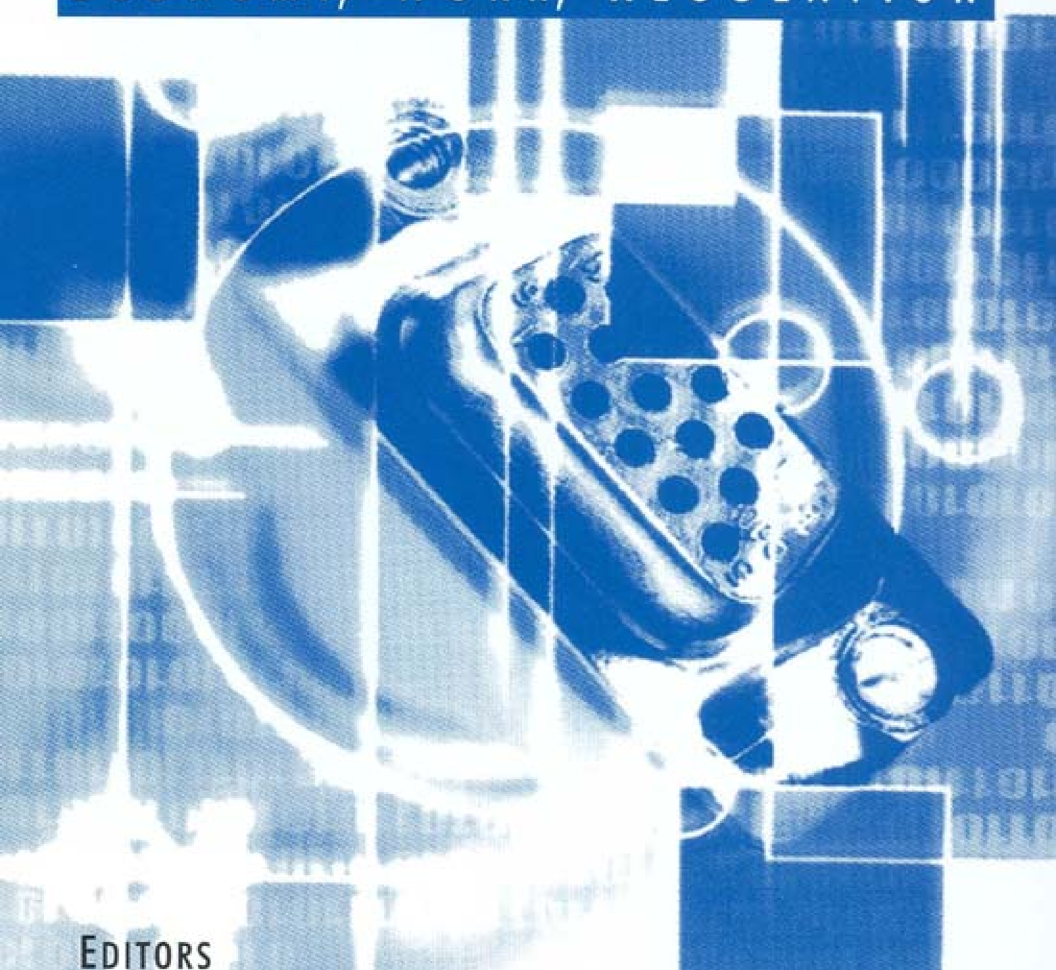
ICTs and Indian Economic Development

Economy, Work, Regulation



Editors
Ashwani Saith and M. Vijayabaskar

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Preface

This volume is based on a set of papers selected from those presented at a major conference on *ICTs and Indian Development* held in Bangalore in December 2002. The conference was distinctive in several respects. First, it adopted a holistic approach across a broad domain. Instead of focusing on some particular dimension of the theme, the conference made an attempt to engage with its multiple facets and interfaces covering economic, technological, political, legal, social and cultural issues. This was a daunting agenda, well beyond the usual circumscribed boundaries of the economic impact and implications of information and communication technologies (ICTs) in India, and it brought together specialists from the full spectrum of the social sciences around the table. This was no mean achievement. The second distinctive feature was that a conscious attempt was made by social scientists to step out of their proverbial ivory towers to engage with the do-ers, the generators, enablers and practitioners of ICTs. As such, the conference included serious contributions from scientists and technologists, from policy makers, from industry, from the worlds of labour and work, and importantly, from development intermediaries. This broader approach was stimulated by the new emphasis being placed generally, as also in the Indo-Dutch Programme for Alternatives in Development (IDPAD), on the social and policy relevance of research efforts in the social sciences. Finally, the conference made a special effort to include contributions from younger scholars in the field. This introduced fresh voices and perspectives into the debates, and at the same time served as an investment in the future of research. An additional feature was the Chinese connection; several specialists made contributions that provided valuable comparative insights into Indian and Chinese experiences of the development of information technology. By all accounts, especially on the basis of the feedback from approximately a hundred participants of all categories, the conference was singularly successful in meeting its objectives of stimulating cross-discipline and cross-specialization interactions and debates.

The wide range of themes in the conference provided sufficient research output for two stand-alone volumes on the relationship between ICTs and Indian economic development. The present one brings together contributions focusing on issues of economy, technology, infrastructure and labour processes, including a comparative perspective on the Chinese experience. The companion volume will deal with the multiple dimensions of ICTs and Indian social change, covering the nature and implications of digital and social divides, governance and democratization, poverty alleviation, gender, regional patterns of IT development, including a valuable database on ICT initiatives in the area of development.

