hardware and software. The former refers, of course to the physical components of processors, storage devices and communications devices. The latter refers to the instructions that govern the flow and processing of information in digital form, within and between hardware devices and components.[2] The production of hardware is

[1] Alternative terms include ICT, for information and communications technology, and ICE, for information, communications and entertainment. I am grateful to Atanu Dey for these suggestions.
[2] Rafiq Dossani has pointed out to me (personal communication) that the distinction between hardware and software has blurred, as some 'hardware' firms have focused on design and outsourced their manufacturing. Design of

classified within the manufacturing sector. Profitably manufacturing semiconductors and other sophisticated hardware components typically requires infrastructure, large-scale investments in capacity, and accumulated experience that India does not possess, and is not in a position to acquire easily. India' development path, despite its emphasis on import-substituting industrialization, has not supported the growth of a robust, world-class manufacturing industry, such as has arisen in many East Asian countries.

Nevertheless, India does perform many hardware assembly tasks internally, for the domestic market. Components in such cases typically come from East and Southeast Asia. The ability to organize this aspect of production may be the basis for further development of hardware capabilities. Several East Asian countries also began as mainly assemblers of sophisticated components produced elsewhere, and extended their presence in the value chain backward as they learned by doing. While being late to the game may make entry more difficult, the fact that manufacturing of components becomes increasingly standardized, and the cost of these components falls, works in favor of late entrants. For example, the production of most memory chips has become commoditized, and moved to developing countries, where 20 years ago it was the core of Intel's business.

The example of firms like Dell and Cisco may also be useful to keep in mind when evaluating the hardware industry in India. Dell outsources most, if not all, of its component manufacturing. It is, in fact, an extremely sophisticated assembler. Its value creation is based on organizing this assembly as efficiently as possible, doing so on demand, and keeping its inventories absolutely minimal. Strong customer service plus management of communications and logistics at both ends of the value chain are also keys to Dell's success. Dell's positioning to

---

hardware involves the writing of software code, and this designing ability can be used for pure software tasks. Our subsequent discussion includes the distinction between design and manufacturing (including assembly).

take advantage of strengths in infrastructure and closeness to a growing customer market is an important lesson for India. The point here, which we shall further develop subsequently in this paper, is that a hardware industry in India is feasible, building on India's experience in assembly, but it will require significant improvements in infrastructure, and careful attention to market needs.

India's software industry is more robust than its hardware industry, at least in certain areas. While selling packaged software to consumer (and most business) markets requires economies of scale and scope, as well as marketing and customer support muscle, project-oriented components of software development do not do so to the same degree. The software development and use life cycle includes analysis and specification of requirements, design, coding, testing, installation, maintenance and support. Many of these activities, particularly coding and testing, involve *relatively* routine IT skills that India's workforce has in large absolute numbers (though small relative to the total population).

The existence of the Indian Institutes of Technology (IITs), the ubiquity of Unix in academic environments, and the relatively low infrastructure demands of learning to use and create software all worked in India's favor on the supply side. The use of English in India's higher education system, the increase in the use of Unix and related operating systems due to the explosion of the Internet, and the large number of Y2K-related projects in the late 1990s all contributed to demand for India's software industry services, in addition to the general growth in IT in the 1990s. Much of this demand came from abroad, as we discuss in the next subsection. However, the software industry's domestic revenues also grew rapidly in the last few years, at over 30% per annum, on average.

Despite the even faster growth of software exports, domestic software revenue still represents close to one third of software industry gross receipts. The National Association of Software and Services Companies (NASSCOM) projects domestic sales to grow substantially faster than export sales in the next decade, enough to make domestic sales over 50% of the industry's sales, but the basis for this projection is unclear. In any case, India's software industry is quite robust. In the domestic market, products and packages make up almost half of revenues, with projects accounting for over a quarter, while professional services, support and maintenance, IT-enabled services and training each make up less than 10%.[3] This pattern is quite different from that of exports, as we discuss below.

Software Exports

India's software exports, in particular, are what have captured the headlines. A growth rate in software exports of over 50% (albeit from a low base) for several years, and consulting firm McKinsey's projection that software export revenue would reach $87 billion in a decade, are two of the most striking statistics in this regard. The latter figure would represent over half of India's projected payments on current account in a decade.[4] More conservative export growth projections used by NASSCOM would still imply that software exports would account for over a third of payments for visible and invisible imports. It must be borne in mind that the current figure for software exports is closer to $6 billion.

The pattern of activities that generates software export revenue is somewhat different from the sources of domestic revenue. In particular, professional services accounted for 44% of export revenue in 1998-99, followed by projects at 36%. Products and packages were only 8%

[3] The data are from NASSCOM (2000).

of the total compared to nearly half for domestic revenue. Desai (2000) suggests that some of the difference in the patterns of domestic and export sales is illusory, because domestic sales of packages are by resellers of packaged software that is licensed from foreign software developers or vendors.

Coding and testing therefore appear to form a significant proportion of the skills used in the Indian software industry. The concerns expressed by analysts[5] are that the Indian software industry is "programmer heavy", and therefore unable to move up to higher value-added segments of software. Related issues that reinforce these concerns are the brain drain of the most talented or experienced IT people, the lack of sufficient managerial skills for more sophisticated contract work, and the lack of domestic spillovers from the "body shopping" of programmers for onsite work in developed countries.

Much of this body shopping takes place in the largest market for India's software exports, the United States. The US is the destination of two thirds of India's software exports, with Europe far behind at 21% (half of that being in the United Kingdom), and Japan and the rest of the world accounting for the remaining 12%.[6] The US share in exports has risen along with its booming economy, and the slowdown there will no doubt reduce that share somewhat, as well as the growth rate of India's software exports.

IT-Enabled Services

As the term suggests, IT-enabled services are not necessarily related to the production of software or IT in general, but use IT to make the provision of services possible. The figures for

[4] This is based on using present payments on current account, and projecting them to grow at the present rate of 7.6% per annum, as suggested and calculated by Desai (2000).
[5] See, for example, Heeks (1996, 1998) and Desai (2000).
[6] The figures are from *Dataquest* (2001). Similar figures are given by Heeks (1998) and Desai (2000).

the software industry in India typically include these IT-enabled services, though they are not strictly part of the IT sector. Customer call centers are one example, where Indians have been training to speak with American accents, in order to deal with customer queries from the US. Accounting services are a second example. Yet another, more long-standing market segment is that of medical transcription.

The medical transcription segment illustrates some of the general problems with Indian industry serving foreign markets. Firms are often too small to market to or deal directly with clients, and relying on intermediaries reduces their margins, making investments in adequate training difficult or impossible. In turn, inadequate training hurts the quality of transcription, ultimately raising costs because problems must be fixed. Despite the success stories of Indian firms in this segment, revenues are only in the millions of dollars, whereas the US medical transcription market outsources several billion dollars worth of business worldwide.[7]

Good communications links are obviously important for the success of IT-enabled services such as medical transcription provided to foreign clients. The severest bottleneck in India, however, may not be telecoms, but the lack of managerial and marketing skills, and of reputations for quality. Recent developments suggest that this may be changing. Part of the solution includes the import of such skills by multinationals such as GE and Citigroup shifting some of their back office operations to India. This trend is behind the optimistic projections of a report submitted to the Indian government's Electronics and Computer Software Export Promotion Council, which sees IT-enabled services exports growing from $264 million in 2000 to over $4 billion in 2005.[8] While these projections may be on the high side, even half as much

[7] See *DQ Week* (2001).
[8] See *The Economist*, (2001).

growth would be impressive. We will return to issues of managerial skills and moving up the value added later in the paper.

