Information Technology and its Role in India's Economic Development: A Review[*]

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Abstract

Information technology (IT) is an example of a general purpose technology that has the potential to play an important role in economic growth, as well as other dimensions of economic and social development. This paper reviews several interrelated aspects of the role of information technology in the evolution of India's economy. It considers the unexpected success of India's software export sector and the spillovers of this success into various IT enabled services, attempts to make IT and its benefits available to India's rural masses, e-commerce for the country's growing middle class, the use and impacts of IT in India's manufacturing sector, and various forms of e-governance, including internal systems as well as citizen interfaces. The paper concludes with an overall assessment of these different facets of IT in the context of the Indian economy.

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1. Introduction

In his foreword to the NASSCOM-McKinsey Report (2002) over a decade ago, India's Minister for Communications and Information Technology called 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 pertains specifically to India's information technology (IT) industry,[1] which has done quite well in the ensuing decade. The second stated goal is much broader, much deeper, and much harder to achieve, seeming to imply that IT can be the cornerstone of India's development. 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 the better? Or will the benefits be restricted to an educated elite with access to jobs and power? This paper offers a conceptual overview of the possible roles of IT in development, and the different dimensions in which IT impacts, or might impact India's economy.

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 make 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, Bresnahan and Trajtenberg, 1995), 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. The formalization of this special role is based on the model of recombinant growth (Weitzman, 1998).

I briefly consider each of these possibilities – comparative advantage, GPTs (and complementarities more generally), and recombinant growth, in turn, as well as other aspects of

[1] Throughout this paper, I mostly use the term IT, rather than the common alternative of ICT, which stands for information and communication technologies. Since IT covers processing, storage and communication, this seems quite appropriate. Where it is useful, I also qualify IT by the adjective "digital," since older technologies such as writing also involve information processing, storage and communication. In some cases, when discussing mobile phones, it is more appropriate to use ICT.

IT and development, not necessarily linked to formal growth theory, including greater efficiency in governance and in the working of markets.

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 which use more intensively the factors of production in which it has relative abundance. In the case of software, the life cycle of development and use 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.[2]

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 characterized 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 (1991a,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.

General models of endogenous growth emphasize 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 provides a somewhat special role for IT, as an example of a GPT. GPTs have three key characteristics: pervasiveness, technological dynamism and innovational complementarities.[3] Helpman and Trajtenberg (1998a, 1998b) 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 abstract 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

[2] 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.

[3] 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 leads to a particular kind of externality: see Ray (1998), pp. 114-115.

about achieving pervasiveness are centered 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.[4] There are also horizontal complementarities, since the downstream sectors may face a coordination 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 (US$)

Costs of computing	1970	1999	2012
1 Mhz of processing power	7,601	0.17	<0.01
1 megabit of storage	5,257	0.17	<0.01
1 trillion bits sent	150,000	0.12	<0.01

Sources: Pam Woodall, "The New Economy: Survey," *The Economist*, September 23, 2000, p. 6, Chart 1, and author's calculations.

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, emphasized by writers such as Kremer (1993) and Milgrom, Qian and Roberts (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 coordinated 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 characterized as coordination failures. This set of problems also arises in the GPT models of Helpman and Trajtenberg, discussed above. Without going into details, I suggest that this literature has some relevance for thinking about the role of IT in Indian development. In particular, while the success

[4] 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.

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.

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). The details of this model are presented in Singh (2008). The central idea of this approach is that new ideas are formed through combinations of old ideas. A key property of this formulation is that the increase in the number of ideas 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." The extension of Weitzman's model, to capture the special role of IT in the innovation process, allows the stock of IT knowledge to independently affect the success rate. In this case, IT gives the growth process an extra 'kick', even beyond that which comes from recombinant growth in general.

The final aspect of IT's specialness 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 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 defense, 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 subsidization 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 judgments, 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 economizing 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 analyze 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 US 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 US 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 transactions costs for completing transactions, such as milk delivery by farmers to cooperatives, 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-labor-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 personalization, 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 recognized 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 recognizing 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 out 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.

2. IT-BPO Industry

The numbers on India's IT industry tend to be well publicized by the industry association, NASSCOM (www.nasscom.org). NASSCOM has over 1200 members, over two-thirds of which have annual revenues exceeding US$ 40 million ("large" according to NASSCOM's own classification).[5] This association represents software (including services and products), as well as business process outsourcing (BPO), but excludes hardware manufacture. The latter term has mostly replaced an earlier term, IT-enabled services (ITES), in describing a whole range of activities driven by the use of IT in various forms. Estimates for 2012 on the IT-BPO sector project annual revenue reaching US$ 88 billion), or ten times the amount (in nominal

[5] There are, of course, relatively few truly large firms by international standards, including TCS, Infosys and Wipro.

terms) of a decade earlier. Growth rates have consistently been in double digits. Adding in hardware takes the total above US$ 100 billion. A decade ago, India's share of the world market, in terms of global expenditure on software and services, was about 2 percent, but the latest numbers represent about a 10 percent share of the global market. To compare the IT-BPO 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 IT-BPO directly contributed about 5 percent to GDP, well above the 1 to 2 percent estimated a decade earlier (Singh, 2002).

Exports continue to be critical to India's IT-BPO sector, accounting for over 3/4 of its revenues (US$ 69 billion). Contrary to initial negative portrayals of Indian IT exports and being the work of "techno-coolies," narrowly focused on low-return routine tasks such as software testing, India's industry has broadened the scope of its exports, as well as steadily moving up the value-added ladder. Even in the case of BPO, Indian firms have been moving from call centers to services that require higher skilled labor or more complex outputs. While call centers and accounting services remain the largest segments, areas such as data management, data analytics and legal services have increased in importance. Table 2 provides a listing of types of BPO and related services. NASSCOM also provides lists of the leading IT-BPO companies (the major companies are all in both spaces) and of BPO firms specifically, in terms of exports and employment. These are presented in Table 3. NASSCOM estimates direct employment in the IT-BPO sector to be 2.8 million, with indirect employment generation of another 8 million.

Table 2: BPO and ITES Types

- Customer Interaction Services
- Business Process Management; Back Office Operations; Accounting Services
- Insurance Claims Processing
- Medical Transcription
- Legal Databases and Services
- Digital Content
- Online Education
- Data Management and Data Analytics
- Data Digitization/GIS
- Payroll/HR Services
- Web Site Services

Sources: http://www.nasscom.org/it_industry/spectrum.asp and author's research

The domestic IT market has also become substantial in size and scope, though the Indian economy's absorptive capacity remains relatively low – a theme of several of the following sections. For 2012, the domestic market size was estimated at Rs. 918 billion, or about US$ 17 billion, excluding hardware. The breakdown of this total was Rs. 589 billion for IT services, Rs. 149 billion for BPO and Rs. 180 billion for software products. The domestic hardware market is also substantial, at Rs. 615 billion in 2012, though in the case of hardware, the domestic value added component is probably much less than is the case for software and ITES.

