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INDIA'S INFORMATION TECHNOLOGY SECTOR: WHAT CONTRIBUTION TO BROADER ECONOMIC DEVELOPMENT?

by

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PREFACE

Until now, India has barely participated in the manufacturing export boom that has long fuelled East Asia's growth. It has, however, established itself as a leading exporter of software and information technology (IT) -enabled services to OECD markets. Software has been a leading growth sector over the past decade and expectations are that it can continue in this role for some time to come. Yet, the industry and its major participants face new challenges and potential constraints on realising that potential. There is also the question of how far the benefits of the software/IT sector's growth are reaching the Indian masses as opposed to a small, educated elite. To explore the prospects for India's software industry and its contribution to broad-based economic development, the OECD Development Centre, in co-operation with the State Government of Tamil Nadu and the Union Government of India, held an international conference on 11-12 November 2002 in Chennai, India. The conference completed the Centre's 2001-2002 Programme of Work on "Globalising Technologies and Domestic Entrepreneurship in Developing Countries".

This Technical Paper was originally presented at the Chennai conference. The author, from the University of California, Santa Cruz, argues that, from a theoretical standpoint, IT can be seen as an especially potent contributor to growth, deriving from its character as a general purpose technology (GPT) and the complementarities and linkages associated with GPTs. On this basis, he makes the case for government's removing some of the regulatory barriers that have hitherto slowed the rate of IT diffusion, and in particular of telecommunications and Internet access, in rural areas of India. On the other hand, he cautions against government's providing special subsidies to IT software or hardware sector development. Far more critical is the continuation of the broad economic reform process that gained momentum in the early 1990s and that, if successful, would lower the costs of capital and of doing business to all economic sectors, stimulating competition and inducing wider IT adoption in domestic manufacturing and services.

The findings of this paper may be specific to the Indian IT sector, but they are also relevant for other developing countries seeking to foster growth through modern industrial development. The struggle to balance what might be technically correct with what might be politically feasible, goes on.

Jorge Braga de Macedo
President
OECD Development Centre
24 March 2003

RÉSUMÉ

Quelle contribution les technologies de l'information peuvent-elles apporter au développement économique de l'Inde dans son ensemble ? Ce Document technique propose un cadre analytique fondé sur les concepts d'avantage comparatif, de complémentarités et d'innovation. Il est clair que l'Inde possède un avantage comparatif important et durable en matière de développement de logiciels et de services informatiques. Les complémentarités — en particulier une industrie nationale de composants informatiques ainsi qu'une demande croissante de logiciels sur le marché national — sont également importantes pour maintenir la croissance dans le secteur informatique, ainsi que pour élargir son impact sur le développement. Cet article examine également les expériences innovantes d'utilisation de l'informatique visant à améliorer les interactions entre citoyens et gouvernements, agriculteurs et entreprises, et entre étudiants et professeurs dans les zones rurales.

Un bref débat sur les perspectives de croissance dans le secteur des services informatiques, sur les contraintes d'une telle dynamique et sur les réponses politiques possibles en la matière conclut ce Document. L'Inde se heurte actuellement à des obstacles réels et potentiels dans divers domaines, comme les infrastructures, la disponibilité de main-d'œuvre qualifiée et le financement d'activités productives susceptibles de limiter la contribution des technologies de l'information à un développement économique plus large. Poursuivre et accélérer les réformes transversales en matière de législation du travail et de l'investissement ainsi que les privatisations serait préférable à s'en tenir étroitement au tandem taxes/subventions et autres incitations spécifiques au secteur informatique.

SUMMARY

What contribution can information technology (IT) make to India's overall economic development? This paper provides an analytical framework centred around the concepts of comparative advantage, complementarities, and innovation. There is strong evidence that India has a strong and sustainable comparative advantage in software development and IT-enabled services. Complementarities — in particular some form of domestic hardware industry as well as growing demand for software within the domestic market — are also important to sustain the growth of the IT sector, as well as to broaden its developmental impact. The paper also reviews innovative experiments of IT use to improve interactions between citizens and governments, farmers and corporations, and students and teachers in rural areas. The paper concludes with a brief discussion of opportunities for future growth in IT-enabled services, constraints to such dynamics, and possible policy responses. India faces existing and potential bottlenecks in areas such as infrastructure, availability of a skilled labour force, and financing of entrepreneurial activity that can hinder the contribution of IT to broader economic development. Continuing and accelerating cross-cutting reforms in areas such as labour and investment laws and in privatisation is preferable to narrowly targeted tax subsidies and other incentives on the IT sector.

I. INTRODUCTION

In his foreword to the new NASSCOM-McKinsey Report (2002), India's Minister for Communications and Information Technology calls for a joint industry-government effort to "ensure that the Indian IT sector remains a dominant player in the global market, and that we emerge as one of the leading countries of the new millennium". The first of these goals remains a challenge, but it is one for which India's IT industry seems to be well prepared. The second stated goal is much broader, much deeper, and much harder to achieve. Does it make sense to pin so much hope on India's IT industry? What contribution can it make to India's overall economic development? Can it help change the country, reduce poverty, change people's lives for good? Or will the benefits be restricted to an educated elite with access to jobs and power? This paper offers some perspectives that can help answer these questions, using concepts and analysis from economic theory.

A brief review of the IT industry is provided in this introduction. The remainder of the paper is structured as follows. Section II provides several possible answers to the question of what might make IT special for growth and development. Section III examines some of the evidence concerning whether the theoretical perspectives have empirical relevance for India. Section IV discusses the opportunities that exist for future industry growth and broader developmental impacts, and the constraints that the industry and the economy face. Section V provides some reflections on policy implications of the earlier discussion, and Section VI is a summary of the conclusions.

IT in India

Information technology essentially refers to the digital processing, storage and communication of information of all kinds[1]. Therefore, 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[2]. 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. An example of IT's broader impact comes from the case of so-called IT-enabled services, a broad category covering many different kinds of data processing and voice interactions that use some IT infrastructure as inputs, but do not necessarily involve the production of IT outputs. India's figures for the size of the IT sector typically include such services.

The numbers on India's software exports are well-publicised (www.nasscom.org). The latest figures on the software and services sector indicate that annual revenue was Rs.480 billion ($10.1 billion) in 2001-02, up from Rs.382 billion ($8.4 billion) in 2000-01 (NASSCOM, 2002*a*) This translates into overall growth of 26 per cent in rupee terms and 20 per cent in dollar terms. While growth rates have been high, India's IT sector is still small, relative both to the world market and to India's GDP. World sales of software and services in 2000 were $440 billion (Desai, 2002*b*). Even if this did not grow at all, India's 2001-02 sales would be just about 2 per cent of the world market. To compare the software sector to GDP, one has to estimate the fraction of sales that constitutes value added. Assuming this fraction to be two-thirds would imply that software directly contributed about 1.5 per cent to GDP. The latest NASSCOM figures no longer include hardware and peripherals, whereas they did earlier (Singh, 2002). Using earlier calculations, the broader IT sector is probably one third again as big, allowing for slower hardware growth. This would imply that the IT sector is about 2 per cent of GDP.

Despite India's emphasis on import-substituting industrialisation, it has not developed a robust, world-class manufacturing industry, and this includes IT hardware. Much of India's hardware industry consists of assembly tasks, almost entirely for the domestic market. India's software industry is, of course, more robust — 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, at least to quite the same degree. To some extent, therefore, India's software industry remains narrowly focused. For example, of India's 2001-02 software and services exports of Rs.365 billion, two-thirds came from IT services, and close to 88 per cent of that amount came from custom application development and application outsourcing (calculated from NASSCOM, 2002*a*; see also Desai, 2002*a*).