The conference was held under the joint auspices of the Institute of Social Studies, The Hague, and the Institute of Human Development (IHD), New Delhi, and it was generously sponsored by the IDPAD. As editors of the volume, we owe considerable debts of gratitude to all colleagues and partners who underwrote the success of the conference in the first place. Here, thanks are due to the two partner institutions, IHD and ISS, and in particular to Prof. Alakh Narain Sharma and his team at IHD that undertook the complex logistics of the conference. We also take this opportunity to express our appreciation to IDPAD and its Dutch and Indian chapters; in particular, Mark Verhagen and Prof. Peter van der Veer in the Netherlands, and to Professor Panchmukhi, Bhaskar Chatterjee, Sanchita Dutta and Avdhendra Sinha of the Indian Council for Social Science Research (ICSSR) in Delhi. We also recognize the valuable institutional support provided by the Madras Institute of Development Studies (MIDS), Chennai, and the Indian Institute of Information Technology, Bangalore (IIITB), in particular by its Director, Professor Sadagopan. Dr Gayathri Vasudevan of ILO, New Delhi, provided crucial support in co-ordinating the academic and the logistical sides of the conference. We are also grateful to the various paper writers, discussants, chairpersons and rapporteurs of the conference whose efforts helped in the selection and revision of the papers included in this volume. Thanks are also due to Mr Narayana Murthy, Chief Mentor, Infosys, who

provided the stimulating keynote address to the conference. At MIDS, we are especially thankful to Mr Dharumaperumal and Mr Senthil of the systems department for their invaluable help in formatting. Finally, we would like to gratefully acknowledge the sympathetic, supportive and efficient contributions made by our editors at Sage India: Omita Goyal, Mimi Choudhury and Shinjini Chatterjee.

Ashwani Saith, The Hague, the Netherlands
M. Vijayabaskar, Chennai, India
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INTRODUCTION

ICTs and Indian Economic Development: Trends, Issues, Options

Ashwani Saith
M. Vijayabaskar

Technology and Development

Scientific and technological breakthroughs often occur in mysterious ways. But while many individual scientific discoveries might well be traced to serendipitous origins, the overall pace of such discoveries within an economy and society, especially their successful conversion into technological innovation and diffusion, calls for systemic explanation based on a complex set of factors. These include the size and growth rate of the economy, its ability to support an extensive apparatus of research and development, its macro-economic policy regime, wider institutional characteristics and intellectual traditions. In turn, such advancement has usually further widened and intensified the process of economic growth in the pioneer economies accentuating pre-existing levels of international economic inequality. One intriguing jigsaw has been the construction of historical explanations for differences in outcomes of such technological capability in terms of their downstream effects. While it has assumed the form of global domination of exploration and markets, and of trade and investment associated with the rise of imperial systems, in earlier pioneer economies like Imperial China and pre-colonial India, the effects were predominantly contained within the boundaries of the respective economies. For the modern imperial pioneers, the cumulative impact of these processes, often intermediated by political muscle, have generated long-lasting techno-economic and political power structures on a global scale. Such dominance has been challenged, though not overturned, by some late-comers, namely, Japan, and the erstwhile Soviet Union, where autonomous state policy regimes at the heart of an empire (in the case of the former), or an extensive network of managed hegemonic 'international co-operation' (in the case of the latter), created a platform for relatively independent paths to economic development. In these instances, state-orchestrated innovative imitation and adaptation of borrowed industrial technologies took root in the domestic economy, and matured into a dynamically inventive and creative process in its own right.

In sharp contrast, for most other twentieth century late-comers, there have been far fewer opportunities and spaces to exploit. After the overturning of Second and Third World attempts to forge semi-autonomous 'non-capitalist' patterns of development, economic processes have reverted to the default, passive non-strategy of essentially following the turbulent slipstream of the more advanced market economies. In general, this has highlighted the dependence of the followers on the hand-me-downs of the leaders, whether in the form of markets, foreign direct investments and other capital flows, or in terms of standardized, non-cutting edge technologies. Arguably, South Korea, Taiwan and Singapore, to varying but limited degrees, have challenged this follower status. But in general, such derivative processes of development have been based on the downward transmission of comparative advantage. The consequent relocation, *a la* the product cycle, of selective manufacturing processes to favoured Third World sites has offered only limited room for the followers' dreams or aspirations of technological and economic leapfrogging.

ICTs and the Indian Case

In the Indian case, perhaps three modern episodes of systemic technological development could be loosely demarcated. The first refers to advanced levels of industrial and technical skills in the pre-colonial era, such as those developed around the imperial *karkhanas* (factories). These failed to serve as a sufficient basis for launching a successful process of proto-industrialization—they resembled more the pattern of the Chinese experience, contrasting sharply with the British or Japanese cases.

The post-colonial state-centred process of import-substituting industrialization built massively on the platform of manufacturing capacity slowly emerging from the turn of the century, especially in the inter-war years. Despite the controversy and counter-claims questioning this formative phase of planned Indian economic development, only a seriously committed ideologue would argue that this experience did not contribute significantly to the generation of a substantial scientific, technological and industrial capability in the country. That it did not interface seamlessly with a subsequent export-oriented, unprotected, competitive economic process does not overturn the argument that the current phase of Indian development is firmly based on many of the earlier achievements.

A third, dramatic episode of systemic technological change in India takes the form of the recent, ongoing ICT 'revolution'. Its origins are rather idiosyncratic in nature, being rooted in the opportunistic, virtually serendipitous, exploitation of the vast latent pool of highly skilled scientific personpower generated by the earlier commitment to autonomous national economic development. Paradoxically, the very under-utilization of this potentially powerful resource, manifest in significant un- and under-employment of scientists and engineers, provided the fortuitous circumstances that could provide a launchpad for a competitive entry of ICTs through the route of offering software development skills to leaders in the global economy. India provides an illustration of a variation on the theme of the Lewis model: it boasts an almost infinite supply of highly skilled labour at an almost fixed low wage rate.