Supply of IT Skills

The reason for the success of India's software industry is the large supply of labor with some IT skills. India graduates perhaps about 125,000 engineers a year, second only to the US worldwide.[9] However, not all these engineers go into the IT industry, and not all IT professionals have engineering or computer science qualifications – this being true of the US as well.[10] India's stock of IT professionals is estimated at 300,000,[11] so that software industry revenues per IT professional (assuming that all of them work in the software industry, which is unlikely) are about $30,000.[12] Government targets and others' optimistic projections imply software industry revenues will increase by a factor of 15. The breakdown of this growth could be something like a doubling in revenue per IT professional, and therefore almost an eightfold increase in numbers.

Both growth components have implications for IT training. Increasing revenue per IT professional requires improvements in managerial and marketing skills[13], but it also requires the production of more highly trained IT people. Training more people in IT requires investments to increase the capacity of this component of the higher education sector. This is an extremely

[9] See *Business Week* (2001). However, Aggarwal (2001) gives a substantially lower figure of 55,000 engineering graduates annually, excluding private institutes and Masters of Computer Applications (MCA). Arora and Arunachalam (2000) estimate an overall figure, including MCAs and graduates of informal training institutes, of close to 140,000 per annum. See also Arora et al (2001a, 2001b) and Saxenian (2001).
[10] See Arora and Arunachalam (2000), as well as Heeks (1996) and Desai (2000) for further discussion. Desai provides a detailed discussion of manpower requirements by type of task.
[11] See Aggarwal (2001).
[12] Arora *et al* (2001a) construct a lower estimate of $15,600 for 1998-99 (their Table 1). However, revenues doubled over the next two years, implying a figure closer to our estimate.
[13] The implication is that changes in the product-service mix toward that involving higher value-added tasks would be associated with these improvements, resulting in increased productivity.

thorny problem. Even at the elite IITs, faculty are poorly paid relative to industry, and the physical infrastructure has deteriorated from lack of investment. One might argue that this could be fixed by increases in government expenditure, but this is difficult in an environment of large budget deficits and long-term neglect of basic education.

Of course increased private investment in, and operation of IT-related training and education, is an option that is rapidly developing. One potential problem is that of maintaining standards and quality. However, reputations should be possible to establish, so that well-educated IT professionals will do better on the job market over time. IT industry investment may also play a role, since the industry has a strong interest in growing the available supply of IT professionals. Private providers such as Aptech, which characterizes itself as "Asia's leading provider of IT training", are also playing a role. Finally, given the strong reputation and talent pool in the IITs and similar institutes, however, it does seem that government investment may be better channeled toward them, rather than indiscriminately setting up new institutes for IT training, as the Ministry of Information Technology seems to be doing.[14]

A further problem besides sheer numbers is the issue of level of training, and even the IITs are hard pressed to provide postgraduate education comparable to what is available in the US. Increasing the level of IT education in India may simply exacerbate the brain drain[15], as the most qualified continue to be attracted to developed countries. Desai (2000) uses this issue to suggest that India may actually be better off by continuing to specialize in the lower end of the market, for coding and testing, as well as in IT-enabled services, at least in the next few years.

[14] Rafiq Dossani has expressed a slightly different view (private communication. He argues that there are a range of IT skills that are needed, and the IITs are not necessarily the best sources for lower-end skills. On the other hand, all kinds of new training and certification institutes may be good alternatives. Our point here applies more narrowly, to the best use of very limited government funds.

[15] The issue here goes beyond the temporary H1-B visa boom in the US, now reversed. The best from the IITs have been going to the US for higher education for decades, and only a small fraction return. While part of the problem is

Which route is most profitable is best left up to the players, with the government's role being to avoid excessive policy distortions that create imbalances across different segments within the IT sector. In any case, the supply of skilled labor is an important consideration for the growth of the sector, both domestic and export-oriented.

4. Telecom Infrastructure

Basic hardware and operating system software (particularly open source for the latter) have declined in terms of both absolute and relative cost. Liberalization of imports has allowed Indian IT firms to more efficiently obtain these inputs into their own production of software and services. While a shortage of skilled labor looms as a future problem, one of the most severe constraints has been the poor state of India's telecom infrastructure.[16] The benefits of well-functioning telecommunications are much broader than just in IT, but the Internet and the associated IT boom have made India's telecoms bottleneck a greater concern. At the same time, rapid technological change implies that the ability to alleviate this bottleneck may be much greater than just a few years ago.

Convergence

"The Indian telecommunications system continues to be governed by the provisions of the Indian Telegraph Act, 1885 and the Indian Wireless Act, 1933." This statement is from the New Telecom Policy of 1999. Until recently, the telephone was considered to be a luxury good

---

simply the extreme subsidy given to higher education in India, other policy factors play a role, and the example of Taiwan shows that the brain drain can be arrested (Saxenian, 2000).

[16] Again, one must acknowledge the problems of electric power and transportation also. To some extent, software avoids problems of physical transportation, but power remains a critical input.

by government policy-makers. These observations illustrate India's starting point in a world where telecommunications are being transformed incredibly rapidly.

The ability to digitally encode all kinds of information, whether voice, data, or video, makes it possible to send all this information over a single network with digital capabilities. This combined network may include copper wires, fiber-optic cables, and wireless transmission. This is the essence of what we mean by "convergence". Additional kinds of convergence are possible. The software protocols that govern communications can converge. The same devices can be used for access of different kinds (data and voice conversations, for example). However, these types of convergence are more specific, and are not necessary consequences of basic convergence of digital networks.

The implication of convergence is that telecoms are receiving more attention than in the past. While India began to encourage the setting up of Public Call Offices (PCOs) throughout the country in the 1980s, teledensity remains very low, between 2 and 4 per hundred. The quality of lines and exchanges is poor, and most telecoms remained a government monopoly until very recently, failing to follow quickly on the path of liberalization begun in 1991. It has been the rise of India's software industry that has focused attention on technological convergence, and the benefits and feasibility of dramatic change in the telecoms sector.

Infrastructure Needs

The software industry uses international data links for accessing clients' hardware, communicating by e-mail, exchanging files among joint development teams, and carrying out remote diagnosis and maintenance work.[17] IT-enabled services use voice lines for call centers,

[17] See Heeks (1996, 1998).

and data lines for transmitting electronic files back and forth. Internet-based media companies also require data links. While all economic activity requires good communications infrastructure, the rapid rise of the Internet has directly and indirectly increased the need for such infrastructure. Meanwhile, India's traditional infrastructure remains poor, with its teledensity being well below other developing countries such as China, and a low penetration of wireless access.

The demands on the telecoms infrastructure span an enormous range. While software firms, other exporters and multinationals require robust high-bandwidth international links, the great majority of India's population has little or no access to the most basic voice services (see further for details). It may seem that the needs of this range of users are so different that they require very different solutions. This is partly true, but technological convergence, and the fact that the domestic and international networks must interconnect, imply benefits to integrated approaches to infrastructure improvements. We therefore examine the network at several levels.

International links are an obvious area for improvement if the Indian software industry is to realize its lofty growth projections. Current bandwidth is only a small fraction of what is required. A key problem has been the monopoly of the government-owned Videsh Sanchar Nigam Limited (VSNL), which has been the sole provider of international access. VSNL's monopoly has severely restricted the expansion of international links, at a time when the cost of doing so has been falling rapidly. It has also greatly hampered the growth of domestic ISPs. After prolonged criticism from numerous sources, the monopoly will finally end in April 2002.