Indicators of the strength of India's software export capabilities include the depth of its base, and the breadth of its global reach. There are over 2 500 Indian software exporters, and while only the top five (TCS, Infosys, Wipro, Satyam and HCL) are — or are approaching the status of — global brands, they together account for only about 35 per cent of software exports[3]. The United States remains by far the largest market for India's software exports, its share of India's software exports being 63 per cent, with Europe coming in at 26 per cent, and Japan and the rest of the world accounting for the remaining 11 per cent (NASSCOM, 2002*a*). Individual firms and organisations such as NASSCOM have shown themselves to be adept at targeting markets with substantial growth potential, such as Germany, and the reputations built in exporting to the United States are proving important[4].

IT-enabled services (ITES) have shown the strongest growth in the last two years. They include a variety of types of service: customer call centres; accounting services and other business process outsourcing; and GIS and engineering services. Thus the required degree of technical sophistication of the workforce and the level of use of IT can vary widely. In fact, these three categories make up most of India's ITES exports, with the first two showing high growth and representing over 60 per cent of the total of Rs.71 billion.

II. IS IT SPECIAL IN THEORY?

IT may have a special role to play in growth and development simply because of empirical characteristics that apply at the current time. In particular, the recent and continuing rapid innovation in IT makes it a dynamic sector that is an attractive candidate as a contributor to growth for that reason alone, much as the automobile industry was targeted by the Japanese after World War II. On the other hand, there may be features of IT that make it attractive from a theoretical perspective on economic growth. For example, IT may be one of the sectors in which countries such as India have, or can develop, a comparative advantage. Even if this is so, IT is likely to share this characteristic with several other sectors.

A somewhat more special characteristic of IT may be that it is a “general purpose technology” (GPT), distinguished by pervasiveness, technological dynamism and innovational complementarities. In this case, IT is one of a special few technologies: other examples of GPTs include steam and electricity (both advances in power delivery systems) and synthetic materials. Finally, IT may be unique in its impact on growth. In this view, IT has a special role in the process of innovation, because it affects the rate at which potential new ideas are converted into additions to the usable stock of knowledge in ways that nothing else can[5]. The formalisation of this special role is based on the model of recombinant growth (Weitzman, 1998). Each of these possibilities — comparative advantage, GPTs (and complementarities more generally), and recombinant growth — will be considered below, as will, in turn other aspects of IT and development, which are not necessarily linked to formal growth theory, including greater efficiency in governance and in the working of markets.

Comparative Advantage

The static theory of international trade is based on comparative advantage, determined by relative factor endowments and/or technology differences. In the former case, a country will export goods that use more intensively the factors of production of which it has a relative abundance. In software development and use, the 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). Hence, attributing India’s software export boom at least partly to standard comparative advantage seems reasonable[6].

One can further elucidate the supply and demand factors that enabled this comparative advantage to play out. 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 favour 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. As Kapur (2002) emphasises, the lack of explicit government restrictions on this sector also helped.

Static comparative advantage theory explains patterns of trade, but not growth. For that one can turn to theories of endogenous growth. The ingredients of these models typically include differentiated capital inputs, monopolistic competition, production of new inputs through R&D, and ultimately economy-wide increasing returns that allow sustained growth to occur. Hence these models shift away from the exclusive focus on capital accumulation that characterised the neoclassical growth model (as well as the core of Indian post-independence economic policy). The work of Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991*a*,*b*) incorporates international trade and the evolution of comparative advantage into endogenous growth models. In these analyses, the economy is typically divided into manufacturing, R&D and traditional sectors, so the IT sector does not necessarily fit neatly into any single model category. For example, design and development of software have characteristics of R&D, while IT-enabled services are more like manufacturing in their use of established techniques for production. The general message of these models, however, is that externalities associated with monopolistic competition may give policy a role in influencing the evolution of comparative advantage in a direction that increases economic growth.

GPTs and Complementarities

General models of endogenous growth emphasise the importance of R&D in general (for adding to the stock of knowledge, which in turn raises productivity of physical inputs), rather than IT *per se*. The concept of GPTs, introduced by Bresnahan and Trajtenberg (1995), provides a somewhat special role for IT, as an example of a GPT. GPTs have three key characteristics: pervasiveness, technological dynamism and innovational complementarities[7]. Helpman and Trajtenberg (1998*a*, 1998*b*) model GPT-led growth, in which sustained growth comes from the periodic, exogenous introduction of new GPTs. Mechanisms that would give endogenous growth are ruled out, but otherwise, the framework, consisting of endogenous R&D, monopolistic competition and the introduction of new intermediate inputs as the implementation channels for growth, is similar to endogenous growth models. In these models, any GPT has similar hypothetical effects.

One can say a little more about how well IT fits the characteristics of GPTs. Pervasiveness seems to be potentially a natural property of IT. In the Indian context, doubts about achieving pervasiveness are centred on issues of cost and access. Table 1, however, illustrates the important positive trends that support pervasiveness.

Technological dynamism refers to the potential for sustained innovation that come with new GPTs, and is again illustrated by the dramatic fall in costs shown in Table 1. The complementarities of GPTs are vertical complementarities, because GPTs spur innovation and lower manufacturing costs in downstream sectors, with positive feedback effects to the GPT itself[8]. There are also horizontal complementarities, since the downstream sectors may face a co-ordination problem in expanding sufficiently to encourage the improvement of the GPT (thus creating positive feedback). Note that international trade with a more advanced country may be one way to overcome some of these externality problems.

Table 1. **Falling Costs of Computing**
(dollars)

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*, 23 September 2000, p. 6, Chart 1.

The general importance of complementarities (aside from being one feature of GPTs) in understanding growth processes has been described in most detail by Matsuyama (1995; see also Ciccone and Matsuyama, 1996). Matsuyama makes three useful observations. The first is the identification of the differing roles played by horizontal and vertical complementarities, such as was discussed in the previous paragraph. The second is the difference between technological complementarities, emphasised by writers such as Kremer (1993) and Milgrom *et al.* (1991) and the demand-based complementarities and pecuniary externalities that drive models such as those of Matsuyama. The third point is the difference between the effects of history and of expectations in affecting equilibrium outcomes and growth. Either or both may work against development and growth, by preventing co-ordinated movement out of a “bad” equilibrium.

Matsuyama examines a range of models, and shows how growth may be arrested or sustained, and what kinds of inefficiencies might arise. In particular, the externalities generated by the structure of complementarities can lead to inefficiencies that are best characterised as co-ordination failures. This set of problems also arises in the GPT models of Helpman and Trajtenberg, discussed above. This literature could have some relevance for thinking about the role of IT in Indian development. In particular, while the success of IT so far may be the result of factors that have to do with initial comparative advantage, the fortuitousness of freedom from government controls (Kapur, 2002) and integration with the world economy during the boom of the 1990s, the kinds of problems that IT may face in the future, as an engine of growth, have to do with potential coordination failures in providing other inputs along with IT, or in the downstream sectors that use IT. For example, if Indian manufacturing remains moribund because of the government’s fiscal problems and their effects on the financial sector, a significant market for India’s IT sector may be stifled. Some of these issues are considered in the next section.

Recombinant Growth

The growth model that best captures the special role of IT (including communications, and including non-digital methods of storing and communicating information) is an extension of the recombinant growth model of Weitzman (1998). Since this model is not well known, and since the extension proposed here seems to be the best way to capture the unique role of IT in growth, some of the formal details are described below.