Clearly, ICTs, as the new aspirant to the status of leading sector, wield considerable transformative capacity. Within the global equation of pioneers and followers, leaders and laggards, India remains at the head of the pursuing pack in the software segment of the industry. Based on the advantages deriving from its early bird status, India has a relatively higher market share than other competitors amongst the followers; and it reaps substantial quasi-rents from its pre-existing stock of the vast educational base in science and technology with its crucial proficiency in the professional use of English.

Does this provide a sufficient impulse for catching up with the leaders? There is undoubtedly a mutually beneficial process of osmosis between the leaders and India. There are several positive backwash effects for India: returning ICT immigrants who bring back even higher levels of skills and capabilities than what they went out with; new companies and investments in India arising from such flows, or from direct investments from overseas by foreign or non-resident Indian sources; and the relocation of ICT service-intensive facilities in the form of call centres to Indian locations.

However, in this osmotic process, there are also several flows on the negative side of the balance sheet. First, it is arguable that there is an enormous leaching of potential resources in the form of a 'brain drain' from India to the advanced economies. The latter benefit disproportionately from such migration of software specialists and engineers who received their education in India, but are employed in the advanced economies, contributing to their further acceleration. Second, international policy and regulatory regimes are such that they do not favour follower countries such as India, and indeed tend to further privilege and codify the advantages of the leaders. Third, both the flow of Indian software engineers overseas, as well as the inward flow of relocated call centre jobs from the advanced economies, have generated sharp backlash effects. There has been a manifest increase in protectionist tendencies, with vociferous, politically expedient calls for new legislation to prevent this relocation of service industry jobs. The irony that such calls for protection against an openly competitive market outcome are made from the heartland of the very system that professes to stand for 'free trade' has not gone unnoticed, and has drawn sharp counter-comment from senior policy makers, and also from senior Indian government sources. The net effect of this two-way flow is not easy to gauge, since much depends on the outcomes of dynamic, longer-term processes that are currently in their infancy. In this sense, the outcomes are also likely to be influenced by proactive policy regimes on both sides of the equation.

On the other side, looking over the shoulder, there is little justification for any complacency with regard to India's ability to continually outpace the diverse group of competing or following countries, including China. An informed guess by an ICT corporate leader puts

India three years ahead of China, though in such a fast-moving scenario, where leapfrogging is the name of the game, such advantages could be very ephemeral indeed. There is some early evidence that in some third markets, Chinese companies are beginning to challenge the superior competitive status of their Indian counterparts. A crucial test will be whether Indian software companies can successfully break into the massive mainland Chinese market. In the meantime, India can only envy the Chinese push ahead in the hardware segment of the ICT industry, even if much of this is the outcome of external investments by major global ICT conglomerates that are using China as a production base. In contrast, neither India's past record, nor its immediate prospects in this sector, provide grounds for unqualified optimism.

There is no denying that the Indian software industry is a major success story, and that it generates very considerable economic benefits at the macro-economic level. Alongside this, of course, there is the parallel process of brain drain, with concomitant transfers out of potential economic surplus. Such a haemorrhaging implies a relative weakening of domestic potential and induces processes of hierarchical incorporation and capture. Global Intellectual Property Rights (IPR) and open trade regimes facilitate, codify and consolidate these trends. In any event, domestic scientific breakthroughs cannot be smoothly converted into technological advances and applications, primarily because the crucial economic, institutional and infrastructural preconditions are absent.

The Questions

It is against such a backdrop that the recent phenomenon of ICT development in India has to be viewed. Can the upward trajectory be sustained? How far can an ICT revolution go towards modernizing an economy of India's size? What could be the capacity of the ICT phenomenon to induce rapid social transformation and change? What is the balance between the benign and the malignant in ICT influence on public and private domains through its interface with processes of governance and culture? Well placed as it seems to be, India is nevertheless at the early stages of a long road, with many a potential pitfall and cul-de-sac lying in wait. Can it navigate itself clear of these hazards?

Can India retain its current comparative advantage and remain a rung or two ahead of the chasing pack on the ladder of competition? While a plethora of questions takes firm shape, most of the possible answers remain relatively unfinished on the anvil.

The papers in this volume collectively throw light on several important sets of issues.[1] First, they provide a systematic overview of the major developments and trends in the Indian ICT sector. Following this, several papers investigate questions about the dynamism of the sector. How significantly has the sector contributed to wealth creation? Is it spiralling up the value chain through innovations and internal organizational restructuring within the sector, or is it really lagging behind and remaining lodged in the mode of body-shopping? Even in its area of special strength—software—does Bangalore dynamically lead or docilely follow Silicon Valley?

Third, another clutch of papers addresses the open and contested questions pertaining to the role of the state and government policy, both with regard to their influence on the ICT phenomenon to date, but more significantly concerning potential opportunities in shaping the future of the sector at this crucial and sensitive juncture.

Fourth, as ICTs diffuse and spread into the wider industrial sector, the volume explores the processes of the restructuring of work and employment by taking up the example of specific ICT using industries.

And finally, the Indian experience is set in a wider context through a discussion of the Chinese experience, alongside a focused comparative analysis of ICT clusters in the two countries.

Debates on whether ICTs provide the wherewithal to undermine existing sources of inequities accompany arguments pointing to ways in which the new technologies can reinforce existing structures of power, be it at the global, regional or household level. While such discussions in the context of advanced capitalist economies are relatively old, their significance for low-income economies like India cannot be overstated. The growth and diffusion of ICTs in India have been intriguing. Despite being one of the fastest growing ICT software service industries in the world, it faces major barriers in harnessing the growth process to generate positive linkages in the larger macro economy. Successful interventions of that kind even at the global level are far too few, emphasizing the need to understand better the processes and structures that shape technology generation and use. Embedding actual processes of technology production and use in the larger socio-economic dynamic is therefore critical.