The domestic infrastructure is equally lacking. Here the government has already introduced competition. However, there have been several policy missteps, which we discuss further in Section 5. Lack of adequate attention to building a domestic Internet backbone has been one problem. This has contributed to the use of US-based servers for hosting "Indian" web

sites and e-mail services, even for purely domestic users, hence increasing the demands on international links and bandwidth. The paucity of the traditional voice infrastructure (both in terms of bandwidth and switching capabilities), which carries Internet traffic also, further inhibits modern communications. Internet use ties up lines for longer periods than voice calls, exacerbating the problem.

While increased and better access to the Internet is an important issue, it comes up in a situation where even the most basic telephone service is unavailable to large segments of the population. Official figures state that over 60% of villages have public telephones (VPTs), but most (over 90%) do not have direct long-distance dialing, and the quality and maintenance of the service is possibly quite low. Again, there are problems with the exchanges that serve these rural areas, which increasing the number of lines and access points will not solve. A problem with increasing access in rural areas is that the fixed cost of providing access is high compared to the potential revenue generation.

Many of the inadequacies of the telecoms infrastructure arise from government provision or inappropriate regulation, an approach that emphasizes quantitative targets, and a lack of coordination between developing different parts of the network. These problems are illustrated by the requirement that three new private fixed service providers (FSPs), awarded licenses, install 42,841 village pay phones in their first two years of operation, without regard to the economics and enforceability of this requirement.[18] Of course, the FSPs were being explicitly required to engage in cross-subsidization, but even if successful, it would result in only an extension of inadequate service, with low utility for users, as long as other bottlenecks or economic constraints such as high interconnection charges are not addressed. In fact, recent

[18] Only 12 VPTs were installed in the required time period.

technological innovations make much more than this possible, as we discuss in the next subsection.

India's telecoms infrastructure needs must be understood not as providing high-quality, high-speed international data links for its premier software firms, and independently providing basic local voice calling capabilities for poor villagers. While clearly what is provided is closely linked to ability to pay, the value of being part of a well-functioning network must not be underestimated, even for the bottom rung. For example, the average annual revenue per line of VPTs is estimated at $16 without long distance, and $760 with that capability.[19] The essence of a network is connectivity, and the domestic network and international gateways, fixed and wireless service, and voice and data must all be built out in a coordinated manner to maximize the value of the network to its users. The government's role should be to ensure this coordination, without stifling competition and innovation, as we discuss further in Section 5. We next discuss innovations that potentially provide cost-effective voice and data telecom access to rural and semi-rural populations. To the extent that such access can stimulate demand for IT products and services geared to the domestic market, there is a positive link between widespread telecom access and the domestic IT industry.[20]

[19] See Telecom Regulatory Authority of India (2000). Yale Braunstein has pointed out to me that this wide spread partly reflects an inefficient tariff structure, with domestic long distance and international calling being priced significantly above cost.

[20] An anecdotal example from my field research in Bathinda district of Punjab in December 2001 can illustrate: a farmer told us he had taken computer lessons, bought a home computer, and signed an Internet service contract so that he could exchange email with his brother in Toronto, Canada. All three IT-related products and services depended on basic telecom availability. See also Prahalad and Hart (2002).

Innovations

Some of the key work on innovation for Indian telecoms has been done by teams led by Ashok Jhunjhunwala, of IIT Chennai.[21] He realistically frames innovation needs in the context of economics. Affordability is critical to making widespread provision of telecoms services economically viable. Jhunjhunwala gives the example of cable services in India, which are priced at $2 to $4 per month, and have 35-40 million subscribers. At this kind of price point, however, a telecom operator in India cannot recover set-up costs for access which are about $800 using conventional technologies.

The economics of widely available telecom services in India is therefore very different from the US, where revenue per connection will be several hundred dollars per year: innovation in the US focuses on increasing revenue through upgrading services, rather than reducing the cost of providing access. The goal of innovations by Jhunjhunwala's team, therefore, has been to bring the cost of access down below $300 per line, and as close to $200 as possible. The latter figure would make access affordable to 50% of Indian households at current income levels. On the other hand, without such innovations, targets of increasing India's teledensity fourfold (from 4 to 15 per hundred), or Internet access tenfold are empty rhetoric.

With the cost of fiber-based backbones falling rapidly, it is the access component of the network that accounts for as much as two thirds of the per line cost. The IIT Chennai group and spin-offs started by alumni have developed several key innovations that can dramatically bring down the cost of access. These innovations include developments in hardware as well as

[21] See Jhunjhunwala (2000), as well as numerous presentations available on his web site, at www.tenet.res.in/ashok.html. The overall group is called the Telecommunications and Computer Network (TeNeT).

software, and address issues of network management and deployment as well as pure access issues.[22] They help bring both affordable voice and Internet access to rural areas of India.

The benefits of this suite of technologies are not restricted to rural users, but also extend to middle class and working class urban users. Current access costs using these new technologies are estimated at $400 per line, but are likely to fall with further innovation. Pilot projects in rural and urban areas appear to have been very successful, and adoption is finally gaining some traction, despite bureaucratic and policy hurdles (see Section 5).

The bottom line is that bringing down the cost of access through innovation targeted at the domestic market is a critical component of any dramatic increase in telecoms connectivity in India. Economically combining Internet and voice access also has the benefit of increasing the value of connecting to the network. The benefits accrue not just to the poor, but also to the tens of millions of lower middle class households who are currently outside the affordability radius. A denser domestic network not only increases the value of international network links, but it also provides opportunities for increasing the rate of training of IT personnel, which is a looming bottleneck (Section 3, above). Finally, the development of an indigenous hardware industry for low-cost access devices and network components has the potential to fill in gaps in India's IT capabilities on the manufacturing front.[23] For this potential to be realized, there will have to be some important policy changes. Before we turn to the policy environment, we briefly consider the organization of some aspects of India's telecoms industry.

[22] The innovations are described in more detail in Jhunjhunwala (2000). They include some wireless components, combined access to voice and Internet connections, and low-cost access devices.

[23] This does not have to mean trying to do it all in-house. India will probably never have a comparative advantage in the large-scale production of various kinds of chips, but efficient design and assembly of devices that use these chips is certainly feasible: again Dell is a useful example to bear in mind.

Industry Organization

Telecommunications was a nationalized industry before 1994, when privatization began. Privatization has consisted of auctioning off spectrum rights for wireless or mobile services, and, more recently, auctioning licenses for fixed service provision. In theory, under some specific assumptions, auctions have the property that those who can provide the greatest value (and hence reap the greatest profits) would bid the highest, achieving both revenue raising and efficiency goals for the government. In practice, the theoretical assumptions required for this result may not hold.[24]

The geographical units for which licenses have been auctioned have been quite large, presumably based on the consideration of economies of scale. Thus large domestic corporations and multinationals have tended to be the successful bidders (with some notable exceptions, such as HFCL). However, even deep-pocketed successful bidders have found that net revenue generation opportunities were more limited than expected, given the technology being used and the actual market sizes.[25] As a result, upfront license fees have been replaced with revenue sharing arrangements.

If revenue sharing is used anyway, then some of the advantages of having large firms as providers (financial strength) are attenuated. On the technology side, the work of Jhunjhunwala and his group suggests that economies of scale no longer require the service areas to be as large as states[26]. Even if there are factors such as building the backbone, which favor larger service areas, all aspects of the network do not have to be provided by the same firms. One possible

[24] In particular, it may be efficient to sacrifice revenue for lower-cost provision, as in the case of Hong Kong's approach: I am grateful to Rafiq Dossani for this example.