The central idea of this approach is that new ideas are formed through combinations of old ideas. The simplest case is where ideas can be combined in pairs. Thus, if A_t is the number of ideas (the stock of knowledge) available at the beginning of period t, the number of potential new ideas in period t is defined to be:

$$H_t = A_t(A_t - 1)/2 - A_{t-1}(A_{t-1} - 1)/2, \qquad (1)$$

where this formula uses the standard combinatorial formula for the number of possible pairings. A key property of this formulation is that the increase in the number of ideas driven by (1) is faster than geometric growth (Weitzman, 1998; Lemma, p. 338). In Weitzman's model, all ideas are the same, and the rate at which potential ideas are converted into new ones depends on a "success function", $\pi_t(j)$, where j is the level of resources spent per potential "hybrid seed idea", i.e. R&D. If $J \equiv jH$, then the actual number of new ideas is given by $\Delta A_t = H_t\pi_t(J_t/H_t)$, i.e. the number of potential new ideas multiplied by the success rate.

The following modification of Weitzman's model captures the special role of IT in the innovation process. Suppose that the stock of IT knowledge independently affects the success rate. To write this down formally in the simplest manner, suppose that the total stock of knowledge can be split into IT (A_{1t}) and non-IT (A_{2t}), where these two quantities sum to A_t. The two stocks of knowledge increase according to the following relationships:

$$\Delta A_{1t} = H_t\, \pi_t(J_{1t}/H_t)\, \gamma(A_{1t}) \qquad (2)$$

$$\Delta A_{2t} = H_t\, \pi_t(J_{2t}/H_t)\, \gamma(A_{1t}) \qquad (3)$$

These two equations have the *same* extra term, a function of the existing stock of IT knowledge. For simplicity, this is assumed to be the same for both knowledge sectors, and independent of time. Naturally, $\gamma' > 0$, so that a higher stock of IT knowledge increases the success rate, other things equal. Thus, IT gives the growth process an extra "kick", even beyond that which comes from recombinant growth in general. One might argue that other technologies can have similar effects in supporting innovation. Nevertheless, it seems that the specificity of IT is precisely captured in (2) and (3): without writing, without telephones, without the Internet, the success rate of converting potential new ideas into actual additions to the stock of knowledge would be lower.

The model is now closed in a simple way, following Weitzman. The production function is given by:

$$Y_t = F(K_t\, , A_t). \qquad (4)$$

This makes the simplest possible assumption, that there is no difference in the impact of different types of knowledge in production. Indeed, the relative importance of IT versus knowledge of chemical and mechanical processes is not clear-cut. The savings/investment equations are given by:

$$K_{t+1} - K_t = sY_t, \quad (5)$$

$$J_{1t} = \sigma_1 Y_t, \quad (6)$$

$$J_{2t} = \sigma_2 Y_t. \quad (7)$$

The first of these is the standard neoclassical growth model savings assumption. The last two of these extend this proportional rate idea to the resources devoted to R&D.

Weitzman shows that long run growth in his model is at the rate $F(s, \sigma/c^*)$, where $c^* \equiv \lim_{t\to\infty} \lim_{H\to\infty} H\pi_t^{-1}(1/H)$, and is interpreted as the limiting unit cost of R&D. In the proposed extension, a modified version of this result holds. The real interest would lie in parametrising the function γ and seeing how this affects the growth rate, but this is beyond the scope of this paper.

Market Efficiency, Governance and Development

The final aspect of IT's specificity explored here is that of efficiency gains and broader economic impacts. Static gains from the use of IT come from more efficient use of scarce resources, allowing higher consumption in the present: they are independent of any impact on growth. Benefits that are measurable as increased market-based economic activity, and hence show up in GNP statistics, are not the only component of development. Development can include improvements in the capabilities of the population, independently of any direct or indirect economic impact. Minimum levels of education, health and nutrition are perhaps the most important examples of such capabilities. The ability to participate in democratic decision-making can also fall into this category. Of course, broad-based improvements in the capabilities of a population can have positive impacts on long-run economic well being, but this is not a necessary condition for desiring such improvements. The role of IT in effecting improvements along non-economic dimensions must also be considered, though this role may be harder to quantify.

Digital IT involves the electronic processing, storage and communication of information, where anything that can be represented in digital form is included in the term "information". Information goods typically have the characteristic that one person's use does not reduce their availability for another person. Thus, a message or weather news can be viewed by many people, simultaneously or sequentially. Depending on the content of the news or message, different people may place different valuations on the information. Only friends and relatives may be interested in a personal message, all farmers in a district may be interested in local weather news, and so on. The ability to share information among users can impact on the feasibility of providing it on a commercial basis. IT dramatically increases shareability of information, and this affects the economics of private provision of information goods and services.

Information goods may also be provided by the government. The potential rationale for government provision exists for any goods that are shareable, and where users cannot be excluded. The classic example is national defence, but such goods may also be local in character, such as public parks or law and order. Of course many local shareable goods can be provided exclusively, in which case private provision is a feasible alternative (in a club-like arrangement). In such cases, government provision may be justified more on equity grounds than on the basis of failure of private provision. In some cases, government financing through taxes or statutory user charges can be combined with outsourcing of delivery to private providers to achieve both equity and efficiency goals.

Often, private provision is feasible but neglects the spillover benefits that it creates, in which case government subsidy may be socially beneficial. For example, primary education has private economic benefits that people are willing to pay for, but it can also have substantial non-economic benefits to the individual and to others in the society (improved understanding, ability to make sound judgements, political decision-making capacity, and so on). Additional roles of government that are important to bring out are in redistribution to achieve equity objectives, and in regulation of private activities through licensing and certification. In both cases, the government also uses economic resources, and IT has a potential role in increasing the efficiency of government.

For both government and private provision, one of digital IT's main direct benefits is in increasing efficiency by economising on resource use. Information that would otherwise be conveyed through face-to-face contact, post, courier, print delivery, telegraph or telephone may instead be communicated in digital electronic form via the Internet. Efficiency gains from Internet use are not automatic: the telephone, in particular, is an efficient means of communication for many types of information. IT also requires new investment, so the benefits of trips, time and paper saved must be weighed against the costs of installing and maintaining the new infrastructure. Efficiency benefits of IT are not restricted to the communication itself. IT can improve the efficiency of the telephone network, and it can make it possible to track and analyse communications. Word processing, maintaining accounts, inventory management, and other such activities that may not require long-distance communications are also made more efficient by IT.

Experience with IT in developed countries, and the United States in particular, suggests that information exchange related to the completion of market transactions is especially valuable. The ability of digital IT-based communications (combined with storage and processing) to bring together buyers and sellers more effectively represents major potential gains. These gains can come about through lower search costs, better matching of buyers and sellers, and even the creation of new markets. The successes of auction websites and employment websites in the United States illustrate these gains. In the rural Indian context, farmers selling their crops and buying inputs, parents seeking matrimonial alliances for their children, and job seekers are all potential users of Internet-based matching services. Farmers and fishermen can receive weather forecasts, market price quotes, advice on farming practices, and specific training. IT can also reduce transaction costs for completing transactions, such as milk delivery by farmers to co-operatives, or micro-credit allocation and monitoring.

Efficiency gains of IT can also come about through the enabling of new goods and services. In many cases, the new good is related to something available earlier, but is presented in a form that reduces costs and expands the size of the market. For example, recorded music is a mass-consumption item, whereas only a small minority of the population could afford or have access to live performances by the highest quality musicians. Educational material is another example where recording and duplication can replace more expensive, skilled-labour-intensive alternatives for delivery. The possibilities for interactivity with digital IT-based educational materials illustrate the advantages of digital IT over older technologies based only on recording and duplication. Interactivity also implies personalisation, in that an individual can select the precise content that he or she wishes to see. This feature also distinguishes IT-based content from what was available through previous technologies. Finally, the sheer volume of information that is accessible through IT is much greater than before: this also allows new kinds of services to be provided at a cost that is affordable to larger segments of the population.

Governance is well recognised as an area where IT can have a positive impact (e.g. Quibria and Tschang, 2001). There are two broad classes of 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 are 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, for government action or response. The use of IT can increase transparency and accountability, simply by requiring information, such as basic complaints, to be logged completely and systematically.