Despite India's emphasis on import-substituting industrialization, 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, rather than for export. The largest hardware segments are notebooks and tablets, desktop PCs, and network equipment. Servers and storage are very small segments of the domestic hardware market. In June 2012, the Manufacturer's Association of IT (MAIT) complained about the challenges facing the domestic hardware industry, including supply chain disruptions, increasing prices of imported components due to the Indian Rupee's depreciation, and an unfavorable tariff structure on components, among other issues.

Table 3: Leading Indian IT Firms

Leading IT-BPO Exporters*	Leading BPO Firms*	Leading IT-BPO Employers
Tata Consultancy Services Ltd	Genpact India Pvt. Ltd.	Tata Consultancy Services Ltd
Infosys Ltd	Tata Consultancy Services BPO	Infosys Ltd
Wipro Ltd	Aegis Ltd	Cognizant Technology Solutions India Pvt Ltd.
HCL Technologies Ltd	Wipro BPO	Wipro Ltd.
Mahindra IT & Business Services	Firstsource Solutions Ltd.	HCL Technologies Ltd
MphasiS Ltd	Aditya Birla Minacs Worldwide Ltd.	Mahindra IT & Business Services
iGate	WNS Global Services (P) Ltd	Genpact Ltd.
Larsen & Toubro Infotech Ltd	Infosys BPO	Serco Global Services
Syntel Ltd	Serco Global Services Ltd	Capgemini India Pvt. Ltd.
CSC, India	EXL Services	Mphasis Ltd.
Polaris Software Lab Ltd	Hinduja Global Solutions Ltd	Aegis Ltd.
MindTree Ltd	HCL Technologies Ltd. - Business Services.	iGate
Zensar Technologies Ltd	Hero Management Service Ltd	Firstsource Solutions Ltd
Infotech Enterprises Ltd	Mphasis Ltd	WNS Global Services (P) Ltd
Hexaware Technologies Ltd	Syntel Ltd	CSC, India
KPIT Cummins Infosystems Ltd		Syntel Ltd
Honeywell Technology Solutions Lab Pvt Ltd		exl Services.com (India) Pvt. Ltd.
NIIT Technologies Ltd		Hinduja Global Solutions Ltd
3i Infotech Ltd		L&T Infotech
Infinite Computer Solutions (India) Ltd		Convergys India Services Pvt Ltd.

*Note: Does not include some companies whose corporate headquarters are located outside India, but have significant India-centric delivery capabilities, and have not shared their India-centric revenue figures with NASSCOM. Had they been ranked based on their India revenues, companies such as Accenture, Cognizant, HP, Capgemini, Oracle and IBM and would also have appeared in the ranking for IT-BPO and firms such as Convergys, IBM Daksh and Sutherland Global Services for BPO.

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 commoditized. 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 organizing this assembly as efficiently as possible, doing so on demand, and keeping its inventories absolutely minimal. Strong customer service plus management of communications and logistics at both ends of the value chain are also keys to Dell's success. Dell's positioning to 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. An obvious example in this context is the Aakash tablet, but it has failed to meet the promises made for it.[6] Another example is low-cost domestically designed network devices, as once envisaged by Ashok Jhunjhunwala's TeNet research group at IIT Madras. 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 other 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, the quality of the infrastructure, and financial constraints. These are generic challenges for Indian manufacturing.

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 skepticism that met the country's plan for an automobile industry, and the two decades it took to make significant inroads into industrialized country markets, brings to mind some of the early responses to, and experience of India's software sector.

To relate this possibility for software to comparative advantage considerations, one can note that the Japanese consciously developed a comparative advantage in automobile production,[7] whereas India's pool of workers with a particular set of software and language skills that are

[6] The earlier failure of the "Simputer" serves as a warning about actually succeeding in domestic manufacturing with sufficient scale to keep costs down. East Asian manufacturers have, in fact, begun to produce better quality tablet computers at a price not much above the target price for the Aakaash.

[7] 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.

valued in the international market gave it an accidental comparative advantage. Arora and Athreye (2002, Table 2), provide calculations indicating India's comparative advantage in software. For example, using 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 US.

To the extent that IT can have significant effects on the efficiency of operations in other industries, there are strong complementarities between the IT sector and the rest of the economy. Examples of areas where increased efficiency may be possible include accounting, procurement, inventory management, and production operations. These are all examples of "forward linkages", since IT adoption has positive impacts on the operations of a range of industries.[8] This is, of course, the standard argument in the US for the virtues of the "new economy" based on IT. These issues are taken up in Section 5.

Models of complementarities typically emphasize pecuniary externalities. Arora and Athreye (2002), on the other hand, suggest that there are strong direct spillovers from the IT sector to other services 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, emphasized 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.

Finally, I discuss expectations, which can have a positive or negative role in determining the nature of equilibrium where complementarities matter. 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 coordination 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 legitimize capitalism in a country whose intellectuals have long harbored 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 technology itself.

3. Rural Development

It may seem paradoxical that modern IT, typically associated with developed country markets and capital-intensive methods of production, has any relevance for a country where hundreds of millions, particularly in rural areas, still lack basic needs of health, education and sanitation. Nevertheless, there are many efforts underway in India and other developing countries to demonstrate the concrete benefits of IT for rural populations, and to do so in a manner that

[8] 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.

makes economic sense.[9] The general presumption behind these efforts is that resources spent in this manner have a positive return on development large enough to justify a possible diversion from other uses that directly address those basic needs.

The conceptual framework includes the idea that leapfrogging technologies may make economic sense. This is easiest to see within the class of digital communication technologies: mobile telephones and telephony over the Internet can be provided to people who have never had access to conventional circuit-switched wired telephone networks. The Internet as a delivery mechanism for daily news can be cost effective in areas where daily newspapers have not penetrated. More broadly, IT may help leapfrogging in other forms of economic institutions: village artisans may advertise and sell their creations on the Internet, without ever having been part of a conventional retail supply chain.

Besides the obvious – and as we have implicitly suggested with the leapfrogging examples, superficial – paradox of introducing modern technologies before satisfying basic needs, the issues involved are not straightforward, since the implementation of rural IT involves organizational and social changes, as well as the adoption of a complex set of modern technologies. Indeed, two points to be emphasized are the catalytic role of IT in spurring complementary innovations, and the special nature of IT, distinguishing them from other types of modern technologies, including other GPTs, such as electric power.