Wider Context

ICTs have proliferated amidst sweeping organizational and market changes, and in fact aid this process. Any examination of the ramifications of ICTs at the micro level needs to therefore situate itself in this macro environment. The important contextual feature that needs privileging is the growing reliance on the world market for economic growth among less industrialized regions. Ensuring competitiveness in the world market therefore assumes an unprecedented importance among policy makers of these countries.

Accompanying the process of globalization are changes in the characteristics of dominant global output markets and the consequent uncertainty about appropriate models of industrial organization. To begin with, there is a perceived shift from mass production catering to standardized product markets to more flexible production meant for fragmented and volatile markets. The earlier era, typically characterized as Fordist and supported by a Keynesian welfare state, emphasized mass production technologies, scale economies, detailed technical division of labour and a vertically integrated hierarchical organizational structure. Its decline, driven by a variety of factors, especially by inherent limits to productivity gains, has led to the rise of two distinct but related trends.

The relative stagnation in mass markets has forced capital to rely increasingly on market segmentation and volatility though driven by fashion and design to enhance profits. Organizational structures ought to therefore transform to meet the requirement of such flexible market conditions. The hitherto dominant model of the vertically integrated firm can be too rigid to compete under such conditions. This has led to the rise of the 'networked firm' as the more relevant model, a form that is less hierarchical, more fluid and capable of responding rapidly to changes. Accompanying the rise of flexibility as a condition of late capitalism is the growing servitization of economies, especially in advanced capitalist economies. Information and knowledge become key resources, rendering information processing and transmission technologies more and more critical. Low-income countries, under such conditions, may have less scope to compete on the basis of cheap labour, but have to develop 'social capabilities' in conjunction with 'technological capabilities' to compete on the basis of knowledge acquisition and deployment.

Changes in the realm of production are also increasingly synchronized with a neo-liberal faith in the power of the market to redeem economies from stagnation and lack of development. State regulation is seen to undermine potential benefits that markets may bring. Any attempt to tinker with trajectories shaped by market forces is out of step from the global march towards welfare for all. Combined with the ongoing process of globalization, the neo-liberal discourse strives to build the global market as an ideal to be attained, leaving little scope for conceptualizing alternatives outside the utopia. Accompanying the rise of these regime and discourse shifts is the growth and rapid diffusion of information and communication technologies.

Dimensions of ICT Impact

ICTs not only provide the technological means to secure some of the objectives mentioned here, but are increasingly seen as drivers of the new regime of accumulation. Arguments in this direction are manifold. Some contend that the growth of this industry will provide an opportunity for developing countries to easily 'catch up' with the industrially advanced nations (Perez and Soete 1988). Resource requirements in this sector are fundamentally different from other traditional sectors. Hence, low-income countries can skip stages of industrialization and enter directly into the 'new economy'. Technologies within this sector are not mature and are at the early stages of the product life cycle. Firms in low-income economies can therefore build capabilities much faster and push trajectories in more relevant directions. Also, many sectors within ICTs rely more on human capital than on physical capital investments, rendering the build-up of human capital base critical to the 'catching up' process. Low-income economies that have a strong human capital base like India or China may therefore succeed in such efforts.

The need for skilled labour, albeit of a different kind, along with the rise of new organizational forms, has also spawned debates concerning the nature of employment and quality of work created. Just as automation reduces the need for manual or physical labour, the growth in services sectors augments demand for 'soft' skills like communication and personal interaction skills (ILO 2001). Together, the changes seem to be favourably biased towards women's entry into the labour market in the post-industrial economy, given the current patterns of gendering of work. Further, the networked organizational model implies a more egalitarian distribution of power within the organization. While ICTs have played a critical role in the skill-biased technical change hypothesis, there are studies that highlight the rise of dualistic or polarized labour markets with the skilled and well paid employees at one end and unskilled insecure employees at the other (Lash and Urry 1987). This raises questions as to whether such technologies foster equality or reinforce existing polarities between regions, classes and gender. That the outcomes are also dependent upon one's location in the global division of labour is obvious. If ICTs serve to reinforce the current global division of labour, then the rise of polarized labour markets would imply that the lower end of these markets would predominate in low-income economies.

Manipulating time differences and distance, critical to ongoing capital accumulation at a global scale, is a task at which ICTs have been deployed quite effectively. Though the 'death of distance' proposition continues to be contested, especially by the rise of agglomerations of economic activity, firms are now much better equipped to coordinate activities dispersed globally. Electronic commerce or e-commerce seeks to enhance trade in services and reduce transaction costs of trade in commodities. Importantly, e-commerce is projected as the means to create a level playing field for big and small firms as the latter too can access and trade with distant clients due to the lowering of transaction costs. Global financial flows and creation of global financial markets, once again, are facilitated by innovations in communication technologies.

The most important argument in favour of the progressive impact of ICTs points to the productivity gains that ICTs bring. The rapid decline in the cost of computing power and transmission of information imply a decline in costs of automation and coordination and hence, improved productivity. And since ICTs can be deployed across the board in all sectors of the economy, the gains are enormous. Initial hype about the huge and pervasive increases in productivity was soon tempered by studies that showed that gains are not particularly significant. However, of late, studies do concede the productivity enhancing potential of ICTs, but point to the combined effect of ICT use backed by appropriate organizational innovations. Also, studies point out that productivity increases show up with a lag (Brynjolfsson and Hitt 2003).