While successful examples of direct implementation of “e-governance” initiatives exist, there is also an alternative. This comes from recognising the fact that citizens typically incur private costs (often substantial) in availing of government-provided services. If the use of IT can reduce such costs, even low-income individuals may be willing to pay at least some fraction of the cost savings, and there is scope for private provision of intermediate services that reduce the cost of access to government. Of course, this idea is not specific to IT: private intermediaries already help in filling in forms, getting access, and so on. One difference that IT can make is in reducing costs even further, often by an order of magnitude. In broad terms (as is also the case with electronic marketplaces and job-matching boards), IT changes the scope and nature of intermediation.

III. IS IT SPECIAL IN PRACTICE?

The recombinant growth model is highly stylised, and is therefore difficult to relate directly to experience. However, some observations are useful. First, the success of regions such as Silicon Valley and Bangalore is consistent with the model in the following way. In such regions, the proximity and mobility of skilled labour imply that potential ideas are combined and brought to fruition with higher success rates than elsewhere, even comparing across different locations within the same country. In terms of the model, this can be interpreted as a higher γ or π. The second observation focuses on γ. The United States has been a leader in IT (broadly construed — in the model, a high stock of A_{1t}), with related high rates of overall innovation [equations (2) and (3) above], while India has lagged in the use of broader IT, particularly modern communication technologies such as the telephone and television, which were treated as luxuries by government policy, and severely constrained in their growth. The model suggests that such policies would result in a lower γ, hence lower innovation. In both cases, these statements are asserted controlling for the level of income. It seems that Indian policies negatively affected innovation in this basic way[9].

Global Dynamics and Comparative Advantage

We have seen that the IT sector might simply have empirical characteristics that make it a suitable growth engine at this time. For example, the Japanese are said to have chosen the automobile industry for development in the 1950s because of its importance as a consumer durable, its potential for growth (high income elasticity) and its use of a set of technologies, mastery of which would benefit other manufacturing sectors. IT is too broad a sector or category to provide a parallel, but “business application software services” might capture well the aspect of IT where India has had major success in the global market, and provide a closer parallel. The Japanese example, with the initial scepticism that met the country’s plan for an automobile industry, and the two decades it took to make significant inroads into industrialised country markets, brings to mind some of the early responses to, and experience of, India’s software sector.

Of course, the Japanese success in automobiles was driven in part by government policy, and led by existing industrial firms. India’s success in software has been associated with benign neglect by the government, and the rise of new, entrepreneurial firms. However, in both cases, the success of the industry was driven by global growth in demand — in one case through conscious anticipation, in the other, through serendipity. To relate this to comparative advantage considerations, the Japanese consciously developed a comparative advantage in automobile production[10], whereas India’s pool of workers with a particular set of software and language skills that are valued in the international market gave it an accidental comparative advantage. Table 2, constructed from data in Arora and Athreye (2002, Table 2), provides an indication of India's comparative advantage in software. If one uses indexes of value added in manufacturing and software revenue as the comparators, India is better placed in software than in manufacturing vis-à-vis the United States.

Table 2. **Relative Productivity Indices (US = 100)**

Country	Manufacturing Output per Employee	Manufacturing Value Added per Employee	Software Revenue per Employee
Finland	112.6	77.6	66.2
France	99.6	78.6	128.0
India	10.1	4.2	7.1
Ireland	117.6	119.2	112.9
Israel	54.5	39.0	79.4

Source: Constructed from figures in Arora and Athreye (2002, Table 2). Original data are from varied sources and those authors' own estimates.

While India missed the boat with respect to the labour-intensive manufactured exports that contributed to the East Asian miracle, it may now be in a position to replicate this phenomenon with labour-intensive software services and (even more labour-intensive) IT-enabled services, building on its apparent existing comparative advantage. Even if such exports cannot sustain earlier growth rates, they can make a substantial contribution. For example, 20 per cent growth in a sector that is 5 per cent of the economy (still quite a bit more than India's current IT sector) 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. India's experience in the 1990s already bears out the specificity of IT from the perspective of the spectacular export growth that occurred, and one can interpret it as a fortuitous combination of global dynamics and comparative advantage.

However, there are two reasons for not stopping here. The first is a defensive one: greater automation of software development and the emergence of other low-labour-cost sources of competing IT skills 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. As both real experience and endogenous growth models suggest, comparative advantage is not fixed, and countries can move towards producing higher value-added goods and services as they grow, with favourable consequences for long run growth[11]. Applying endogenous growth 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 labour. Nevertheless, upgrading is something to consider.

Complementarities, Linkages and Spillovers

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 include accounting, procurement, inventory management, and production operations. These are all examples of "forward linkages", since IT adoption has positive impacts on the operations of a range of industries[12]. This is, of course, the standard argument in the United States for the virtues of the "new economy" based on IT. These benefits are situated in the B2B arena. 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, more expensive approaches such as Electronic Data Interchange, which represent significant legacy investments in countries such as the United States.

Miller (2001) surveys the potential for B2B e-commerce in India. He gives the example of Reliance Industries, which, though still quite diversified, is now heavily into production and distribution of chemicals. Of the company's 20 000-plus customers in India, about 3 000 are major buyers, accounting for over three-quarters of total sales. These major customers are electronically linked to a Reliance-controlled Internet-based market exchange. Using leased-lines, customers can process orders and Reliance can communicate dispatching details, better manage inventory, carry out invoicing, and provide customer support. Using this system, Reliance has reduced receivables from 310 days to 90 days. General cost improvements have come from an overall tightening and acceleration of processing within the company, and between the firm and its customers. The speed of order delivery has greatly improved and inventories have been reduced. A shift from leased lines to the Internet will provide further cost savings. There are not too many similar Indian examples, but the existing ones do illustrate the possibilities.

In the context of models of complementarities, it is also important to recognise that the effects of IT use are not just in terms of cost savings. IT implementation may enhance the quality of service beyond anything that is feasible through other methods, thus effectively enabling the offering of "new" products and services. Furthermore, depending on the customers, 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). Similarly, Internet banking is mainly targeted at well-off and upper-middle class individuals[13].

However, the use of IT in rural banking and micro finance can impact a much broader cross-section of the population. The evidence of pilot schemes such as the SKS InfoTech Smart Card project is encouraging. Handheld computers and smart cards can substantially reduce the costs of making loans, as well as monitoring them. Reducing these transaction costs may turn out to be critical for the scalability and sustainability of micro-finance schemes. The success of projects such as the SKS smart card will depend, in turn, on the availability of appropriate, low-cost hardware, such as the Simputer, an indigenously developed hand-held computer with an integrated smart card reader/writer, illustrating another aspect of complementarities. What makes digital IT special in these types of cases is its low cost and flexibility, as the result of two decades of very rapid innovation.

The examples considered so far are either scattered instances of IT use, or are projects that have yet to take off. Hence, in practice, IT in India has not realised the potential for complementarities or linkages[14]. The general problem lies with the nature of the domestic market for IT products and services which, while not insubstantial, has not played the full role it might have. Its growth has been *relatively* slow, despite some good years. The use of IT in Indian business is patchy. One can argue that there is no problem: to the extent that exports provide much higher profit potential, software firms rationally concentrate on them rather than domestic sales. This is partly true, but it is not the whole story.

The nature of information goods in general is that they involve high fixed costs of production and low marginal costs. While customisation and service provision mitigate this property, they do not negate it. Reputation and experience effects, on the other hand, enhance the importance of 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. Since Indian software firms can compete successfully abroad, they should also be able to succeed in their own backyard[15]. In fact, they have advantages in the domestic market, knowing their customers better and being closer to them. Desai (2002*a*) emphasises another important aspect of the domestic market, as an arena for learning by doing. According to him, the lack of sufficient opportunities for using local markets as a proving ground for software hurts Indian firms vis-à-vis their competitors in the United States, Israel, or other countries. In his view, the domestic market does not necessarily need to be large, but must be challenging and demanding.