[25] According to Ashok Desai, (personal communication) the 35 telecom circles that made up the franchise areas do not generate enough traffic for current economic sustainability, with the exception of four metro circles. Revenue from inter-circle interconnections goes entirely to the DoT. However, the economics of the situation may change if set-up costs are brought down substantially, as innovations discussed below may achieve.

example of industry organization is that of cable TV, where small operators connect to a larger network, often operating at a level as small as a group of urban neighborhoods. Of course cable operators offer one-way, last-mile connectivity to a much larger broadcast network, and the telecoms network is somewhat more complicated in these respects. Thus the argument is not necessarily for smaller franchise areas, but for a system where tiered franchising might be possible.

A serious problem with a decentralized or franchise model of access provision is the monopoly aspect of some components of the network. A monopoly charges high prices and hence restricts output. However, even a profit-maximizing monopolist would do better to allow small access providers to connect to the backbone network at rates that allow the access provider to make a normal rate of return, than to shut them out entirely, if the small firm is more efficient in its operations. The real problem in India may be the imposition of high license fees and interconnection charges to new local providers by the biggest monopolists in the telecoms industry, namely state-owned firms. Adjusting these policies can therefore lead to an industry organization that is better positioned to take advantage of recent innovations in hardware and software for access, and more quickly extend the reach of the telecoms network.

5. Policy Environment

Since 1991, India has pursued policies of economic liberalization. Policy reform has been uneven. Controls on private industry and non-tariff trade barriers have been removed or substantially reduced. Liberalization has been slower in areas where there is clear interest group

[26] The states in India are comparable in population size and area to European countries, though of course not in terms of income.

opposition, such as labor laws and privatization. Reform has also been slow in areas where new regulatory institutions needed to be created: there is still a substantial amount of learning by doing that is taking place. Finally, government revenue considerations also affect policy decisions in areas such as import tariffs and telecoms privatization. The IT sector in India is important not just because of its performance and potential, but because these factors have influenced the policy environment in India.

Policy Goals

The overall goals of policy are quite standard: high growth together with macroeconomic stability and poverty reduction. Balancing these goals is the difficult part. For example, incentives for exports, such as tax breaks, are designed to spur growth, but may adversely affect the government's fiscal deficit. As quantitative controls have receded in importance, such tax-subsidy policies have become more significant policy components. The growth of India's IT sector, and the success of the software industry in particular, has tended to skew policy toward the industry, with targeted incentives being implemented or recommended.

Targeting incentives to the software industry is not necessarily the best method to promote the industry, nor to achieve broader goals of growth and human development. Providing implicit or explicit subsidies to the industry can introduce distortions, and it involves forgoing other uses of funds, given the severe budget constraint that the government faces. Broader promotion of the IT sector also suffers from some of the same problems. Investing heavily in government-sponsored IT-related training is problematic when basic education in India is so poorly provided by the public sector. Policy goals for the IT sector would be better met by

focusing on infrastructure provision, enabling the private sector to play a role here as well. The telecoms sector is a case in point.

The historical case for regulation or nationalized provision in telecoms was based on economies of scale, implying that competition would be unstable or inefficient. Technological change has removed this justification in significant portions of the telecoms value chain by lowering fixed costs and adding new technological options, allowing competition to become feasible. Since monopoly may persist in portions of the value chain (i.e., portions of the network), regulation of interconnection charges may still be required, to maintain a level playing field.[27] However, directly managing technology choices and competition is not easily justified on economic grounds. The broad policy goals of promoting competition and innovation in the provision of telecoms infrastructure and services are moving in the right direction, if one compares the NTP of 1999 with that of 1994, but the proposed details of implementation leave much to desired, as we discuss in the remainder of this section.

Regulatory Institutions and Laws

Broad-based growth of India's IT sector will depend on improving the telecoms infrastructure, and on training enough people for the sector and using them effectively and efficiently. For telecoms, the regulatory framework is crucial, whereas for human resource development and use, the labor laws matter greatly. It may also be noted that laws that directly constrain manufacturing remain on the statute books, and adversely affect areas such as

[27] Atanu Dey (personal communication) has pointed out to me that the solution that many countries seem to be converging on in the case of interconnection is that of 'light-handed regulation'. The parties involved privately negotiate their interconnection terms, and only in case of impasse does the regulator step in.

manufacturing or assembling hardware – the problem here is one that still affects Indian manufacturing in general.[28]

In India the regulatory institution for telecoms is the Telecom Regulatory Authority of India (TRAI), which was constituted in 1997 and substantially modified in structure and role in 2000. The new TRAI has more authority than the old, and some contradictions in the 1997 legislation have been removed.[29] However, the government's Department of Telecommunications (DOT) still has final authority over licenses and license terms. The difficulties and costs of obtaining licenses for local service provision are, in fact, a major barrier to increased competition and the implementation of the innovations discussed in Section 4. The DOT is the owner of the domestic long-distance monopolist, Bharatiya Sanchar Nigam Limited (BSNL), and the present regulatory structure involves a conflict of interest.

In general, the present TRAI has a broad scope, including establishing quality of service parameters, monitoring compliance, examining technology choices, and so on.[30] It is supposed to establish a level playing field and encourage competition, but it lacks authority precisely where it needs it the most, in setting entry fees and some interconnection charges. Unfortunately, bringing quality of service, technology choice, and universal service obligations (see below) into the regulatory mix only serve to muddy the waters, and divert attention from the central task of enabling effective competition.

Recently, the central government has introduced a Communications Convergence Bill, which is meant to establish a unified regulatory framework for voice and data communications. While this development is welcome, as our previous discussion suggests, it is the details of the

[28] I am grateful to P.D. Kaushik (personal communication) for this point – by his count, there are over 400 central government statutes governing manufacturing, as well as numerous state laws. He also notes that the software industry escaped these constraints partly by not being recognized by the government as an industry by itself.
[29] See Dossani and Manikutty (2000) for details.

regulatory set-up and its implementation that will matter most, rather than the recognition of technological convergence. One practical development that promises to be significant is the announcement that voice calls over the Internet (VoIP) will be allowed from April 2002. As of end-2001, the convergence Bill itself was still winding its way through the legislative process.

Desai (2000) examines the problems of labor laws, using the Report of the Subject Group on Knowledge-Based Industries (2000) as his starting point. The report calls for exemption for the IT sector from a broad set of rules relating to labor, including provisions relating to overtime, working conditions, restrictions on contract labor, and dismissal of workers. Interestingly, if IT workers are in short supply, they should be able to negotiate terms that are attractive enough to make the labor laws redundant. Desai suggests that the main function of the labor laws in this sector is to enable government labor inspectors to demand bribes. He also argues for broader reform of labor laws, and rightly points out the potential for distortions if one sector is given an exemption. He also acknowledges the political difficulties of more comprehensive reform. In this case, the IT sector may usefully serve as the thin edge of the wedge that begins cutting down some of the worst problems with India's labor laws, in particular the lack of permitted flexibility in contracting.

Access and Efficiency

One interesting feature of recent policy pronouncements and targets has been the emphasis on increasing access to telecommunications. This contrasts greatly with previous Indian policy views of telephones as luxuries. Universal service obligations are being built into licensing deals for private service providers. These take the form of quantitative targets for

[30] See for example, the paper by M.S. Verma, Chairperson of the TRAI (Verma, 2000).

installing rural telephones. As we have discussed earlier, there are problems with enforcing such requirements. In fact, it is not clear that numerical targets of this sort have any use at all, especially when licensing and interconnection fees make it uneconomical for local access providers with lower-cost technology to enter.