Even a simplified picture of rural households' economic activity drives home the point that they engage in a broad range of transactions and decisions with economic impacts. These include production and marketing decisions, saving, consumption, investment and risk management. What is noteworthy besides the complexity of this economic decision-making is that many decisions are made with very limited information, and that market interactions are often subject to high transaction costs, due to imperfections and asymmetries in information, as well as high transportation costs, inefficient intermediation and time delays. High transaction costs will always prevent marginal transactions from being undertaken; in extreme cases, the market may fail to function at all. Given this scenario, the role of IT can be understood in terms of reducing transaction costs, as well as improving the efficiency of decision making within rural households (both as producers and as consumers).

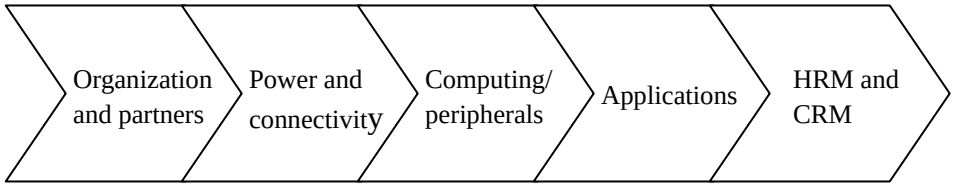
Reductions in communication and transaction costs are particularly beneficial where they can allow new markets to develop, in the sense that existing goods and services, otherwise restricted to urban areas, or to a very limited segment of rural populations, now can be offered to broader cross-sections of the rural population.[10] Examples include financial services, particular types of education, health services, long distance communications, and expertise on a range of production-related decisions. Whether this can be done in a sustainable manner depends on the supply conditions for IT-based rural services.

[9] See Singh (2007) for a more extensive discussion of the potential role of IT in India's rural development. The discussion in the current paper also draws on Singh (2004).

[10] See Singh (2008) for a model that develops this point formally. The original insight that transaction costs can lead to certain markets being non-operational is due to Romer (1994), but he emphasizes tariffs rather than internal transaction costs in his formal analysis.

On the supply side, we can illustrate the various stages of decision-making and delivery of IT-based services in terms of a typical value chain, as shown in Figure 1. At each stage of the chain, the IT components include a mix of hardware, software and services. For example, an Internet kiosk would have a computer, printer, web cam, modem, power back up, and software to enable standard Internet browsing, as well as handle specialized tasks such as education in the local language, agricultural information, e-governance and entertainment. At the other extreme, an alternative might be just a mobile phone, for basic voice and text communications. The creation of an organizational structure and value network is a critical first step, while managing human resources and customers is vital for successful final implementation.

Figure 1: Value Chain for IT-Based Services



Organizational and policy issues relate to all the stages of the value chain in Figure 1, albeit to varying degrees. The organizational structure necessary for the delivery of rural IT services typically requires commercial goals of profitability to be built in at some level, if scalability and sustainability are to be achieved. In the absence of commercial goals, the organization's incentive structure is unlikely to be financially sustainable without continual external infusions of support.

The organizational models of experiments such as the MSSRF in Pondicherry and DHAN in Tamil Nadu[11] both rely on ongoing external funding. The reason for this is an emphasis on "developmental" goals over financial sustainability. As will be clear, however, all rural IT projects require some degree of initial subsidization, and some ongoing cross-subsidization: the difference in the organizational models therefore lies in the balance between pecuniary and non-pecuniary motives as sources of incentives for efficient action. There is no unique answer, but it can be argued that a proper role for commercial incentives is essential if positive impacts are to be long-term and large-scale.

At the other extreme, a standard corporate structure is used: ITC, with its *e-choupals*, is the most significant example of this approach. EID Parry, a processed food company, has also been involved in rural IT efforts, though not as comprehensively as ITC.[12] It is clear that, for scalability, some minimum size of the organization is required, to spread the fixed costs of

[11] MSSRF is the MS Swaminathan Research Foundation, which operates 12 Village Knowledge Centers in Pondicherry, a Union Territory south of Chennai (Dossani *et al*, 2005, Parthasarathy *et al*, 2005). DHAN is the Development of Humane Action Foundation, which operated 37 kiosks as of June 2004, in Madurai district of Tamil Nadu (Parthasarathy *et al*, 2005).

[12] ITC has several thousand kiosks spread across multiple Indian states. EID Parry has been involved with several dozen kiosks in Nellikuppam district in Tamil Nadu.

administration efficiently. In addition, there are fixed costs of innovation that can be spread more effectively across a larger organization. Note that the organization referred to in this case is not necessarily the whole company, but could be the division that implements the rural IT services project. A variant on the corporate model is where there is a producer organization that controls the project, as in the case of the Warana sugar cooperative in Maharashtra (Dossani et al., 2005).

Another common organizational model is a hybrid one, combining non-profit and profit motives. For organizations that are dedicated specifically to rural IT-based services delivery, social goals can be incorporated by vesting controlling ownership of the corporation in a non-profit entity that has an explicit social focus. This model was followed by n-Logue, TARAhaat and Drishtee, for example, though none of them can be termed a success, for reasons that include difficulties of scaling enough to spread the fixed costs of building an organization. A variant on this involves controlling ownership through the public sector, typically the state government (e.g., Akshaya in Kerala – see Parthasarathy et al., 2005), though in smaller-scale cases, a rural local government may be the main stakeholder (e.g., Bellandur Gram Panchayat, Karnataka – see Dossani et al., 2005).

Even in the case of existing for-profit corporations which have broader businesses, social goals may enhance reputation, meet corporate social responsibility guidelines, or otherwise be consistent with the mission and values of the organization. In other words, including social goals may make good bottom-line business sense. In the case of ITC, this is clearly a factor in their efforts, though the supply chain efficiencies that are realized are critical to the expansion and continuation of their efforts.

For all types of organizations, building the right capabilities requires some effort. Creating what amounts to a brand new infrastructure for rural IT service delivery requires a broad mix of skills, and finding talented and trained people who can be effective in a role that mixes entrepreneurial tasks with corporate line responsibilities, all in an unfamiliar rural environment, can be a challenge. One significant aspect of this challenge is finding skilled people willing to work in rural areas. In many respects, the problems that emerge here are a symptom of the government's failure with respect to a broad range of practical education and training, especially in rural India. Kendall and Singh (2012) find, for example, in a sample of n-Logue kiosks, that an operator's having a college degree or even having completed high school did not significantly increase kiosk revenue: the minimum level of formal education needed to be a successful kiosk operator is not very high, provided adequate training is provided.