The role of the government in supporting the rise of a “challenging and demanding” domestic market in India has been mixed. In earlier reports, NASSCOM notes that the strong growth in domestic market in 1999-2001 was partly fuelled by central and state government IT purchases, for internal computerisation as well as e-governance initiatives. This effect appears to have petered out in 2001-02. Smaller IT firms (in personal interviews) expressed frustration that government procurement did not give preference to domestic suppliers. In the United States and Europe, these kinds of preferences have helped domestic firms to thrive in some circumstances, though they may ultimately be inimical to competition, innovation, and hence long-run growth (Tschang, 2001, p. 26). Given the government’s own precarious fiscal position, creating a favourable environment for IT use in industry may be more important than direct government purchases.

In any case, the domestic situation is not static. Bright spots already exist, as in the case of accounting and inventory software. Two strong domestic competitors exist here. One is Bangalore-based Tally Solutions, a private company that makes Tally accounting software. It seems that Tally is a market leader for small business accounting software, and that even small shopkeepers are interested in acquiring it and learning to use it. For larger businesses, Tally has recently introduced a server version, which fits the needs of businesses with multiple locations or offices. The second product is E.X.

from Tata Consultancy Services (TCS), which is the oldest of India's IT services companies, currently the largest exporter, and a firm with a substantial presence in the domestic business software market. The two companies' products are priced similarly, and in each case one can find all the features of distribution channels, after-sales support, marketing, and product versioning that exist in competitive US markets[16].

Hardware may offer additional opportunities to Indian IT firms in the domestic market, and there are again important complementarities to consider. Low cost hardware specifically for the Indian market may speed the adoption of low-end versions of software such as Tally or E.X. In developed countries, the establishment of the PC market took place before the Internet took off. In a good example of complementarities, however, the growth of the Internet has increased the demand for PCs and other access devices. Internet access 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 kiosks, with shared access, are a solution that has emerged for urban and rural areas, with the start-up cost for a very basic kiosk having been brought down to under $1 000. While Internet use is beginning to grow rapidly, the number of subscribers remains minuscule, at below 2 million. The main reasons for this backwardness have been the government's long-standing monopoly, through VSNL, of the country's Internet gateways, as well as the generally poor condition and high cost of the telecoms infrastructure. While the situation is now changing, high costs of using the network, and its poor quality, have represented a major impediment to realising possible linkages between IT and the rest of the economy[17].

Models of complementarities typically emphasise pecuniary externalities. Arora and Athreye (2002), on the other hand, suggest that there are strong direct spillovers from the IT sector to other service industries, in the form of improved managerial practices that have developed in IT and are easily applied to a range of services. In fact, they argue that software for export by itself has few other linkages. A particular example of spillovers or diffusion of management practices, emphasised by Arora and Athreye, has been in the case of ITES. Kapur and Ramamurti (2001) argue for even broader impacts, extending to industries such as biotech, chemicals, media and entertainment, and construction. All require knowledge services that go beyond the basic definition of IT-enabled services and have all benefited from the change in management approach wrought first within the IT sector.

The argument of Kapur (2002), that India's success in software exports has increased the confidence of Indians, may also be couched in terms of a positive shift in expectations, helping to overcome a potential co-ordination failure. More broadly, Kapur gives the effect of IT's success on attitudes in India pride of place among the sector's impacts: "the success of IT, more than any other change, has helped legitimise capitalism in a country whose intellectuals have long harboured suspicion of markets and the private sector." (p. 103). He goes on to discuss changes in attitudes to entrepreneurship, business culture, and reputational effects, which can include both horizontal and vertical impacts on expectations of entrepreneurs and customers in other knowledge-based sectors. Thus, in Kapur's view, these "indirect" effects may be quite pervasive, more so than the effects of the technology itself.

Efficiency and Broad-Based Development

As an example of information processing enhancing efficiency in agricultural markets, Chakravarty (2000) describes IT use at milk collection centres in co-operative 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. Another efficiency gain is in the communication of information, where the examples are many. 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 such as fixed or mobile telephones, while other types require the capabilities of the Internet[18]. Some evidence suggests, not surprisingly, that richer farmers and fishermen, as well as middlemen, are faster adopters of such technologies (*The Economist*, 2001*a*), but falling access costs will broaden information access and its benefits.

In some cases, corporations dealing in agricultural products have moved to provide their suppliers with Internet access to improve market efficiency, production efficiency, and even bargaining power. The most significant example is ITC, with its *e-choupals*. Their annual report (ITC, 2002) states:

> Project "e-Choupal"…links the Indian farmer with domestic and international markets …It already reaches out to more than half a million farmers to provide web-enabled real-time information on the weather, best farming practices and commodity prices. Through virtual clustering, these "e-Choupals" are conferring the power of scale on even the smallest of individual farmers. This…e-infrastructure will dramatically enhance efficiency in the purchase and sale of agri-inputs and farm produce, with direct benefits to the farmer. 770 "e-Choupals" are already operational, covering 4 500 villages across four states in India.

Even if one allows for the possibility of exaggeration in this statement, and even if one is not satisfied with the distribution of bargaining power and benefits between a large corporation and small farmers, the scale of what has been implemented so far is evidence of the efficiency benefits of IT in India's agricultural sector.

Another area of impact involves communication of information in a more fundamental way. IT-based delivery mechanisms can overcome traditional barriers to widespread delivery of education at all levels. Completely aside from the importance of IT training for the growth of IT exports, even basic education may be enhanced by the use of IT. While it may seem paradoxical that delivery of basic education should rely on "high tech", there is nothing new in this. The radio and television have been very successful distance-education media in the past, and computers and the Internet offer several advantages, in terms of the potential for interactivity, customisation and sheer volume of material. Given the poor state of basic education[19], while improved incentives for teachers and school administrators (either in the public or private sector) will help, technology can play an important complementary and even substitutive role. For example, TARAhaat (a semi-commercial subsidiary of an NGO), in attempting to develop a network of rural Internet centres in a district in Punjab, found that even in the absence of reliable connectivity that would allow access to a variety of Internet-based services, it was able to tap into an underserved market for education in the vernacular medium in the basics of computers and the English language[20].

The TARAhaat example illustrates several general points. First, in all attempts to introduce IT to rural India in a manner that promotes development, sustainability is a key issue. The TARAhaat franchisee model offers important promise in this regard with respect to incentives and scalability, though there have been difficulties in implementation. Second, the experiment validates the idea that IT costs have come down sufficiently to make rural IT services financially viable. Third, the issue of complementarities, both technological and pecuniary, raises its head again. One major roadblock for TARAhaat has been the poor quality of existing telecoms infrastructure. This has severely limited the scope of services that its franchisees could offer[21], and is an example of government failure. On the other hand, the provision of complementary inputs such as financing and physical infrastructure, through subsidised loans from nationalised banks and the use of local government buildings, have been important in reducing start-up as well as operating costs. The most important complementarity emerged when the Punjab Technical University (PTU) quickly piggybacked on TARAhaat's efforts, enhancing the franchisees' initial financial viability through its own offerings of college-level IT education[22]. This example suggests how the kinds of co-ordination failure identified in the work of Matsuyama and others may be overcome.

There have been numerous examples of successful pilot e-governance programmes in India. These include:

— computer-aided registration of land deeds and stamp duties in Andhra Pradesh, reducing reliance on brokers and possibilities for corruption;

— computerisation of rural local government offices in Andhra Pradesh for delivery of statutory certificates of identity and landholdings, substantially reducing delays[23];

— computerised 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[24].