In addition to such economic gains that ICTs bring, the latter are also used discursively to put forth arguments for a neo-liberal regime (Gadrey 2002). To many, the very nature of origins of the internet points to the advantages of non-regulation. The internet's growth and rapid penetration into different sectors is attributed to ingenious private initiative that could develop its possibilities only due to the non-interference of the state. Hence, any effort to regulate will only hamper its efficiency and diffusion potential. Also, its potential to transcend national barriers by itself renders any kind of national-level regulation ineffective.

Such positions are however not uncontested (Lessig 1999). The internet is seen to be too important to be left unregulated, given its potential to subvert personal security and privacy. Even its role in ensuring an efficient global marketplace can be impaired if there are no supra-national institutions to ensure that the transaction costs associated with integrating national systems of trade and exchange are reduced. An important case, in this regard, is the setting up of global standards, which obviously requires a high degree of international co-ordination. Another important area is the need to ensure property protection and regulation of contracts entered via the internet that would reduce transaction costs in global e-commerce. Provision of open access and taxation of e-commerce are some of the other major regulatory challenges.

That the promotion of ICT-based economic growth has been the concern of many a state initiative in low-income countries should therefore come as no surprise. Its adoption by user industries imparts greater flexibility and efficiency to production systems. Also, the growing share of knowledge-based production at the global level warrants that economies develop a degree of technological capability that would equip them to compete in the global market better. And finally, given a perceived ability to create decent employment opportunities, governments perceive the promotion of ICTs to be critical to the generation of quality employment. Lack of infrastructure, telecommunications or educational institutions may, however, constrain economies from taking advantage of this window of opportunity.

Initiatives in low-income countries have been directed at both promotion of sectors that produce information and communication goods and services, as well as sectors that are enabled by these technologies. India has been a forerunner in this regard, and has managed to build capabilities in some segments of ICTs, especially in the software services segment. The next sub-section captures the specificity of India's experience with promotion of ICTs.

Growth of ICT Sectors in India

Four decades of import substitution-based industrialization has led to the build up of capabilities in a few segments of ICTs. Efforts have been undertaken to promote high-technology sectors and it is in fact one of the first low-income economies to have a technology policy. A key instrument used to build capabilities was the creation of public funded R&D labs in various critical sectors, and the setting up of public sector firms for production of critical technologies and premier educational and training institutions of higher learning.

An important outcome of this process is the creation of a human capital base that was critical once the economy was forced to integrate with global markets from the early 1990s. The recent promotion of ICT sectors in India takes place amidst a gradual opening up of the economy and concerns of large-scale underemployment. Employment creation in the formal sector in India, already confined to less than 8 per cent of the total workforce, has further suffered due to a decline in its labour absorption potential in recent years. The growth of ICT-based sectors is therefore viewed as critical to the generation of quality employment.

The build-up of capabilities, coupled with trends at the global level, has led to the creation of a vibrant software services industry. Despite being located in a peripheral region, it is one of the fastest growing segments of the global software industry. The consistent annual growth rate of over 50 per cent throughout the 1990s is unparalleled. Further, it has shown a consistent rise in its contribution to the macro economy. While its contribution to the GDP has increased from 0.72 per cent in 1997–98 to 2.38 per cent in 2002–03, its share in exports has increased from 4.9 per cent to over 20 per cent during the same period.[2] There has also been a shift towards offshore services as opposed to onsite services over time. The sector's growth has generated considerable employment as well. In 2001–02, employment in the IT sector (including the IT-enabled services sector) was over 0.5 million. Though it accounts for less than 0.5 per cent of the total non-agricultural employment in the country (O'Connor 2003: 5), its potential in this regard is expected to grow rapidly. A concern however has been the relatively low labour productivity of the Indian software sector as compared to competing countries like Ireland and Israel (Singh 2003: 10).

Within the software services segment, innovative capabilities are evident in the banking and telecommunications sector, especially with regard to telecom software. Also, few firms have succeeded in moving into more value-adding segments of the software value chain. India's share in the global software market was however less than 2 per cent even in 2001–02. More importantly, the learning acquired in the software services segment has not found its way into other segments hinting at strong barriers to diffusion. Further, the growth of the hardware sector in India has been abysmal. Few studies take stock of the nature of development of ICTs and their impacts on various realms of the Indian economy. The papers in this volume address some critical dimensions of this phenomenon. In the rest of the chapter, we discuss the contributions to this volume.

ICT Diffusion in India: Economy, Labour and Regulation

A major factor attributed to lack of dynamism of India's ICT sector, software services included, has been the lack of adequate involvement by the state, according to C.P. Chandrasekhar (chapter 1). While many authors attribute the success of the Indian software sector to the state's 'benign neglect', Chandrasekhar argues that the state has played a more active role than what most others concede. The initial impetus, many would agree, came from the availability of a pool of highly skilled labour produced through state-funded Indian Institutes of Technology (IITs) and other institutes of higher learning created due to the imperatives of an import substitution-based industrializing regime. The pool of skilled labour drawn from other engineering colleges, many of them state-funded, also sustained growth in the initial phases. The construction of software technology parks, while ensuring quality data transmission and exchange facilities, allowed firms to increase revenues from offshore projects, which in turn enabled firms to build valuable learning in project management skills.

On the flip side, withdrawal of the state from some strategic areas has led to a weakening of the sector in many ways. Chandrasekhar argues that the decline of India's hardware sector is precisely due to the state's failure to nurture the industry sufficiently to withstand the competitive onslaught from global capital. The sudden opening up of the economy led to the industry's downfall as competition from foreign firms forced local firms out of production and into the marketing and distribution of hardware. Firms have not been able to leverage their technological competence to interact synergistically with the software sector.