The final stage of the value chain in Figure 1 refers to human resource management (HRM) and customer relationship management (CRM). In this context, these more general terms take on specific focus. Training of rural kiosk operators, whether they are formal franchisees or independent farmer operators, becomes a key aspect of the delivery model. Training the field personnel at various levels (village and district hub) is also critical. Gathering customer information on usage patterns (nature and timing of use), revenue streams, responsiveness to pricing, social acceptance, and so on, is also vital, as these are brand new markets in terms of the nature of service delivery. Furthermore, being able to respond to this information with appropriate and timely changes in strategy is also necessary for successful implementation.

Providing appropriate IT applications presents more challenges. The range of possible applications is vast. Many IT-based services require non-IT logistics or processes as complements. Availability of local language software becomes more of a constraint. There is much more variation across localities, not just regions. Delivery of services or development of content often stretch the resources and expertise of the primary provider, and require varied partnerships or other contractual relationships. Local language content development can be hindered by a lack of software and hardware standards (see, e.g., Bajpai and Singh, 2005, for the case of Hindi).[13]

Deciding the sequencing, scope and sophistication of various applications can be a major challenge, since many of the services are being offered for the first time, or are being delivered in novel ways that challenge existing institutional frameworks and relationships. However, one of the benefits of the numerous rural IT experiments that have been conducted throughout India is that the kinds of applications that are valuable to rural households have been identified and refined. As one would expect, computer games are popular with children, and some kinds of communication and information retrieval (e.g., forms, certificates, examination results) are highly valued. Word processing is often needed by children and adults, and digital photographs are also very much in demand. One can generalize somewhat, to say that basic digital applications, often taken for granted in developed countries, are the basis for any rural IT kiosk's financial sustainability.

The second stage of the value chain for IT enabled services, illustrated in Figure 1, concerns access to electric power and Internet connectivity. For both, a major constraint on rural IT initiatives is the failure of the public sector to deliver adequate power and telecommunications to rural India – and the country as a whole, for that matter. This is no longer because these technologies are too expensive or sophisticated for a poor country – the failure is purely institutional. Privatization has helped in the case of telecommunications, as has technological change. In particular, the widespread adoption of cellular phones has been driven by the opening up of this sector to competition almost from its inception.

Combinations of a fiber optic backbone (which is now extensive in India), and wireless technologies for last-mile access are likely to emerge as cost-effective solutions, provided the government is able to implement socially desirable policies for investment as well as interconnection charges. The main thrust of the report of Dossani et al. (2005) is to argue for using Universal Service Obligation (USO) funds collected from telecommunications providers to finance improved rural IT access. This perspective is a valuable one. Digital convergence in IT means that separating voice from data in formulating policies for rural access no longer makes sense. Similarly, calls to focus on mobile phone access rather than Internet kiosks (*Economist*, 2005) neglect the convergence in technologies as well as the different functions served by the two access modes.[14] In many ways, this convergence, as well as poorly designed regulation of

[13] More general discussions of local language content issues for ICTs in India are in Kumar (2004) and Sangal, Bharati and Chaitanya (2004). Much of the problem lies with poor standard setting at the state government level. Thus, in Punjabi, there are multiple, independently and privately developed fonts, with varying keyboard mappings, making it difficult for ICT based written communication in the language. In contrast, East Asian countries such as Japan and Korea have developed standard fonts and modified dual-language keyboards as national standards.

[14] Shared mobile phones are very effective for certain types of communication, and their capabilities obviously keep expanding. Indeed, smart phones with larger screens and tablets of various sizes have created a spectrum of IT

telecoms, contributed to the failure of n-Logue, which attempted to bundle voice and Internet services for rural India.

Electric power is in many ways more of a problem than telecoms connectivity, and this is true throughout India. The reason is a serious institutional failure. The production, transmission and generation of electricity in India are seriously inefficient, as a consequence of poor organizational incentives and vested interests in the traditional public sector. For rural IT access, the lack of power for long periods seriously hinders accessibility. Battery backups are an essential part of rural Internet kiosks, though they are a very partial solution to the lack of reliable power supplies since they cannot provide sustained power during long power outages. The need for heavy duty battery backups also adds significant capital and maintenance costs for these kiosks. Of course, this is a microcosm of the problem faced by all electricity consumers in India – they are forced to use inefficient, small-scale backup power supplies, because of the total inefficiency and unreliability of what should be much cheaper large scale provision of electricity.

I began this section with the paradox of investing in IT for rural India, when basic needs are not being met. Two problems in rural India for the critical areas of health and education are access to service providers and access to useful information. Rural teachers and doctors, even when paid by the government, do not show up at schools or clinics. Textbooks and medicines are often not available in rural areas. While medicines cannot be digitized, information can. And rich digital content and long distance communications can overcome physical absence.

The amount of content that can be delivered cheaply through CDs or flash drives and through the Internet dwarfs what is possible through the traditional textbook model. In this context, even computer games have educational value, and several of the initiatives mentioned earlier have demonstrated that children are very quick to assimilate and use all kinds of IT tools for some mix of entertainment and education.[15] Rural IT kiosk operators can provide such educational services at low cost, as part of an overall array of services.

There is thus no presumption or expectation that the use of IT in kiosks can substitute for basic education. Nevertheless, educational services through rural IT kiosks can provide an important complement, and even a multiplier effect, for more traditional educational efforts. One area where IT-kiosk based rural education may have a significant role to play is in adult education, ranging from basic literacy to very specific skills for those who have received a conventional school education. Initiatives such as n-Logue focused on developing local language content, including print, digital text and digital video, for various types of education, with the

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devices with communication capabilities. However, for many types of information access, where quantity and ease of reading and processing matter more than mobility, the use of desktop PCs may be more efficient. In addition, a desktop PC with printer is able to provide a wide range of services that are not communication-related, but just involve processing of information. Nevertheless, mobile phones can be sufficient and significant for conveying basic information such as market prices in multiple locations, in advance of travel to a particular market. See Eggleston, Jensen and Zeckhauser (2002), and Jensen (2007).