As in the broader case of using the Internet for communications and transactions, sustainability of e-governance initiatives is a significant issue. Since governments at all levels are financially strapped, the initial investments and ongoing expenditures for IT-based service delivery may act as a barrier to adoption as well as to long-run sustainability. However, a franchise model can be successful here. Low-cost rural Internet kiosks, a tiered franchising model, and a suite of basic government access services for which users are willing to pay, are key components of what Drishtee, a spinoff of the Gyandoot project in Madhya Pradesh, is implementing in several parts of India[25]. Co-operation of local governments and subsidised financing have been important elements for Drishtee, as in the case of TARAhaat, with the former being critical in the case of Drishtee. In terms of the discussion in the previous section, the Drishtee model can increase transparency and accountability, simply by requiring information, such as basic complaints, to be logged and aggregated completely and systematically outside the government. In this respect, the use of a non-governmental intermediary such as Drishtee may have advantages over purely internal government initiatives, beyond that of financial viability.

It is important to note that once Internet access is available, its 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. This is certainly part of Drishtee's long run model. Here also, a commercial approach may provide more flexibility. For example, in Jaipur district in Rajasthan, Drishtee has piggybacked on the expansion of a fiber optic company, and combined its Internet kiosks with cable TV franchises for greater and more immediate financial viability.

IV. OPPORTUNITIES AND CONSTRAINTS

India’s strength has been in software rather than hardware; and there are different routes that India’s software industry can take: more of the same, moving up into higher value-added activities, and moving out into related areas such as ITES. These opportunities are not mutually exclusive and, given the right policy environment (Section V), India’s IT industry can pursue all of them. As Desai (2002*c*) puts it, “They [Indian IT firms] do not need advice; they are scanning the market and will take informed decisions”. For example, the annual *Dataquest* magazine survey (*Dataquest*, 2001) provides details of how the large firms, in particular, have tried to develop new lines of business and consolidate by acquiring smaller competitors. In all these cases, of course, reputation matters[26].

ITES

IT-enabled services currently are the poster boy for the possibilities that exist for India’s IT sector. Their rapid growth is not just fuelled by call centres, which require IT infrastructure but otherwise a different set of “soft” skills. As noted in the Introduction, business process outsourcing represents a significant chunk of India’s ITES, and this involves higher-level skills. The list of ITES segments constructed by NASSCOM also displays ample scope for work that is well beyond any IT version of sweatshops (Table 3).

Another method of organising the categories comes from Raman Roy, then CEO of Spectramind (since acquired by Wipro), who suggests five categories of “teleworking”: data entry and conversion, rule-set processing, problem-solving, direct customer interaction and expert “knowledge services”, ranked in terms of increasing sophistication and value added (*The Economist*, 2001, p. 60). Note that in this categorisation, direct customer interaction is high on the list, and reflects the complexity of this often-maligned category (also reflected in the difficulties of CRM software in making significant inroads). In practice, even within a single one of the 10 service types listed in Table 3, there is room for specialisation and focus. For example, Daksh (Table 4) has a 90 per cent concentration on customer service, whereas HCL Frontline (a division of HCL) is 100 per cent focused on technical support (*Dataquest*, 2001, p. 134).

The high growth projections for ITES depend on government policy (Section V) for achievement, as well as sufficient managerial and marketing expertise. However, the fact that India currently serves only 0.5 per cent of the global market by value suggests that the scope for growth is indeed high, even in the face of competition from other developing countries.

Table 3. **IT-Enabled Services Types**

Customer Interaction Services
Business Process Outsourcing / Management; Back Office Operations
Insurance Claims Processing
Medical Transcription
Legal Databases
Digital Content
Online Education
Data Digitisation / GIS
Payroll / HR Services
Web site Services

Source: http://www.nasscom.org/it_industry/spectrum.asp.

Table 4. **IT-Enabled Services Companies**

Indian Third Party ITES Companies (Call Centre & BPO)	GIS, Multimedia, Engineering & Design Services	Leading Captive Remote Services Companies (alphabetical list)	
exl services	Pentamedia Graphics	American Express	Galileo
Spectramind	Rolta India	Axa Business	GE Capital
GTL Ltd	Infotech Enterprises	Bechtel	Healthscribe
Daksh	Geometric Software	Convergys	HP
Tracmail	RMSI	Dell Computer	HSBC
Firstring		Delphi Automotive	McKinsey & Co.
Epicentre		e-Funds International	Sallie Mae
24x7 Customer.com		eGain Communications	Standard Chartered
Customerasset (ICICI Onesource)		eServe Intl	World Bank
Brigade Corporation		Fidelity	World Network
		Ford	Services

Source: NASSCOM (2002*a*).

Hardware

Despite India's past weakness in hardware manufacturing, hardware still provides opportunities. The design of hardware involves the development and use of appropriate software code, and value has tended to shift to design activities as production has become increasingly commodified. India has already established some presence in areas such as circuit design. However, hardware assembly should not be dismissed. The example of firms like Dell and Cisco is useful here. Dell outsources most, if not all, of its component manufacturing. It is, in fact, an extremely sophisticated assembler. Its value creation is based on organising 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 take advantage of strengths in infrastructure and closeness to a growing customer market is an important lesson for India.

The possibility of designing and building lower-cost hardware in India may represent an opportunity in niche markets. One example is the Simputer. Another example is low-cost Internet and telecom access devices, as envisaged by nLogue (a commercial spinoff from an IIT Chennai research group). Not all components have to be built in-house. What is essential is designing products for the under-served domestic market, and managing the entire value chain as efficiently as possible. Management and infrastructure are the key inputs that are required. 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.

As in any industry, the availability of adequate supplies of inputs is critical for the growth of India's IT sector. Much of the caution about the prospects for India's IT industry has been focused on potential bottlenecks in the supply of skills, and the quality of the infrastructure. Financial constraints are also a factor.

Skills

A major reason for the success of India's software industry is the large supply of labour with some IT skills. India graduates perhaps about 140 000 engineers a year (2002-03 estimates), second only to the United States worldwide[27]. Not all these engineers go into the IT industry, and not all IT professionals have engineering or computer science qualifications. Once one adjusts for these factors, the estimated number of new IT professionals is currently about 100 000 per year. India's stock of IT professionals is estimated at about 520 000 (2001-02), so that IT industry revenues per IT professional (assuming that all of them work in the industry, which is unlikely) are about $25 000[28]. Projections imply IT industry revenues will increase severalfold over the next few years. Some of this growth will be due to increases in revenue per IT professional, but the rest will require an increase in numbers. To the extent that much of this future growth will come in IT-enabled services, the additional employment there may come in areas where different, easier-to-acquire skills are needed.

Whether growth comes in revenue per employee or number of workers, there are implications for training. Increasing revenue per IT professional requires improvements in managerial and marketing skills[29], as well as 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. Desai (2002*d*) argues that there will be enough programmers, and that management skills will be the bottleneck. In fact, a particular mix of high quality IT education and management training may be what is particularly needed. Given the rapid expansion of regional engineering colleges and of private IT training[30], the real need may be concentrated investment in the IITs, which represent the frontier for education in engineering. This approach would be consistent with the O-ring view of value creation in this sector (Note 29).

Infrastructure

Government failure in the realm of infrastructure provision has been a major characteristic of Indian economic development. Of the various infrastructure constraints, probably that of electric power is the most fundamental, and the most difficult one to tackle. It will not be addressed here, because the subject is too large and it is not central to the analysis, though electric power is clearly necessary for an IT industry[31]. Other infrastructure constraints, such as water, roads and ports, have served as greater bottlenecks for manufacturing. In fact, one of the reasons software exports were able to take off in India was their lack of dependence on these latter kinds of infrastructure. The development of software parks by eager governments has helped to relax physical infrastructure constraints where they did exist. However, a severe potential constraint is the poor overall state of India's telecom infrastructure.