In the software sector, the government encouraged exports through tax incentives to the detriment of the domestic segment. While this may have enabled the growth of exports, even that link can be contested given the high profit margins export firms enjoy. Tax incentives therefore cannot be a critical impetus to Indian firms to compete globally in their markets. The loss of revenue due to tax concessions also means that the state has fewer resources to invest in capability enhancing activities for the sector. Improvements to the skill base and provision of infrastructure have suffered due to this policy. The state, by deliberate withdrawal from production, has created a segment dominated completely by private capital whose interests may be geared towards profit making in the short run rather than being guided by larger long-term societal gains. The absence of a hardware sector also implies that software production is heavily dependent on imports of expensive hardware, draining the net foreign exchange earnings. Further, the state, through provision of tax concessions to export firms, has worked against firms catering to the domestic market which have better chances of contributing to the sector's dynamism in the long run. Chandrasekhar therefore questions the ability of the ICT sector in India, in its present state, to create adequate positive linkages in the macro economy and thereby transform India's position in the global division of labour. Importantly, the paper argues that there are structural constraints that confront initiatives in that direction, thereby reinforcing or aggravating inequities scripted by the current global capitalist dynamic.

A related area of concern is the trajectory of growth of the Indian ICT sector, especially its ability to leapfrog and compete with advanced capitalist nations. The skewedness towards the software sector also means that the sector may be unable to take advantage of possibilities opened up by innovations at the global frontier. Each segment of ICT—hardware, software and telecommunications—is subject to specific market and technological pressures and hence has different internal dynamics. The Indian IT sector essentially consists of a relatively vibrant software industry, a stagnant hardware industry and a telecom industry that is moderately dynamic. Globally, there has been an increasing convergence of these technologies, each deployed in conjunction with one another. Hardware production requires large-scale use of software. Advances in software development are partly based on advances in hardware. Telecommunications too has witnessed increasing digitization and use of information processing technologies to reduce costs and improve speed and quality of delivery. Another significant trend that reiterates the need for a balanced development of all three segments is the ever-growing integration of these components towards newer applications and penetration in various sectors. Nagesh Kumar (chapter 2), through a detailed analysis of existing secondary data, maps out the various trends in the growth of the software services sector. In doing so, he highlights the need to go beyond current patterns of specialization if ICTs are to create virtual linkages in India.

Kumar argues that the skewed pattern of evolution of the software industry makes capability building difficult even within the industry. The Indian software industry, primarily driven by exports of low value-adding services, does not embody intellectual capital required to build up competence in high-end software development. The more value-adding segments of the software service value chain, like design and systems analyses, are confined to client firms in high-income countries due to intellectual property protection needs and also due to lack of adequate control over quality of design development among Indian software firms. More importantly, since innovations in software development are largely by way of finding new applications in various segments of the economy, software development needs close understanding of user requirements that may be very difficult for firms in India. Another possible area of development, into more value-adding software product markets, is constrained by high entry barriers created through branding and marketing, and lack of design expertise due to reasons mentioned earlier.

The competitive edge therefore lies primarily in the low cost of labour. Such specialization and an inability to break into new segments threatens to erode the competitive advantage as lower entry barriers allow regions with similar low-cost labour pools to compete with India in such segments. The ubiquitous threat of competition from China is true of this sector as well. Also highlighted is the geographical concentration of exports, with the USA accounting for 60 per cent of total exports. The resultant vulnerability of the Indian software sector to macro-economic shocks in the importing economy raises questions about the stability of the sector's long-term growth.

Concerns about the low road trajectory of the Indian IT industry are contested partially by Joseph and Abraham (chapter 3), who, by building an index of 'claimed technological competence', attempt to show that Indian firms claim to have upgraded into relatively more value-adding, high-end services. Arguing that most existing measures of innovation do not capture adequately the growth in innovative capacity of firms in the IT sector, they draw upon the growing literature on technological opportunity to build their index. The index seeks to capture the extent to which firms have specialized or claim to possess expertise in sectors with greater technological opportunities. The paper definitely points to a discernable trend among Indian firms to move into newer segments of the software services sector. This result is also supported by Kumar's observation that labour productivity in Indian software firms has witnessed a marginal upward trend since the latter half of the 1990s. Joseph and Abraham, however, caution about the pitfalls of promoting software exports without adequate policy measures directed at enhancing diffusion of ICTs among user firms in India.

The low wage cost advantage that India has leveraged to compete in the global software services segment is well known. Within India, however, software professionals enjoy a wage premium compared to labour in other sectors. The huge wage differential at the global level and a policy among many firms to recruit only engineering graduates has led to a sharp rise in salary levels since the mid-1990s. Global market pressures may have forced firms to move into segments that warrant better technological competence. But Athreye (chapter 4) argues that the role of such a tight labour market in forcing firms to utilize labour better cannot be undermined. Rising labour costs erode the profitability of firms. Athreye argues that to offset the loss of competitive edge, firms deploy them in more value-adding activities, resulting in higher labour productivity.

Firms are also faced with loss of employee-specific knowledge due to high attrition rates. The latter, Athreye points out, has led to the development of human capital management strategies like employee stock options, less hierarchical organizations and teamworking. Growth in offshore services has also led to the use of similar human capital management models in other sectors as well, especially in the fast growing back office processing (BPO) sector. Such trends also show that enhancing the efficiency of utilizing existing human resources is more important than augmenting labour stock through the expansion of tertiary education.