[15] The most famous example of children's' ability to adapt to and learn from new technology is the NIIT "hole-in-wall" experiment, in which a computer was made accessible to slum children through a hole in a wall, without any prior instruction or information. The children rapidly developed their own technology vocabulary and learned to make effective use of the computer for game playing, for example (http://www.niitholeinthewall.com/home.htm).

most obvious application being training in basic computer skills, though its spoken English modules were very popular.[16]

Turning to health, to some extent, there are pervasive informational problems in health care provision, and not all of them are amenable to easy solutions. However, with respect to rural health care, since the informational gaps are more severe than for the urban middle class, the role of IT can be quite positive, and multidimensional in nature. One obvious possibility is the provision of basic medical information online, or on CDs and flash drives. The benefits of this will be limited by the ability of rural populations to absorb such information and act on it. Therefore it is important for basic medical information to be made available in local languages, but it is more likely that this would be a tool for rural medical practitioners, rather than something that could usefully be directly accessed by individual patients.

Another kind of information that can be valuable is online listings of information about availability of care; furthermore, tools for making appointments and providing health histories in advance of travel to a medical facility can also be made available online. While these kinds of IT tools can substantially reduce uncertainty and transaction costs for individuals in rural areas, their adoption may require substantial investments and back-office reengineering by health care providers, whether public or private. The Health InterNetwork (HIN) India, part of a global initiative sponsored by the World Health Organization, has experimented with giving consortia of medical colleges access to digital information on health care, as well as placing PCs in Primary Health Centers (PHCs) and Community Health Centers. Interestingly, while the appropriate content for rural local users was not much available, an immediate and beneficial use was for relaying basic information on local conditions (in particular, a daily heatstroke report) to district health centers (Kuruvilla et al, 2004).[17]

4. E-Commerce

E-commerce can be interpreted broadly to include business-to-business (B2B) transactions, or even internal processes. The latter are taken up in the next section, in a discussion of manufacturing. B2B transactions are part of the supply chain, and management of the supply chain is also a weak link in India. Again, this is an issue discussed further in the next section. In Section 2, I discussed the complementarities between the IT sector and the rest of the economy. These complementarities arise from transactions situated in the B2B arena. 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 US.

[16] However much one may decry English language imperialism, and push the importance of local language content, it is true that spoken English competency is an important asset in the Indian workforce, and paternalism or nationalism should not deny rural Indians access to this skill. One major problem with rural teaching of English is the lack of proficiency of the teachers themselves – video or audio modules for spoken English provide an obvious and cost-effective relaxation of this supply constraint.

[17] A somewhat different example of relaying local information is provided by the application of IT for disease monitoring in tsunami-affected districts of Tamil Nadu (Voxiva, 2005). The question arises in this case as to the benefits of data transmission versus simple voice messages. The benefits of the former seem to be accuracy and richness of the information that can be transmitted, and ease of integrating new information into existing databases.

For example, Miller (2001) surveyed 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 reduced receivables from 310 days to 90 days. General cost improvements came from an overall tightening and acceleration of processing within the company, and between the firm and its customers. The speed of order delivery greatly improved, and inventories were reduced. A shift by customers from leased lines to the Internet will provide further cost savings.

Turning to retail, or B2C e-commerce, a key statistic is that India has only about 150 million Internet users, of whom 75-80 percent are active or regular users. Hence, the current potential of the B2C market is well below that of the population. About 30 percent of the user base is in rural areas, including those who use mobile devices. Urban Internet users prefer communication and social networking, while entertainment (e.g., music, photos and videos) is the primary driver of Internet use in rural India. Content sites such as Yahoo! are popular in India, and Google offers multiple Indian languages for its search engine.

Given issues of inadequate systems of payment and delivery, rural Internet users in India are more likely to be part of the attention economy, paying for access to content through their attention to advertising. Urban Indian consumers, however, are more like their Western counterparts, using e-commerce for a wide variety of goods. Since e-commerce came relatively late to India, its trajectory did not follow that of the West, starting with books and CDs. However, goods that are expensive to stock in full variety, like books and music, are natural candidates for online selling. One already finds a wide range of sites for Indian e-commerce, either very broad-based, like Flipkart, or specializing in specific ranges of goods, such as apparel, shoes, electronics or household items. These online sites, to some extent, fill the gap of the absence of sophisticated department store chains, which are relatively weak or scarce in India (with the partial exception of the southern part of the country).

Indian e-commerce sites have had to adapt to the Indian scenario, in terms of logistics, payment systems and legal mechanisms. Interestingly, they have been reasonably successful, despite the institutional weaknesses. The use of cash on delivery and private couriers and the importance of trust and reputation have allowed e-commerce transactions to gain a foothold in Indian retailing. Recent moves to allow FDI in multi-brand retail in India specifically exclude e-commerce, providing some "infant industry" protection to India firms. Flipkart, for example, has not had to compete with giants such as Amazon, and will continue to be sheltered in this respect. Of course, content and market intermediary services such as eBay are very much part of online offerings in India. Furthermore, the nature of e-commerce is that Indians are also able to make purchases from foreign e-commerce sites, and in many cases shipping costs are not prohibitive. There is also very little to prevent foreign sites from acting as intermediaries between Indian buyers and sellers.

Online services have played an important role in Indian e-commerce. Of the US$ 2.5 billion Indian market for e-commerce in 2009, 75 percent was in travel and mobility services (airline and railway tickets, hotel bookings and mobile phone recharges, for example). Indian sites are also used extensively by foreigners, for gift giving (e.g., flowers and sweets), or for travel-related services. In terms of pure e-tailing (excluding travel services as does the US Department of Commerce), the market size in India is still well under US$ 1 billion. Growth projections for Indian e-commerce are quite optimistic, with annual growth rates of 30 to 60 percent being forecast, but the basis for these projections is not always clear. Much of the outcome of these projections depends on the evolution of Indian retailing in general, as well as the overall growth rate of the economy. A slowing down from GDP growth rates above 8 percent to around 6 percent will inevitably impact growth in consumer spending. The ability of the government to accelerate the penetration of broadband access to the Internet will also be an important factor in the growth of e-commerce.

One area where e-commerce can have some impact on rural India is not from the perspective of consumers, but of producers. It is possible to use IT, specifically the Internet, to market rural handicrafts to widely dispersed consumers, in developed countries, as well as urban areas of developing countries. For example, DrishteeHaat offers a web site with a range of "ethically sourced gifts & handicrafts from rural India." There is a potential role for rural Internet kiosk operators in such cases, as intermediaries in the marketing process. For example, in DrishteeHaat, kiosk operators have in some cases been trained to identify local handicrafts that might be marketed on the Internet, and to create the relevant content for advertising these products. This is far from the only example in India, nor is India the only developing country to see the potential for using the Internet to overcome distance in bringing rural products to wider markets at effective cost. It should also be noted that a hybrid model may be the most successful even in this case. Companies such as FabIndia, which were already successful in sourcing a range of products from rural India to upscale stores in urban India, have naturally extended their reach to online offerings. Such intermediaries are important in providing branding and reputation, thus creating trust for buyers in otherwise unknown sellers and products.