A different issue is the problem with cross-subsidization when the user base is so small. A literal universal service obligation (USO) with cross-subsidization within the sector would require taxes on this small customer base to support providing access to new users. This model is inherently unworkable, as pointed out by Dey (2000). USOs have worked in circumstances where the user base is the great majority of the population. Imposing a USO prematurely, as Indian policy now seeks to do, makes no sense. The problem is even more striking when the contradiction between government USO rhetoric and government-imposed entry barriers is noted. Subsidizing entry by new competitors makes more sense than imposing quantitative targets that are hard to enforce meaningfully. There are similarities between the requirements imposed on new private entrants to install VPTs and the traditional mechanisms of Indian planning, which have emphasized spending money on projects without making them economically viable enough so that they actually provide a stream of benefits.

Ultimately, neither the TRAI nor the DOT will be able to effectively manage quality of provision, technology choices, or true availability of access. Instead, the focus should be on actually achieving a policy environment where competition is effective. When consumers have the option to switch, this will force competitors to pay attention directly to quality of service and technological efficiency. When firms can make profits extending the network, without being blocked or impeded by government fees and restrictions, they will provide access efficiently.

This scenario may have been impossible just a few years ago, but technological change has altered the possibilities, and government policies have to catch up.

6. IT as Growth Engine

Ultimately, the case for IT as an engine of growth rests on standard economic criteria, such as comparative advantage, complementarities, and global dynamics. Briefly, the IT sector can be an important source of growth for India if the country has a comparative advantage in providing certain kinds of IT-related products and services, if the global demand for these products and services is likely to grow rapidly, and if the growth of the sector has positive spillover benefits to the rest of the domestic economy. Furthermore, these conditions are not purely exogenous, but are partly functions of economic policy. We examine these considerations in this section.

Value Added

The static theory of international trade is based on comparative advantage, determined by relative factor endowments and/or technology differences. Empirically testing this theory is difficult, however, since other factors may also be at work. For example, intra-industry trade driven by product differentiation and economies of scale may involve different trade patterns than those based on traditional comparative advantage. In the case of software exports, attributing the export boom to comparative advantage does seem reasonable.[31] We have noted India's pool of workers with software and language skills that are valued in the international

market: they are the source of India's comparative advantage in at least some segments of the software industry.

The comparison of software exports involving coding and testing with garment exports and sweatshops, while typically made in a negative manner, actually has positive implications for India's software industry. While India missed the boat with respect to the labor-intensive manufactured exports that contributed to the East Asian miracle, it is now in a position to replicate this phenomenon with labor-intensive software services and (even more in terms of labor-intensity) IT-enabled services. Even if exports of this nature cannot sustain growth rates of 50% (and the recent slowdown seems to confirm this caution), they can make a substantial contribution to India's economic growth. For example, 20% growth in a sector that is only 5% of the economy still adds one percentage point to overall economic growth. In the very short run, therefore, moving up the ladder of value added (or establishing a broader hold on the value chain) may not be a critical issue. This strategy also addresses brain drain issues if large numbers IT professionals are so highly trained that they simply migrate to developed countries.[32]

There are two reasons for not stopping here, however. The first is a defensive one: greater automation of software development and the emergence of other low-labor cost sources of competing IT skills[33] may lead to export growth falling or even reversing as global demand for Indian programming services slows or falls. The second reason is that it may be possible to do even better. Comparative advantage is not fixed, but can evolve over time. There are now numerous formulations of endogenous determination of innovation and growth with international trade, and they suggest that countries may be able to move toward producing higher value-added

[31] Note that, to the extent that India is providing intermediate goods or services in its software exports, the situation is more complex than that of standard trade theory, where only final goods are traded.
[32] As we noted earlier, Desai (2000) is the source of these perceptive observations.
[33] These include other Asian countries such as China and the Philippines, but also the countries of the former USSR.

goods and services as they grow, with favorable consequences for long run growth.[34] Applying these models is not an automatic proposition, since results are sensitive to assumptions. For example, learning by doing in manufacturing (including software production in this abstract conception) gives different outcomes than the assumption of a separate R&D sector that competes with manufacturing for skilled labor.

If we accept the potential theoretical benefits of moving up the value added ladder, what does this mean in practice for India's software industry? One possibility is offering higher value added component services, involving design and strategy. Another is offering more complete packages or bundles of services. The latter differs from the former in that a higher management component is included in the package than in particular aspects of software development, even if those require more technical skill. While the slowdown in the US that began in 2001 will hamper these developments in India, there is no reason why Indian software firms cannot enter such markets. A growing number of professionals with combinations of engineering and management skills will help in this area.[35]

Companies such as TCS have long-standing domestic and developing country consulting expertise, but they may be less suited to compete in a crowded US market than India's new software giants such as Infosys and Wipro, or smaller newcomers such as TechSpan, MindTree and Planetasia.[36] What is the possible competitive advantage of these firms? Certainly lower costs will help, but these may be better used to provide upgraded or broader services, rather than in competing on price alone. In particular, empirical research (Banerjee and Duflo, 2000) shows that reputation effects are quite important for Indian software exporters. Such companies may

[34] In particular, see Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991a,b).
[35] Similar considerations apply to IT-enabled services, where there is also a value added ladder going from data entry and conversion through rule-set processing, problem-solving and direct customer interaction, to expert "knowledge services". See *The Economist* (2001b), p. 60, where this classification is credited to Raman Roy.

also develop a strong niche in other developing countries, where lower prices may be more important. A high tech slowdown in the US may actually aid the development of such firms in India, if it leads to some reversal of the brain drain.[37] Otherwise, managerial and high-level technical skills may constrain movement up the value added ladder. In some cases, including consulting as well as IT-enabled services, multinational firms have relaxed some of the managerial constraints through their own entry, importing managers as well as training local ones.

The Domestic Market

The domestic market for IT products and services is certainly not independent of the export market. To the extent that Indian software firms can compete successfully abroad, they can also succeed in their own backyard. In fact, they should have an advantage in the domestic market, in knowing their customers better, and being closer to them. On the other hand, a poor domestic infrastructure, dependence on imported hardware, late mover disadvantages, and lack of economies of scale and learning by doing, can all reduce or eliminate any advantage that Indian software firms might have over foreign competitors.

Two mitigating factors operate on potential disadvantages of Indian firms. First, some of the problems are faced by all firms, irrespective of location: for example, entering the market for desktop operating systems in the face of Microsoft's dominance is difficult, if not impossible, for any firm anywhere in the world. Second, the boundary lines between domestic and foreign can be blurred when multinationals have Indian subsidiaries, particularly for IT or IT-enabled services. In such cases, the effects on the local economy are not that different from when these

[36] See Das (2001) for a discussion of the Indian e-business consulting market.

services are provided by Indian firms. Two differences in the case of multinationals, however, are in profit repatriation and the creation of another brain drain channel, if Indian employees of multinationals can be assigned to other countries (as often happens).

At the level of business software and software services, therefore, it seems that issues for the domestic market boil down to the same concerns as for export markets. These are availability of the key inputs, namely various types of skilled IT personnel and managerial and marketing skills. Location and ownership are not of direct importance, but are only proxies for whether the IT software and services provider has the right combination of people, knowledge, experience and reputation to compete successfully. Liberalization in general means that all Indian firms face the challenge of building such combinations of assets. The software industry happens to be significant because it has developed independently of India's traditional business houses, and hence mostly free of the bad habits those business groups developed over many decades of operating in noncompetitive environments.