Despite such positive aspects of the sector's growth, there has been considerable scepticism about its quantum of contribution to the economy. Joseph and Harilal (2001), for instance, point to the much lower realization of net foreign exchange earnings of the sector. However, the fact that its share in total exports from India has been steadily rising cannot be neglected. Dennis Rajakumar (chapter 5) contributes to this debate by using a novel method to calculate the sector's contribution to net wealth creation in the economy. To him, a firm can be said to have created wealth only if its economic value added, that is, net operating profits minus the weighted cost of capital, is positive. Along with economic value added, he uses 'market value added', that is, the market value net of book value to calculate the extent of the sector's contribution. Interestingly, he finds that though the sector has contributed significantly in these terms, there is a high degree of concentration of wealth. This concentration also appears to confound the proposition that software is a sector where ease of entry favours the rise and success of small- and medium-sized firms.

Such contributions to growth are still insufficient if ICTs are to be a means of leapfrogging. Innovations in the IT sector crucially depend upon formulation and implementation of appropriate public policy frameworks. The state can influence sectoral outcomes in multitude of ways. At the level of the larger macro economy, policies can be framed to provide appropriate signals to different economic actors. Thus, the recent emphasis on market forces, internal and external, forces individual firms to compete globally to sustain themselves. Giving a greater role for market forces also implies that the state can do little by way of directing growth in directions other than that dictated by market signals. At the sectoral level, governments—national, state and local—can intervene by actual involvement in production or in building up of research capabilities, setting up of institutions to create a pool of requisite skills, providing incentives like tax concessions, provision of infrastructure, etc. High-technology sectors like ICTs tend to agglomerate in a region due to positive externalities, and local institutions including public policies play an important role in creating/sustaining innovative dynamism in such clusters. Policies at the regional level too are therefore critical.

The failure or success of the state can therefore be addressed/understood at any of these levels. Also, failures may result due to lack of coordination between different sets of policies across these levels. Again, while the failure of the state can be treated as one explanation, it is also important to comprehend the forces that undermine the ability of the state to act appropriately. A partial explanation for the inability of the state to act on behalf of larger societal interests lies in the global neo-liberal trend of perceiving it as impeding market forces and therefore, economic efficiency and growth.

While the role of neo-liberal trends cannot be undermined, Balaji Parthasarathy (chapter 6) contends that the inability of the state is also due to erosion of its autonomy from various interest groups. Synthesizing insights from the 'embedded autonomy' explanation for the nature of state intervention and literature on social embedding of economic activity at the local level, he argues that the capture of power by coalition governments instead of single party governments during the 1990s has reduced the ability of the state to implement appropriate policies to sustain the growth of the Bangalore software cluster. The manner in which the government embedded itself in private capital enabled the growth of the Bangalore cluster. However, Parthasarathy argues that its failure to ensure socio-economic progress has led to its declining autonomy over time. As a result, the government has been unable to formulate policies that can transform Bangalore into India's Silicon Valley.

Nowhere is the importance of state intervention more evident than in its role in the provision of essential public goods/services, especially infrastructure. Infrastructure provision requires state intervention due to its character as a public good. The link between infrastructure and economic growth, though fairly well agreed upon theoretically, throws up a more complex relationship when confronted with empirical studies. Torero, Chowdhury and Bedi (chapter 7) address this complexity by positing that national income levels play an important mediating role in influencing outcomes. Relating the telecommunications infrastructure to output growth and national incomes, they observe that income levels do influence telecommunications. On the face of it, it seems plausible that in advanced capitalist economies, the incremental change in output cannot be that high given the existing high levels of infrastructure. The more interesting finding, especially in the context of India, is that the impact on output is more pronounced in countries with moderate income levels than that in very low-income economies. India, being placed in the middle-income bracket, the paper calls for a strong state intervention in the provision of telecom infrastructure, given the higher gains to be had from such investments.

Sunil Mani (chapter 8) too highlights the scope of state intervention in a globalized competitive environment in his examination of India's telecom equipment manufacturing sector. Encouragement to substitute imported switching equipment created capabilities in the production of switching equipment among a few public sector firms. C-DOT, the organization promoted for this purpose, not only developed switches more conducive to local conditions, but also, importantly, through a policy of public procurement ensured diffusion of equipment manufacturing capabilities among its 700-odd vendors. Another innovation, the corDECT, that provides communications access to rural areas with poor infrastructure at affordable costs, developed by a group of scientists at IIT, Chennai, also exemplifies the success of local state-supported initiatives to build up capabilities in the telecom sector. Products from both these initiatives have not only penetrated the domestic market, but have even found their way into exports, especially to low-income economies with similar infrastructural and capital constraints like India. A secondary impact of creation of such capabilities is the expertise built in telecom software. The changed market scenario, with the entry of multinational corporations with oligopolistic power into the Indian equipment manufacturing sector, however, threatens to undermine the efficacy of such public policy instruments to direct capability building efforts towards nationally desired directions.

In the context of a highly dynamic ICT sector, regulation becomes imperative not only to build upon the existing base of technologies, but also to take advantage of rapid changes in technologies. The importance of this dimension of regulation is most evident in the context of standards setting, as Basant and Ramadesikan (chapter 9) point out. The increased use of various segments of the ICT sector in conjunction with each other, enhanced networking of computers and the need to 'talk' to each other, and the setting in of network externalities, all render adoption of appropriate standards critical to the effective use of new technologies. The highly dynamic nature of ICTs poses limits to the use of rigid standards, while at the same time, being standard neutral may reduce the ability to fully take advantage of a dominant standard. Establishment of a single standard is critical to not only market creation, but also faster technological diffusion. Markets, however, often fail to enable the optimal standard to become the dominant one. Once a standard becomes dominant, it is very difficult to shift to a better one due to the huge sunk investments, the costs of learning to use new technologies and the consequent technological lock-in. The state or a lead firm needs to, therefore, ensure that standard adoption serves to enhance diffusion of a new technology optimally. Basant and Ramadesikan discuss the issue of standards setting in the Indian telecom sector through insights from the experience of the US, EU and South Korea. Due to high uncertainty in technological trajectories and the lack of a well-developed technological base in mobile telecom equipment manufacturing in India, they argue out a case for observing standard neutrality. Such neutrality, they state, is also useful to build capabilities in telecom software solutions, a segment where India has a competitive edge. At the same time, they also highlight the importance of state support to standard creation in niche segments in the domestic economy, which can later be used for market expansion elsewhere.