5. Manufacturing[18]

Compared to many other developing countries, India's manufacturing sector has played an unusual role in the national growth experience. In 1950-51, the first year for which comparable data is available, manufacturing was approximately 9% of GDP. By 1979-80, this ratio had risen close to 15%, but thereafter has hardly increased. The highest share of manufacturing in any year was in 1996-97, at16.6%: after then the figure has hovered on either side of 16%, even in the years when India's GDP grew at over 9% annually.[19] In this context, the new National Manufacturing Policy's (NMP, 2012) explicit goal of increasing manufacturing's share to 25% by 2022 is extremely ambitious.

Panagariya (2008), comments on the situation of Indian manufacturing: "In contrast to other countries that have successfully transitioned from the primarily rural and agricultural

[18] This section draws heavily from Sharma and Singh (2013).
[19] These percentages are calculated by the authors from National Accounts data from RBI (2012).

structure to the modern one, rapid growth in India has not been accompanied by a commensurate increase in well-paid formal sector jobs. In large part, this has been due to a stagnant share of industry and manufacturing, especially unskilled-labor-intensive manufacturing, in the GDP. This pattern of growth has meant that the movement of the workforce out of agriculture and into the organized sector has been slow. Modernization of the economy requires the expansion of employment opportunities in the organized sector." (Panagariya, 2008, p. 309)

Of course, neither the NMP nor Panagariya is guilty of what might be termed manufacturing fetishism. The services sector in India is well recognized to have been successful in generating GDP growth as well as employment. This includes software and ITES, as well as a wide range of other services. The implicit argument in statements such as Panagariya's is that the services sector by itself cannot provide the sustained growth in output or employment that will be needed in the long term.[20] There are also problems with the nature of the manufacturing sector itself: for example, Kochhar et al. (2006) suggest that India's manufacturing sector was more diversified, more skill-intensive, and less (unskilled) labor-intensive than average, compared to countries at similar levels of development. This skill bias was accentuated in the 1980s and 1990s, according to their empirical analysis, and would not be conducive to the kind of pattern of growth discussed by Panagariya.

Panagariya goes on to argue that, "India must walk on two legs as it transitions to a modern economy: traditional industry, especially unskilled-labor-intensive manufacturing, and modern services such as software and telecommunications. Each leg needs to be strengthened through a set of policy initiatives." (Panagariya, 2008, p. 287) His own policy recommendations include somewhat separate discussions for each of his two "legs" of the Indian economy. For labor-intensive industry, he emphasizes labor law reform, bankruptcy reform and privatization, while software and telecommunications require attention to education and urban infrastructure. However, an important potential linkage exists between these two parts or "legs" of the economy, namely, the use of IT in domestic manufacturing as a potential avenue to spur productivity and employment growth in that sector.

Chandra and Sastry (2002) summarized the findings of the 2001 National Manufacturing Survey (NMS). The focus of this survey was on the organized manufacturing sector, representing less than 1% of the country's firms at the time, but employing 19% of its industrial workers and contributing almost 75% of gross value added. Chandra and Sastry were quite critical of Indian manufacturing management. Their study noted the lack of spending on R&D, and the relatively small numbers of employees with advanced degrees, in the surveyed firms. They also noted that Indian manufacturing firms gave low priority to investments related to information technology, such as computer-aided manufacturing (CAM), computer-aided design (CAD), computer integrated manufacturing (CIM), and computer-aided engineering (CAE). They also suggested that domestic IT firms did not have the right products for Indian manufacturing firms in these application spaces.

The next NMS, in 2007, was analyzed in Chandra (2009). Supply chain management remained a key weakness in the later survey, and investments in R&D remained low, despite

[20] A detailed discussion of services is beyond the scope of the current paper: Singh (2008a) provides an analysis of India's service sector in relation to manufacturing and their respective roles in overall growth.

perceptible benefits to innovation. Investment and usage of IT on the shop floor also remained low, at about 45% for this later sample, which is not much higher than the 2002 figure. Chandra concluded, "Once basic IT investment is done, only then will Indian firms be able to implement and take advantage of automation on shop floors. IT firms in India have failed to develop a viable and low cost IT solution for Indian Manufacturing. Firms other than the large ones are struggling on this count." (Chandra, 2009, p. iv)

Chandra (2009) also summarized regional differences in IT use among the NMS sample firms. IT use was highest in the South, and lowest in the East, but also in Uttar Pradesh (in the North). Interestingly, IT use tended to be concentrated among managers, and to some extent supervisors, with less IT use by operators on the shop floor. To some extent, the pattern of IT use (or non-use) was symptomatic of under-investment in both physical and human capital, reflecting high financial costs as well as an unfriendly policy environment. At the same time, Indian manufacturing firms were able to make strong profits in this period, despite their inefficiencies.

Still more recently, a joint study by the National Manufacturing Competitiveness Council (NMCC) and NASSCOM specifically focused on promoting IT adoption in Indian manufacturing. The NMCC-NASSCOM report makes several familiar points, but with newer survey data to back them up. It starts by noting the relatively low penetration of IT in Indian manufacturing, especially among smaller firms, as well as its relatively low productivity in terms of value added per capita. As in the earlier NMS reports, the link between IT use and productivity is not quantitatively established in this report, but the case is made conceptually, by describing the numerous potential benefits of IT across a range of applications, with several brief case studies.

The report discusses the barriers to IT adoption as revealed by the survey data. In many cases, even when IT is adopted by the surveyed firms, it is restricted to basic or non-core operations, limiting its impact. However, the hurdles to any adoption at all are numerous: lack of infrastructure such as reliable power, high costs, unsuitability of off-the-shelf IT solutions, lack of awareness among businesses of IT investment options, lack of enabling business and policy environments, and especially lack of internal capabilities to make and implement informed decisions. In the context of this last point, the report's conclusion is striking: "ICT adoption levels in manufacturing firms were primarily influenced by their management team. More than three-fourth of the companies especially in the micro and small firms category are strongly influenced by the owner/management team for their ICT investments." (NMCC-NASSCOM, 2010, p. 11)

According to the report's findings, overcoming this particular internal barrier to IT adoption will be challenging. External influences such as IT consultants and vendors, government agencies, and even peer group companies were found to be limited in their impact on IT adoption. These limits suggest that the strictures criticism made by Chandra (2009) of the domestic IT industry's failure to promote IT adoption may be too harsh: the problems are systemic, and require system-level solutions. The NMCC-NASSCOM report does emphasize the

importance of clients in influencing IT adoption, implying that supply chain network effects can be an important avenue for overcoming the barriers.[21]