The nature of information goods in general is that they involve high fixed costs of production and low marginal costs. While customization and service provision mitigate this property, they do not negate it. Reputation and experience effects, on the other hand, enhance economies of scale and scope. Hence it is important for Indian software firms to compete simultaneously in domestic and export markets, in order to take advantage of these economies. This is true even though the product-service mix that is being sold in different markets is going to be somewhat different.

We have focused the discussion so far on software. Hardware may offer additional opportunities to Indian IT firms in the domestic market. In developed countries, particularly the

[37] For a description of how Infosys is struggling with the tech slowdown, to "transform itself…from a great code-writer to a one-stop technology services provider", see Bjorhus (2002).

US, the establishment of the PC market took place well before the Internet took off. PC prices are low enough relative to incomes that a large number of households prefer to have an-all purpose device that enables Internet access, rather than a more limited, but cheaper "network appliance". Internet access (providing access to large quantities of information, entertainment, and an inexpensive communications channel) is probably the most attractive use for many potential consumers of IT in India but Internet penetration may not go far enough with hardware designed for developed countries. Internet cafes, with shared access, are a partial solution, but their economics may still restrict them to middle class households.

The possibility of designing and building lower-cost access hardware in India may represent an opportunity for the domestic IT industry. While India has tried to develop a domestic hardware industry since the 1980s, it has not succeeded in establishing an industry that is efficient and globally competitive.[38] Much of the problem has lain with lack of scale and infrastructure. For components such as sophisticated chips, this will continue to be the case, but, as noted earlier, Indian industry can build on existing capabilities in assembly of standardized components. If some of these components are designed specifically for the broader Indian market, for example to go into low-cost Internet and telecom access devices, as envisaged by the IIT Chennai group, where they are built may not be crucial.[39] We note once more that Dell is a profitable company because it serves targeted markets efficiently, not because it manufactures sophisticated components. Instead, management and infrastructure are the key inputs that are required.

[38] See Hanna (1994), for example, for further details.
[39] The most immediate example of this possibility is the 'Simputer', designed by scientists from the Indian Institute of Science. The portable $200 device will use some parts manufactured in Singapore, Linux-based software developed in India, and run on 3 AAA batteries.

Broad-Based Growth

Are a software industry that serves the domestic market as well as exporting, a hardware industry that can produce low-cost access devices, and IT-enabled services for foreign markets, together enough for broad-based economic growth? Clearly the IT industry alone can only contribute one or two percentage points to India's growth rate. The concern is that it will remain an enclave, exacerbating inequality, and doing little for long-run growth. Even in the US, tall claims for the benefits of IT for the broader economy, through enhanced productivity growth, are met with skepticism, and the evidence from varied studies is mixed.[40]

While one may hesitate, therefore, to claim that IT is the answer to India's ills, there are reasons to argue that it potentially has beneficial effects beyond its direct contribution to growth. The argument one can make is rooted in standard analysis from development economics.[41] To the extent that IT can have significant effects on the efficiency of operations in other industries, there are strong *complementarities* between the IT sector and the rest of the economy. Examples of areas where increased efficiency may be possible include accounting, procurement, inventory management, and production operations.[42] This is, of course, the standard argument in the US for the virtues of the "new economy" based on the Internet. It should be recognized that the difference for India is that it is starting from a much lower level of IT-adoption, and the potential gains may be higher. In fact, developing countries have the opportunity to leapfrog over older,

[40] See, for example, Pohjola (1998) and Woodall (2000).
[41] A general discussion of the concepts presented next can be found in Ray (1998), which also provides detailed source references.
[42] These are all examples of what are also known as "forward linkages", since IT adoption has positive impacts on the operations of a range of industries. The effect of the growth of the IT sector on the provision of technical education would be an example of a "backward linkage". In either case, there is a complementarity at work.

more expensive approaches such as Electronic Data Interchange, which represent significant legacy investments in countries such as the US.

The usual concern with IT-adoption is job loss, and there is certainly the potential that certain kinds of clerical jobs will be eliminated or reduced in numbers. Unions in Indian industries such as banking have opposed "computerization" for this reason. However, the evidence suggests that increases in other kinds of jobs as a result of IT use more than make up for job loss, so that total employment is not a significant issue. This leaves the issue of adjustment costs, and here severance pay rules or government job adjustment assistance can be more effective and efficient than the current morass of detailed restrictions embodied in India's labor laws. This is why Desai (2000) is right to stress the importance of broader labor law reform if the benefits of growth in India's IT sector are to be fully realized.

In the context of complementarities, it is also important to recognize that these effects are not just in terms of cost savings. IT implementation may enhance the quality of service beyond anything that is feasible through other methods. Furthermore, depending on who the "customers" are, the benefits may accrue to a broad cross-section of the population. Improved efficiency in the stock market as a result of automated trading and settlement may benefit a small section of the population (though the indirect benefits of greater capital market efficiency may be broader). The use of IT in banking may impact only the middle classes.[43] However, the computerization of the Indian Railways' reservation system has had tremendous benefits for the masses who use this mode of transportation. To summarize, the existence of these benefits, and of efficiency gains, together representing the working of complementarities or linkages, is an argument against the "enclave" view of the IT sector in India.

[43] P.D. Kaushik has suggested to me that rural banking and other financial services may be substantially improved through the use of IT.

Note that potential benefits do not necessarily translate into actual ones. Firms and managers can make mistakes. However, this is no different from any other kind of investment. The point is that, in a reasonably competitive industry, with sufficient information available, there is always pressure to make the right decisions, rewards for those who do, and punishments for those who do not. Indian industry must be allowed to follow this model to realize the potential benefits of IT. If it is discouraged from making such investments, the domestic market for Indian IT will not grow, with negative consequences for the IT sector as a whole.

We have focused implicitly so far on the formal, organized or "large-scale" sector in assessing the impact of IT. Even if the growth of the IT has positive spillovers for other industries, this leaves out a substantial portion of the economy. We postpone a discussion of government use of IT to a separate section, but now turn to issues of truly broad-based impacts of IT. There are two related, but separate areas of impact. First, information processing may enhance efficiency in agriculture as well as in manufacturing. While individual farmers cannot make IT investments, agricultural cooperatives can provide the institutional framework that allows farmers to benefit. For example, Chakravarty (2000) gives the example of IT use at milk collection centers in cooperative dairies. This permits faster and safer testing, better quality control, quicker and more accurate payments to farmers, and time savings for farmers in their deliveries. The falling cost of information processing means that such success stories can potentially be widely replicated.

The second impact is in the communication of information. Here the case studies are legion. Farmers and fishermen can receive weather forecasts, market price quotes, advice on farming practices, and specific training. Offers to buy or sell livestock, or other two-way communications are also possible. Some of this information dissemination and exchange is best

done through voice media, while other types require the capabilities of the Internet. Some evidence suggests, not surprisingly, that richer farmers and fishermen, as well as middlemen, are faster adopters of such technologies (*The Economist*, 2001a), but falling access costs, through innovations such as those of the IIT Chennai group, should broaden information access and its benefits. Broad-based benefits of IT require broad-based access to the network, as we have discussed in Section 4.

Ultimately, the central feature of the information revolution has been the dramatic fall in the costs of information processing, storage and transmission (see Table 2). It is this fundamental technological fact that makes IT special or different from other sectors. It is this fact that makes IT of potential value to the masses of a poor country such as India. The challenge is to translate this potential into cost-effective, valued products and services. Meeting this challenge requires a policy environment within which entrepreneurial energy can flourish.