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. 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[32]. IT-enabled services use voice lines for call centres, and data lines for transmitting electronic files back and forth. Internet-based media companies also require data links. At the same time, rapid technological change and the success of India's IT industry are together leading to solutions.

International links are an obvious area for improvement if the Indian software industry is to realise its lofty growth projections. Belated, but now rapid, deregulation is likely to remove international bandwidth constraints[33]. Several problem areas remain which will require attention. These include the system of interconnect charges, licensing fees and deposit requirements for entry, restrictions on franchising, bandwidth allocations, and so on. The challenge of building a financially viable, robust and extensive telecoms infrastructure still exists[34]. The tendency of government regulators still appears to be to over-regulate, one prominent example being the requirement for new private telecoms to meet old-style quotas for installing village telephones, without adequate regard to efficiency or financial viability (see Section V).

With appropriate policy adjustments, technological progress, including domestic innovation, may be an important factor in removing current telecoms infrastructure constraints. Ashok Jhunjhunwala (Note 34) 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 rural telecoms operator in India cannot recover set-up costs for access, which are about $800 using conventional technologies. The goal of innovations by Jhunjhunwala's team, therefore, has been to bring the cost of combined Internet and voice access down to $200. The latter figure would make access affordable to 50 per cent of Indian households at current income levels. Without such innovations, government targets of increasing India's teledensity fourfold (from 4 to 15 per hundred), or Internet access tenfold are empty rhetoric.

Finance

A striking feature of the Indian economy pre-reform was its inefficient use of capital. Relatively high savings rates were associated with relatively low growth rates. Financial sector reform in India has focused on making the country's organised capital markets more efficient. Simple institutional improvements such as electronic trading and settlement, guidelines for corporate governance, and so on, have been introduced. However, the nature of the financial system overall still involves "financial repression", with the banking sector and a large number of other financial institutions being subject to parking of government and state enterprise deficits and to directed lending[35]. These problems mean that substantial inefficiencies remain in the financial system. This has negative implications for industry overall[36], but particularly for a fast-growing sector such as IT.

For IT start-ups in developed countries, venture capital has been extremely important, and this should be the case for India also. While the initial lack of a venture capital industry in India may have been positive, in the sense that the policies to create one could be considered from scratch, efforts to do so have become tangled with existing mazes of financial regulations and legal restrictions, including tax and corporate law. An important beginning was made by a committee on venture capital appointed by the Securities and Exchange Board of India (SEBI), India's chief financial regulator. The committee's report was adopted by SEBI in June 2000, but many of the changes required are beyond SEBI's jurisdiction[37].

Despite policy hurdles, which are still receiving attention, venture capital in India is starting to take off. A government sponsored venture capital fund, the National Venture Fund for Software and IT industry (NFSIT), was launched in December 1999. States such as Andhra Pradesh, Karnataka, Delhi, Kerala, Gujarat, and Tamil Nadu have also set up their own venture funds. It is not clear how effective government-sponsored funds can be, since venture capital involves high risks that are not normally associated with government activities, and government intervention may be subject to other incentive problems. Putting aside these issues, it is true that venture capital funding in India's IT sector increased from $80 million in 1997-98 to over $1 billion in 2001-02[38]. If a venture capital industry can flourish, and stock market institutions can continue to develop, the growth of India's IT sector can be fuelled, but the problems of the rest of the financial sector still cast a shadow.

V. POLICY THOUGHTS

The overall goals of economic policy in India are 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 foregoing 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 might 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.

Broad-based growth of India's IT sector will depend on improving the telecoms infrastructure, on training enough people for the sector and using them effectively and efficiently, and making capital available for growth. For telecoms, the regulatory framework is crucial, whereas for human resource development and use, the labour 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 manufacturing or assembling hardware — the problem here is one that still affects Indian manufacturing in general[39].

In India the regulatory institution for telecoms is the Telecom Regulatory Authority of India (TRAI, 2000), which was constituted in 1997 and given greater and clearer authority in 2000[40]. The scope of the TRAI includes establishing quality of service parameters, monitoring compliance, examining technology choices, and so on[41]. It is supposed to establish a level playing field and encourage competition, but it has lacked clear 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 (USOs) into the regulatory mix only serves to muddy the waters, and divert attention from the central task of enabling effective competition.

USOs are being built into licensing deals for private service providers. These take the form of quantitative targets for installing rural telephones, and funds created through a form of tax on basic service, to be used for proposed subsidies for rural users. It is not clear that numerical targets have any use at all, when licensing and interconnection fees make it uneconomical for local access providers with lower-cost technology to enter. The distinction between rural users in general, and shared access through Internet kiosks is crucial, but has not been accepted by a majority of the TRAI committee that reported on the USO[42]. The start-up problems of TARAhaat and Drishtee suggest that a narrowly targeted subsidy for enabling reliable telecoms access (including solutions such as that of the IIT Chennai group) to Internet kiosks makes most sense.

Desai (2000) examines the problems of labour 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 labour, including provisions relating to overtime, working conditions, restrictions on contract labour, and dismissal of workers. Desai suggests that the main function of the labour laws in this sector is to enable government labour inspectors to demand bribes. He also argues for broader reform of labour 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 labour laws, in particular the lack of permitted flexibility in contracting. The development of ITES, which broadens the scope of this new approach to working conditions regulation, will be a litmus test of the changing role of labour laws in India.

While it seems that large IT firms can rely on retained earnings or the stock and bond markets for growth, start-ups need a venture capital industry that is just beginning to emerge. As in the case of labour laws, one can argue that the policy environment must be geared toward industry in general, and not just the IT sector, or even just knowledge services.

Some of the greatest difficulties face small-scale entrepreneurs, who have been protected by reservations, but who do not necessarily have easy access to the right kinds of help they need as start-ups. Again, on the experience of the local franchisees of TARAhaat and Drishtee suggests that the nationalised banking sector, with its system of directed credit, and simultaneous forced holdings of government and PSU loans, which have left bank portfolios in bad shape, is not well placed to provide small-scale financing of this kind. In particular, in the case of TARAhaat, difficulties in obtaining start-up capital from banks appeared to be one impediment to expansion of the franchising scheme, even within a small geographic area[43]. This is where the overall macroeconomic problem of the fiscal deficit appears to trickle down all the way to the village, with a negative impact on development.

With one exception, the policy problems are mostly general ones, and not specific to IT. Problems in financial market institutions, labour laws, and regulation in general are best dealt with from an economy-wide perspective. The exception is the case of rural telecoms and Internet access, where it seems that narrow targeting of limited subsidies (through waiving certain fees rather than explicit payments) for start-up costs may be worthwhile in generating growth of communications, and of enterprises that use communications.

Of course potential benefits do not necessarily translate into actual ones. Firms and managers can make mistakes in their IT investment decisions, but this is no different from any other kind of investment. 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 realise 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. This line of thought again argues in favour of a sound competition policy, rather than any specific incentives.

VI. CONCLUSION

The main emphasis of this paper has been to stress that IT has some special characteristics, both in theory and practice, which make it a promising engine of broad-based growth in India. The final message, however, of the paper is somewhat counterintuitive: instead of special incentives, the sector and the economy as a whole will benefit from a continuation of a broad reform agenda. If there is any exception to this general conclusion, it is in providing the conditions for rapid increases in access to modern communications (voice and data) for India's population.

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[44]. State governments also may be better off removing general restrictions to 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.

The exception in the telecom sector is that it has particularly strong complementarities with the broader IT sector. Policies to achieve development goals would do better to emphasise removing barriers to innovations that will support lower-cost access to telecom networks of all kinds (wireless and fixed, voice and data). Very specific, targeted, start-up subsidies to enable widespread, shared access to telecoms and Internet in rural areas are likely to have high social returns, since it appears that financially sustainable franchise models exist. These high returns include better governance, as well as knowledge that is an important input into "empowerment", or "development as freedom" (Sen, 1999). In this respect, rural IT access is an important complement to and enabler of local government reform in India (Rao and Singh, 2000).