The NMCC-NASSCOM report emphasizes the potential role that can be played by national and local industry associations in developing best-practice business process re-engineering guidelines to manage the organizational changes that are often needed to realize benefits from IT investments. Human capital development to overcome lack of appropriate skills can be addressed through improving the quality of government-provided training programs, and through tax incentives for firms to spend on this training. Anomalies in the tax code, broader deficiencies in the legal framework, poor telecoms infrastructure and lack of access to finance all emerge in the report as barriers to IT adoption that can be overcome through new policies. The report also discusses possibilities for adding requirements for electronic communications in certain contexts, and the possibility of creating a more efficient national market for IT products and services, through information dissemination, creation of electronic market platforms, and award programs. Many of the issues raised in the report illustrate the status of IT as a novelty for Indian manufacturing firms, especially the smallest ones.

In addition to the case study and qualitative evidence, several econometric studies have reinforced the conclusion that IT has a positive effect on manufacturing productivity. Gangopadhyay, Singh and Singh (GSS, 2008), used Annual Survey of Industries (ASI) data for 1998-2002 to examine the determinants and impacts of IT investment in India's manufacturing plants. The GSS study found that IT use was possibly constrained by factors such as the availability of electricity and of short-term finance. At the same time, there was evidence that plants that used IT were more profitable and more productive than those that did not. This finding has recently been confirmed and extended in Sharma and Singh (2013). The latter use newer data, which also allows them to construct a panel of manufacturing plants, and therefore to control for plant-level fixed effects. Including these fixed effects, which may plausibly be attributed, at least partially, to differences in managerial ability or availability, reduces the estimated impact of IT investment on productivity, but does not eliminate it.

Kite (2012) finds very similar results using the PROWESS database from the Centre for Monitoring the Indian Economy (CMIE). This data covers large and medium sized firms listed on India's stock exchanges, as well as public sector enterprises. Services firms (including financial services) are included, along with manufacturing firms. The analysis covers four years, 2005-08, with most firms in the sample reporting data for more than one of the years. She focuses on expenditure on IT outsourcing, proxied by a reported measure of "expenditure on software and other professional services," but also uses measures of in-house software and hardware. Her basic result is that all the three IT variables have positive and significant impacts on output, and the results are robust to a variety of changes in the sample, the specification and the estimation method.

GSS (2008) also estimated a full set of demand equations for unskilled and skilled labor (proxied by wage and salaried workers, respectively, as is standard in working with ASI data), and found that IT use increased the demand for both types of workers. This result can be

[21] Both Chandra and Sastry (2002) and Chandra (2009) emphasized weaknesses in supply chain management as a problem among Indian manufacturing firms.

interpreted in the following manner. Even if IT leads to the substitution of capital and skilled workers for unskilled workers (as is theoretically plausible), the positive output effects of increased efficiency on the demand for unskilled workers outweigh any negative substitution effect. This result strongly reinforces the case made in the NMCC-NASSCOM report for focused policy attention on promoting the use of IT in Indian industry. While broad systemic reform is needed if India's manufacturing sector is to have any hope of meeting the NMP goals, attention to IT investment and diffusion of knowledge of possibilities in this area may be a relatively low-hanging fruit for policy-makers.

6. E-Governance[22]

Poor public service delivery is a major symptom of poor governmental performance in India at all levels. The problem is probably more acute at the subnational level because day-to-day and basic services – such as health care, education, water and sanitation – are more the responsibility of subnational tiers, while, at the same time, these tiers of government have been disadvantaged with respect to fiscal and administrative capacity. Increases in patronage politics and rent-seeking over time have also resulted in a decline in the quality of public expenditure. Seeing this situation in terms of the functioning of accountability mechanisms, whether of elected officials to citizens or of other government employees to elected officials, a major problem is lack of good information flows both within government and across government boundaries to citizens.

IT has a dual role to play in the case of governance and administrative reforms aimed at increasing efficiency and effectiveness. First, the use of IT for improving internal government processes is important, through its potential to increase the efficiency of these processes. For example, the costs can be lowered, and accuracy improved, of data entry for tasks such as the preparation of electoral rolls and lists of welfare eligibility. Second, and perhaps more importantly (because it can hasten the first change), transparency, accountability and responsiveness can all be enhanced by using IT to alter the citizen-government interface. This second avenue is particularly relevant in rural areas, where government is both extremely important and also stretched very thin: effective access to government services can be difficult and costly for the average rural citizen.

There are now many examples of IT use in governance in India, and we will discuss some of them briefly, especially in the context of their impacts on expenditure quality and service delivery. Before we do so, we discuss a conceptual framework (Pritchett and Woolcock, 2004) in which to consider the examples. Pritchett and Woolcock begin by identifying two dimensions of variation for public services: transaction intensity and degree of discretion. They further distinguish between policies (when the service is non-transaction-intensive and discretionary), programs (transaction-intensive and non-discretionary problems) and practices (transaction-intensive and discretionary services). They argue that practices are the most challenging category from the perspective of governance.

[22] This section draws heavily from Singh (2010).

Shah (2006) adduces three types of benefits of IT within this conceptual framework: reducing discretion (converting practices to programs), reducing transaction costs, and improving incentives by improving information and transparency (the core of improved accountability). One of Shah's case studies is the computerization of the railway reservation system. Given the size and reach of the Indian Railways, this has rightly been perceived as one of the most successful government implementations of IT in India. Shah discusses how the use of IT achieved all three benefits, reducing the discretion of individual reservation clerks, cutting transaction costs, and increasing transparency (reducing information control by any individual) and thereby improving incentives for reservation clerks. A key feature of Shah's analysis is his identification of the stages of implementation: it began in 1985, and proceeded from branch-level databases to a unified national database, with electronic remote access by consumers (in other words, an IT-based citizen-government interface) via the Internet coming much later. In fact, the vast majority of ticket purchasers still do so by queuing up at reservation counters. As Shah observes, opportunities for discretion and corruption remain, but they have been substantially reduced.