Table 2: Falling Costs of Computing ($)

Costs of computing	1970	1999
1 Mhz of processing power	7,601	0.17
1 megabit of storage	5,257	0.17
1 trillion bits sent	150,000	0.12

Source: Pam Woodall, "The New Economy: Survey," *The Economist*, September 23, 2000, p. 6, Chart 1.

Economic Policies

The issue of economic policy is obviously much larger than we can adequately tackle here. However, we will briefly comment on general microeconomic and macroeconomic policy issues, and then address specific policies for the IT sector. The two areas may, of course,

overlap. For example, the growth of the IT sector and of software exports in particular, may make certain kinds of general policy questions more salient.

We have noted, in Section 2, the central areas of India's policy reforms: replacing quantitative trade restrictions with tariffs, lowering effective levels of protection, removing an area of discretionary controls on private sector investment, and creation of modern financial markets. Standard examples of where these reforms can be built upon, to further stimulate growth, include removal or relaxation of obsolete "small-scale sector" reservations and size restrictions, privatization of inefficient state-owned enterprises, rationalization of tax-subsidy policies and tax administration, and relaxation of severe labor market restrictions. This list can be characterized by its emphasis on improving the efficiency of the mechanisms with which the government directly affects the private sector. The entire Indian economy, not just the IT sector, can presumably benefit from such reforms, which will reduce distortions of private sector behavior.

A second area where attention is required may be characterized as enabling reforms. These include reforms of contract law and judicial institutions; financial sector regulatory institutions; telecom sector regulatory institutions; infrastructure such as electric power, roads and ports; and systems of education and training in general.[44] Again, the benefits of such reforms are potentially quite general, and not restricted to any one sector of the economy.

A third area of policy is macroeconomic management. While India's record here is quite good, it needs to make a transition in its policy institutions here as well, since removing detailed microeconomic controls requires changes in the regulatory modes of macroeconomic management. Perhaps the area that has received the most attention is policies toward

international capital flows and their implications for exchange rate management. Desai (2000) has suggested that large projected increases in software exports could create a "Dutch disease" phenomenon,[45] in which a resulting exchange rate appreciation hurts other sectors, and revenues from exports are wastefully spent. Several factors mitigate this concern: the likelihood that export revenue growth will slow down from recent levels; the substantial linkages that exist between software, the IT sector as a whole, and the broader economy (unlike natural resource extraction enclaves); and a better understanding of exchange rate management than existed 25 years ago, when the phenomenon first was identified and labeled. Our conclusion, therefore, is that, while exchange rate policy is certainly important in general, the growth of the IT sector will not necessarily raise special concerns.

Given that there is plenty that remains to be done in terms of overall economic policy reform, are there areas where the IT sector deserves special attention? The answer we give here, with one partial exception, is "no". Special subsidies or export incentives are likely to be inefficient ways of stimulating the growth of the IT sector, or of positive spillovers for the rest of the economy. Similarly, special central government initiatives to increase the availability of IT training and related education are also likely to represent a mistargeting of scarce government resources. The same stricture applies, to some extent, to state government policies to encourage the IT sector.[46] In these cases, the government may be better off removing general restrictions to

---

[44] Problems of primary education have been well recognized: see Dreze and Gazdar, (1997) for example. While higher education has been *relatively* favored, the public monopoly here is also failing to deliver effectively, as pointed out perceptively in a recent piece by Panagariya (2001).

[45] The best simple explanation of Dutch disease I have come across is by John McLaren, at www.columbia.edu/~jem18/teaching/pepm/dutchdis.pdf. McLaren clarifies the source of concerns that are associated with Dutch disease, including exacerbation of *prior* distortions, and of inequality.

[46] Bangalore in Karnataka is well known as a regional IT center in India, having developed initially without much explicit government support. The governments of Andhra Pradesh (Eischen, 2000) and Tamil Nadu (Bajpai & Radjou, 1999, and Bajpai & Dokeniya, 1999) have led in attempts to establish IT-based industries with conscious government policies. Other state governments, such as Punjab (see www.dqindia.com/mar1599/news.htm) are following suit.

doing business, as well as providing an enabling institutional infrastructure (appropriate laws and regulations), rather than attempting to target the IT sector through a form of industrial policy. Thus, for example, allowing greater private (particularly IT industry) initiative in training and certification of IT professionals makes more sense than the creation of new government institutes.

The partial exception lies in the telecom sector, which, as discussed in Sections 4 and 5, has particularly strong complementarities with the broader IT sector. Development of the telecom sector is certainly critical, but rather than setting unrealistic quantitative goals and trying to bureaucratically manage change, policies to achieve development goals would do better to emphasize removing barriers to innovations that will support lower-cost access to telecom networks of all kinds (wireless and fixed, voice and data). Interconnection charges and licensing fees are the main policy instruments that need attention in this respect, encouraging competition rather than forcing unrealistic cross-subsidization targets on large private monopoly or duopoly licensees.

Governance

One area where government can provide indirect support for the IT sector is by boosting the domestic market though its own purchases. Of course purchases of sophisticated equipment and software that sits unused in high-level bureaucrats' offices will have little positive impact. However, there are reasons to be more optimistic about the use of IT in government.

There are two broad uses of IT for improved government functioning. First, back-office procedures can be made more efficient, so that internal record keeping, flows of information, and tracking of decisions and performance can be improved. Second, when some basic information is

stored in digital form, it provides the opportunity for easier access to that information by citizens. The simplest examples would be e-mailing requests or complaints, checking regulations on a web page, or printing out forms from the web so that a trip to pick up the forms from a physical office can be avoided. More complicated possibilities are checking actual records, such as land ownership or transactions. Still more complicated are cases where information is submitted electronically by the citizen.

What is encouraging is the number of examples of successful pilot e-governance programs that have made some of the above actions possible. These examples include:

- Computer-aided registration of land deeds and stamp duties in Andhra Pradesh, reducing reliance on brokers and possibilities for corruption
- Computerization of rural local government offices in Andhra Pradesh for delivery of statutory certificates of identity and landholdings, substantially reducing delays[47]
- Computerized checkpoints for local entry taxes in Gujarat, with data automatically sent to a central database, reducing opportunities for local corruption
- Consolidated bill payment sites in Kerala, allowing citizens to pay bills under 17 different categories in one place, from electricity to university fees
- E-mail requests for repairs to basic rural infrastructure such as hand pumps, reducing reliance on erratic visits of government functionaries[48]

While the extent of such programs, and therefore their benefits, are still very limited, one of the essential characteristics of information is that it is a non-rival good. Hence there is every reason to believe that the economics of such projects will continue to improve, particularly if costs of access continue to fall. It is important to note that once Internet access is available, its

[47] These two examples are from Bhatnagar and Schware (2000), which also provides broader examples, including ones driven more by the efforts of NGOs than governments.

benefits are not restricted to e-governance. Individuals can obtain market information, training, job information, advice on farming techniques, and so on, as discussed earlier in this section. There are economies of scope as well as of scale. Also, Metcalfe's "Law", that the value of a network is approximately proportional to the square of the number of users, probably holds with full force in many Indian contexts.[49] Denser local communications networks are likely to aid economic activity in general.

Given the poor quality of governance in India, one is therefore inclined to strongly favor e-governance initiatives that provide direct benefits to citizens, particularly those who are less well off (the rich in any case hire intermediaries to collect information, make payments, etc.). Here we suggest that in addition to the direct benefits, there may be advantages through support of the growth of the domestic market. Increasing the size of the market, while encouraging competition, may be more cost-effective for the government than any direct subsidies or incentives to the IT industry.