NOTES

1. A popular alternative is ICT, for information and communications technology: the World Bank, for example, favours this term.
2. To give a sampling of research in the United States, David (2000) emphasises the lag with which any new technology affects productivity; Gordon (2000) offers a sceptical view of the impact of IT on productivity, arguing that the empirical evidence indicates that the impact is narrow and limited; Jorgenson (2001), in the most comprehensive analysis, finds that IT has contributed significantly to total factor productivity growth (TFPG) in the United States. Of course, higher TFPG implies higher overall growth, *ceteris paribus*.
3. These figures are calculated from data in NASSCOM (2002*a*), and exclude IT enabled services, which are discussed separately later in this section.
4. For example, see http://www.tcs.com/news/tcs_media/htdocs/sh01/nov01_FT_article.htm.
5. In this perspective, IT includes communication technologies, and pre-digital technologies such as writing and printing. This is also consistent with the GPT view of IT. I am grateful to Keshav Singh and Bhairav Singh for clarifying this unique role of IT for me.
6. 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.
7. See Lipsey, *et al.* (1998) for a detailed survey and examination of the concept, as well as the other pieces in Helpman (1998). A complementarity is a particular kind of externality: see Ray (1998), pp. 114-115.
8. Thus vertical complementarities are related to the older idea of linkages, with the downstream impact being a forward linkage, and the feedback being a backward linkage. See Basu (1997) and Ray (1998) for references and further discussion.
9. This statement is strengthened when one considers policies that stifled competition and access to foreign innovations: see Marjit and Singh (1995). The recombinant growth model does not make the resources devoted to R&D a choice variable, where it would be affected by competition, but one can extend the model in that direction (Olsson and Frey, 2001).
10. Here one should note that predicting the pattern of production and trade of differentiated products such as automobiles does not rely on standard comparative advantage models. Nevertheless, at an intuitive level, the statement seems justified.
11. In addition to the Japanese automobile example, one can note that several East Asian countries began as mainly assemblers of sophisticated components produced elsewhere, and extended their presence in the value chain backward as they learned by doing.
12. Alternatively, 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.
13. Miller (2001) discusses the examples of HDFC bank and ICICI bank. The former uses IT in several ways: for internal communications and data transfer, to reach out to retail customers, and as a

clearing house for stockbrokers. NASSCOM (2002*a*) identifies the energy sector as one where IT firms can find domestic opportunities as the sector moves toward deregulation. However, privatisation has become stalled in this sector (Singh and Srinivasan, 2002), and this may again slow IT adoption.

14. Kumar (2000) does provide some evidence of forward linkages in the informal IT sector itself, where the provision of IT maintenance, data entry and customisation services for domestic users are developing. He estimates the jobs created in this way at over half a million.

15. The reverse need not be true, as Arora and Athreye (2002) emphasise in their discussion.

16. It is worth recalling that VisiCalc, the first spreadsheet programme, was the “killer app” that helped drive the adoption of personal computers. Small business accounting software may play a similar role for IT adoption in India.

17. Desai (2002*a*) is characteristically bold and forthright on this point. He says, “The real use of internet is in business communication. And for that use, fast and reliable telecommunication is the key. If this were understood, the government would …provide a free broadband backbone to the entire country.” While Desai dismisses consumer use, such a backbone would presumably also allow a dramatic expansion of consumer use as well. Furthermore, as US experience has shown, linking businesses and consumers efficiently is important for a host of IT applications.

18. Eggleston *et al.* (2002) provide some quantitative evidence for the market efficiency effects of improved communications and information transfer, using data from rural China.

19. See Dreze and Gazdar (1997) and the PROBE report (1999). One can also make a case for access to IT based on broader notions of development, such as Sen (1999). That the poorest of the poor can benefit is borne out by instances such as the famous hole-in-the-wall-computer (http://www.niitholeinthewall.com/home.htm).

20. See Kaushik and Singh (2002) for more detail on the TARAhaat effort. TARAhaat is also offering specialised courses in using Tally accounting software. The demand for these courses in small towns indicates the depth of penetration of the software.

21. An example from field research in Bathinda district of Punjab in December 2001 illustrates: a farmer told us he had taken computer lessons at the TARAhaat kiosk, bought a home computer, and signed an Internet service contract so that he could exchange email with his brother in Toronto, Canada, as well as look for information on agricultural practices. All three IT-related products and services depended on basic telecom availability. See also Prahalad and Hart (2002).

22. Subsequently, TARAhaat has chosen to forbid its franchisees from offering PTU courses, in an attempt to solidify its brand and quality control. Whether this is the optimal strategy requires a separate analysis.

23. 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.

24. These three examples are from *India Today* (2000), which also lists several other similar projects.

25. Further details of Drishtee’s efforts are in Kaushik and Singh (2002). Our Drishtee fieldwork has been in Sirsa District of Haryana.

26. Banerjee and Duflo (2000) show that reputation effects are quite important for Indian software exporters. Arora *et al.* (2000) and Arora and Athreye (2002) discuss Indian firms’ efforts to signal quality by hiring engineers, and through international certification of their processes. They document the positive impact of the latter on value added per employee

27. These and subsequent figures are from NASSCOM (2002*b*), Chapter 5.

28. This uses \$13.5 billion as the size of the Indian IT industry, and is overstated to the extent that it excludes some types of employees. Arora *et al.* (2001) construct a lower estimate of \$15 600 for 1998-99 (their Table 1).

29. The implication is that changes in the product-service mix toward one involving higher value-added tasks would be associated with these improvements, resulting in increased productivity. This is a complementarity argument at the level of the internal workings of the firm, as formalised in the "O-ring" theory of production, developed by Kremer (1993). See also Basu (1997), Chapter 2.

30. See Arora and Athreye (2002) and Kapur (2002) and the references therein. The former paper emphasises the regional concentration of engineering colleges in India.

31. See Dossani and Crow (2001) for an excellent survey and analysis of power sector reform in India.

32. See Heeks (1996, 1998).

33. See Singh (2002) for further details and additional references.

34. Two sources for tracking policy issues and broader concerns are www.trai.gov.in, the website of the Telecoms Regulatory Authority of India, and http://www.tenet.res.in/Papers/papers.html, which features the work of the IIT-Chennai group headed by Ashok Jhunjhunwala. The most recent of these is www.tenet.res.in/Papers/techolo.html. See also Jhunjhunwala (2000).

35. See Singh and Srinivasan (2002) for a more detailed discussion in the context of federalism and reform.

36. It is arguable that the problem of low growth in India's manufacturing is substantially attributable to difficulties in financing investment. One aspect of this is therefore slow adoption of IT for internal use.

37. Important overviews of the issues are in Dossani and Saez (2000) and Dossani and Kenney (2001). Rafiq Dossani was one of the members of the SEBI committee.

38. The data, and other information on India's VC environment, can be found at http://www.nasscom.org/artdisplay.asp?cat_id=61.

39. 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 recognised by the government as an "industry".

40. See Dossani and Manikutty (2000) for details.

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

42. See the report at http://www.trai.gov.in/recom.htm, and especially the two Annexes, which are a dissenting comment by Rakesh Mohan, and the rest of the committee's response. See also Dey (2000) and Singh (2002).

43. Drishtee was able to avoid this problem to some extent, with smaller-scale kiosks that allowed poorer entrepreneurs to avail of targeted government loan schemes.

44. Bangalore in Karnataka is well known as a regional IT centre in India, having developed initially without much explicit government support. The governments of Andhra Pradesh (Eischen, 2000) and Tamil Nadu (Bajpai and Radjou, 1999; and Bajpai and 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, with mixed success.

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