Examining the railway reservation example more closely, one can note that reducing discretion is a benefit when the discretion is misused: this is therefore a subset of improving incentives. Incentives are improved, and inappropriate discretion curbed, when digital information systems increase transparency and access by service users. Report cards that rank various e-governance initiatives (e.g., Kochhar and Dhanjal, 2004, 2005) use an array of evaluation criteria, including "ease of use," "speed of delivery," "low incidence of errors," "reduction in corruption," "staff behavior" and "staff competence." With some minor over-simplification, one can argue that these lists can also be reduced to the two fundamental criteria of reducing transaction costs and improving incentives. Going back to the Pritchett and Woolcock (2004) classification in the context of the railway reservation example, one can further argue that the key characteristic for citizen-facing public services is transaction-intensity, while discretion is a much more malleable characteristic.

To summarize, citizen-facing public service delivery that is also transaction-intensive suffers from two potential problems. First, the transaction costs are often quite high, relatively uniformly across users, and independent of the effort of service providers (government officials). In the language of economics, the production technology is inefficient. If IT can be implemented to reduce these transaction costs, by making access to information easier, or executing procedures (e.g., applications for documents and certificates, or making payments) more efficiently, this is a straightforward welfare gain. If service providers are not hurt (losing income or jobs) by the IT, they should not be opposed to such implementation.

The second problem is that of distortion of targeting and of user charges. Citizens may be forced to pay more than is required by law to access services, or may not be able to obtain services to which they are legally entitled, if service providers can exercise inappropriate discretion. Using IT to correct this second problem can conflict with the interests of government service providers, since it reduces their real income. Depending on the nature of the service, controlling discretion may also require organizational restructuring, which is challenging in any circumstance and for any purpose. Shah (2006) correctly observes that the failure to understand

the needs and difficulties of incentive-restructuring lies behind the failure of several government-sponsored IT projects in India.

Another aspect of public expenditure governance is quite different from the case of transaction-intensive service delivery. In many cases, the accountability issue in governance is one of the appropriate use of budgeted funds. Infrastructure projects, ranging from national highways to local village meeting halls, are subject to varying degrees and types of malfeasance, including rigged bidding, skimming or totally misappropriating funds, skimping on construction materials, and defective design. Many of these problems require monitoring by technically qualified outsiders, and IT has only a tangential role to play, by permitting better information-sharing, tracking and benchmarking. Posting flyers on bulletin boards in villages may reveal the information, but could be subject to manipulation as well. IT used for creating electronic records potentially allows such information to be independently verified, whether by citizens or by higher-level officials. In fact, the absence of the latter verification has been a key weakness of hierarchical mechanisms of accountability in the Indian context.

IT can play a role in improving the efficiency of internal government processes and in enhancing transparency, accountability and responsiveness by altering the citizen-government interface. International comparisons (Singh, 2010) suggest several lessons: the importance of legislative or administrative backing for IT implementations that seek to change incentives; the importance of adequate scale; the benefits of building up to a national-level implementation from the state level, as well as down to the local level; the dangers of trying to be too broad in scope, or not specific enough in applications or services; the need to address all value chain components (including organizational infrastructure as well as technology); and the centrality of internal expenditure (and general information) management systems in successful IT implementations in government.

From the perspective of the foregoing analysis, India's recent national e-governance plan raises several potential red flags. By focusing on a broad, ambitious set of public services, delivered through a vast new, decentralized infrastructure (100,000 common service centers), it may both overpromise and focus on the wrong initial areas for improvement. As long as state and local expenditure management systems are not upgraded, through the implementation of IT systems, training and reorganization where necessary, it will be difficult to deliver the kinds of services that are envisaged. It is also not clear to what extent national control will override decisions that might be best made at the state and local level, in terms of local infrastructure and service delivery: this is a trade-off with standardization and inter-operability that has to be recognized. Of course, the front-end citizen-government interface is important for engaging ordinary people in the functioning of government, but the less glamorous, less politically popular back-end should not be neglected either. And with respect to the back-end, there are two layers as well – one which provides the infrastructure for IT-based service delivery, but also, another deeper layer, which provides basic tracking of expenditure and outcomes. This tracking can be integrated into a "dashboard" for guiding better policy-making and expenditure management.

7. Conclusion

This paper has provided a review and overview of various facets of IT in India's economy. The most obvious of these is the IT sector itself, including IT enabled services such as business process outsourcing. This sector has proved to be resilient and innovative, continuing to expand and upgrade its offerings. The export orientation of the sector has contributed to its competitive discipline and success, though that success has never been a forgone conclusion.

At the other end of the development spectrum, this paper discussed several aspects of rural IT in India. A decade ago, there were many ambitious attempts to harness the potential of IT for providing rural communications and other IT-based services. The story of these attempts illustrates many of the general problems of development. Often, the binding constraint was a lack of certain types of human and social capital. Low levels of income also were an obvious challenge in creating sustainable business models for rural Internet delivery. Nevertheless, various experiments and more ambitious ventures have provided lessons about how to go about such efforts in the future, and they have suggested that IT access for India's rural masses is not a pipe dream.

One joint lesson from the two polar extremes of IT in India's economy has to do with the role of government. When the government provided some basic infrastructure and human capital development roughly appropriate for software development and IT enabled services, the sector took advantage of global opportunities and took off. In the case of rural IT, the story is often one of government failure, failure to provide physical infrastructure (e.g., electric power), and failure to provide organizational infrastructure (e.g., efficient legal and regulatory frameworks). But this is just part of a larger story of government failing to deliver public goods when it is supposed to do so.

This paper also examined e-commerce, which is a conventional outgrowth of IT and the Internet. Indian e-commerce is in its nascent stages, and is again held back by the government's inability to catalyze a rapid deployment of broadband connectivity, especially in urban areas. Indian entrepreneurs are not lacking in their desire to innovate and succeed, and are often hindered by an unfriendly environment for doing business.

This problem is most acute in the case of manufacturing, and here the paper marshaled qualitative and quantitative evidence for the benefits of the use of IT in manufacturing, and throughout the supply chain, as well as the fact of its under-adoption. While it has been suggested that the Indian IT industry is itself to blame, in not providing suitable products for domestic firms, the overall inefficiency and backwardness of much of Indian manufacturing must shoulder the most responsibility for this state of affairs. Again, one might argue that the government's failure to provide a policy environment in which business can function effectively is a major roadblock to development.

If the major theme of a review of IT in India's economy is that the government must do better, the natural question is what role IT can play in that effort. This paper's penultimate section provided some thoughts on how IT can improve the functioning of government itself. Of course, technologies that enhance information flows and improve transparency and accountability are not guarantors of major positive change. Ultimately, what determines

outcomes is the quality of ideas, not of the technology. IT is ultimately just a tool, but it is inherently powerful and extremely versatile. The final message of this paper is that using IT to enhance many aspects of the Indian economy and the lives of ordinary people is both practical and sensible.

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