7. Conclusion

Our goal in this paper has been to assess the possible role of India's IT industry as a driver of higher economic growth in India, without exacerbation of inequalities or creation of instability. Our conclusion is cautiously positive. While projections for software exports may be over optimistic, complementarities or spillovers in the domestic market, including increased government use of IT, are likely to be strong. For this rosy scenario to play out, however,

[48] These three examples are from India Today (2000), which also lists several other similar projects.
[49] Ashok Desai raised the issue of how Metcalfe's "Law" and economies of scale can be consistent with a model of small private competitors. I think that a distinction that helps here is between ownership and usage. Usage networks are where demand side economies of scale matter. On the other hand, on the supply side, ownership networks can be smaller, as long as interconnection charges are regulated appropriately.

continued broad economic reforms will be important, as well as reforms in the telecom sector that promote competition and innovation in providing last-mile access. These reforms include reductions of licensing barriers to entry and high interconnection charges for higher levels of the network. Such enabling reforms are more likely to support broad-based, sustainable growth than narrowly targeted incentive schemes.

References

Aggarwal, Balaka B. (2001), Faculty scarcity at IITs threatens knowledge capital, March 19, http://www.ciol.com/content/news/trends/10103902.asp.

Arora, Ashish and V. S. Arunachalam (2000), The globalization of software: the case of the Indian software industry. A report submitted to the Sloan Foundation. Carnegie Mellon University, Pittsburgh PA. http://www.heinz.cmu.edu/project/india/publications.html.

Arora Ashish, V. S. Arunachalam, Jai Asundi and Ronald Fernandes (2001a), The Indian Software Service Industry, *Research Policy*, 30, 1267-1287.

Arora Ashish, Alfonso Gambardella and Salvatore Torrisi (2001b), In the footsteps of the Silicon Valley? Indian and Irish Software in the International Division of Labour, paper presented at the conference, 'Silicon Valley and its Imitators', Stanford Institute for Economic Policy Research, July 2000.

Bajpai Nirupam and Navi Radjou (1999), Raising the Global Competitiveness of Tamil Nadu's Information Technology Industry, Development Discussion Paper No. 728, October, Harvard Institute for International Development.

Bajpai, Nirupam and Anupama Dokeniya (1999), Information Technology-Led Growth Policies: A Case Study of Tamil Nadu, Development Discussion Paper No. 729, October, Harvard Institute for International Development.

Banerjee, Abhijit V. and Esther Duflo (2000), Reputation Effects and the Limits of Contracting: A Study of the Indian Software Industry, *Quarterly Journal of Economics*, 115,3, 989-1017.

Bhatnagar, Subhash and Robert Schware (2000), *Information and Communication Technology in Development: Cases from India*, New Delhi: Sage Publications.

Bjorhus, Jennifer (2002), India's Infosys Struggles through Transformation, *San Jose Mercury News*, February 11, 1E.

Business Week (2001), India 3.0: Its software outfits take on the world, February 26, 44-46.

Das, Shyamanuja (2001), The Indian Challenge: Will They…Or Won't They?, March 7, http://voicendata.com/content/top_stories/101030703.asp.

Dataquest (2001), SW INDUSTRY: Working around the Slowdown, February 14, http://dqweek.ciol.com/content/search/showarticle.asp?artid=21244.

DQ Week (2001), Medical Transcription: Not in the Pink of Health, February 2, http://www.ciol.com/content/search/showarticle.asp?artid=21128.

Desai, Ashok V (2000), The Peril And The Promise: Broader implications of the Indian presence in information technologies, Working Paper, August, CREDPR, Stanford University.

Dey Atanu (2000), New Telecom Policy 1999: A Critical Evaluation, paper presented at Conference on Telecommunications Reform in India, Asia/Pacific Research Center, Stanford University, November 9 & 10.

Dossani, Rafiq and S. Manikutty (2000), Reforms in the Telecommunications Sector in India: An Institutional View, paper presented at Conference on Telecommunications Reform in India, Asia/Pacific Research Center, Stanford University, November 9 & 10.

Drèze, Jean and Haris Gazdar, (1997), Uttar Pradesh: The Burden of Inertia, in Amartya Sen and Jean Drèze, *Indian Development: Selected Regional Perspectives*, Delhi: Oxford University Press.

Economist, The (2001a), Another kind of net work: Mobile phones in India, March 3, 59.

Economist, The (2001b), Outsourcing to India: Back office to the world, May 5, 59.

Eischen, Kyle (2000), National Legacies, Software Technology Clusters and Institutional Innovation: The Dichotomy of Regional Development in Andhra Pradesh, India, University of California, Department of Sociology.

Grossman, Gene and Elhanan Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, MA: MIT Press.

Hanna, Nagy (1994), Exploiting Information Technology for Development: A Case Study of India, World Bank Discussion Paper 246.

Heeks, Richard (1998), The Uneven Profile of India's Software Exports, IDPM Working Paper No. 3, October, University of Manchester.

Heeks, Richard (1996), *India's Software Industry: State Policy, Liberalisation and Industrial Development.* Sage Publications, New Delhi, Thousand Oaks and London.

India Today (2000), Is e-Governance for Real?, December 11, pp. 70-75.

Jhunjhunwala, Ashok (2000), Unleashing Telecom and Internet in India, Paper presented at the Conference on Telecommunications Reform in India, Asia/Pacific Research Center, Stanford University, November 9 & 10.

National Association of Software and Service Companies (2000a): Indian IT industry. New Delhi. http://www.nasscom.org/template/indianitss.htm.

National Association of Software and Service Companies (2000b): Indian software and services industry. New Delhi. http://www.nasscom.org/template/itinindia.htm.

Panagariya, Arvind (2001), Abolish this Monopoly, *Economic Times*, March 28.

Pohjola, Matti (1998), Information Technology and Economic Development: An Introduction to the Research Issues, WIDER Working Paper No. 153, November, United Nations University.

Prahalad, C. K. and Stuart L. Hart (2002), The Fortune at the Bottom of the Pyramid, http://www.strategy-business.com/media/pdf/02106.pdf.

Ray, Debraj (1998), *Development Economics*, Princeton: Princeton University Press.

Rivera-Batiz, Luis A. and Paul M. Romer (1991), Economic Integration and Endogenous Growth, *Quarterly Journal Of Economics*, 106, 2:531-555.

Rivera-Batiz, Luis A. and Paul M. Romer (1991), International Trade With Endogenous Technological Change, *European Economic Review*, 35, 4:971-1004.

Saxenian, AnnaLee (2000), The Bangalore Boom: From Brain Drain to Brain Circulation?, forthcoming in Kenneth Keniston and Deepak Kumar, eds., *Bridging the Digital Divide: Lessons from India*, Bangalore: National Institute of Advanced Study.

Saxenian, AnnaLee (2001), Bangalore: The Silicon Valley of Asia?, Working paper No. 91, Center for Research on Economic Development and Policy Reform, Stanford University, February.

SGKI (2000), Subject Group on Knowledge-based Industries, Prime Minister's Council on Trade and Industry. *Recommendations of the Task Force on Knowledge-based Industries.* Prime Minister's Office, New Delhi. http://www.nic.in/pmcouncils/reports/knowl/

Telecom Regulatory Authority of India (2000), Consultation Paper on Issues Relating to Universal Service Obligations. TRAI, New Delhi, July 3.

Verma, M. S. (2000), TRAI's Objectives and Policy Focus In A Changing Environment, Paper presented at the Conference on Telecommunications Reform in India, Asia/Pacific Research Center, Stanford University, November 9 & 10.

Woodall, Pam (2000), The New Economy, *The Economist*, September 23, Survey p. 6.