Another key mode in which the state can support generation and diffusion of ICTs is through public investment in the use of ICTs. Government spending accounts for the largest share of the domestic market for software services. Hence, firms catering to the government can use the expertise to leverage it in other markets, even in the export market. Also, the state can use ICTs to improve the efficacy of its service delivery mechanisms. Such e-government initiatives have been undertaken both by the central government and various state governments. An important exercise by the former is the computerization of the Indian stock exchanges. Meena Abraham Chacko (chapter 10) analyses the impact of ICTs on the functioning of the Indian stock market. It was primarily aimed at improving the efficiency of stock markets by reducing the entry barriers erected by the intermediaries and enabling direct transactions by investors. While the process has led to benefits like reduction in transaction costs and wider participation, it has been accompanied by greater volatility, once again pointing to the need for appropriate regulatory institutions. Even the observed effects cannot be attributed solely to the diffusion of ICTs.

The private sector too is a significant domestic user of ICTs. The decline in costs of ICTs over time is argued to enable even small and medium-sized firms to adopt ICT-based innovations in their production processes and to link up with suppliers and buyers. However, the impacts of such adoption do vary across firms, with the nature of organizational restructuring that accompanies adoption playing an even greater role. The rapid diffusion of e-business technologies at the global level definitely prompts us to examine the process of its adoption in India and its impacts on organizational efficiency. The factors conditioning the adoption and diffusion of technologies among firms operating in the Indian market have hardly been examined. Kaushalesh Lal (chapter 11) makes an attempt in this regard. Lal puts forth two important propositions about factors influencing the extent of adoption and the impact of adoption. One, he posits that the knowledge base of the entrepreneur has a key role in enabling adoption; two, that organizational restructuring significantly influences the nature of impacts. His analyses of data collected from a sample survey of firms confirm his propositions, pointing to the importance of human capital and organizational change in propelling firms to succeed in the 'new' economy.

Impacts of diffusion of ICTs are not only felt in the realm of productivity gains, but also have important ramifications for the labour market. The impact that ICTs can effect upon work and employment is the subject of many a debate. The causal links between labour markets and ICTs can be twofold. While labour market characteristics strongly influence the trajectory of ICT growth and diffusion in other sectors, several propositions are put forth on the way ICTs can impact labour markets. Apart from impacts on quantity of employment due to automation, attention has been focused upon the ability of ICTs to provide qualitatively enriching work.

In the Indian context, Vijayabaskar (chapter 12) examines some of these propositions through a study of the automobile sector. Once again, the paper highlights the mediating role of organizational factors in conditioning outcomes. While the distribution of power within an organization conditions the nature of impacts across different levels in its hierarchy, firms are confronted by an inability to retrench labour because of laws pertaining to the organized sector. The diffusion of ICTs in the Indian automobile industry, characterized by relatively strong labour unions and employment security, has pushed firms into training and upskilling sections of workers to deploy them in more value-adding activities. The inability to reduce costs through retrenchment directs firms to 'actively', rather than passively, compete on the basis of labour cost cutting. Operating in a highly competitive but quality-conscious global market, such a trajectory augurs well for the prospects of the industry. The finding is especially significant in the context of arguments demanding greater employment flexibility as a prime condition of competing in the global market.

While analyses of the various facets of IT use and production in India is critical to public policy formulation, it is also important to understand the trajectory of growth in other low-income economies and the role of public policies in that direction. It is increasingly pointed out that an understanding of the Chinese experience is critical to formulation of appropriate policies. The strong role of the state in influencing the direction of China's encounter with ICTs renders it an important case for examining the appropriateness of various forms of state regulation. Two papers that deal with this exercise round off the volume.

China, for instance, has demonstrated how learning acquired through production for the domestic market can be leveraged to compete globally. In the case of the telecom sector, Wensheng Wang (chapter 13) delineates the way in which the Chinese government has gone about restructuring the state-held telecom sector so as to cope with pressures of the global market. Its policy of 'competition without privatization' definitely questions the increasingly accepted association between building efficiency and privatization. The government has also used financial incentives innovatively in this regard.

However, Wang points to another dilemma associated with increasing diffusion of ICTs in China, namely, the growing inequities in access to the enabling benefits of ICTs. Gender-based disparities are not acute compared to the huge gap that exists between different regions, particularly between rural and urban areas. Differences due to educational attainment and income levels persist as well. Digital opportunities arising out of reduced costs of IT devices and their applicability in the provision of various services has not been adequately addressed by existing policies. Wang concludes with suggestions for further reforms that would contribute to both enhanced efficiency and reduced inequities in terms of access.

Meine Pieter van Dijk's paper (chapter 14) is an exercise in direct comparison of India and China with respect to policy formulation to promote ICT-based clusters. He compares the relatively well-established Bangalore software cluster with the nascent Nanjing cluster that has been promoted actively by the state in a less urbanized region in east China. He draws two key lessons emerging from his analyses of the Nanjing cluster: first, that production for the domestic market can infuse limited dynamism into the cluster as well as insulate it from the vagaries wrought by global demand; second, he attributes its relative lack of dynamism to its inability to attract skilled labour, which in turn is due to the better 'quality of life' and growth opportunities for skilled labour in the bigger cities. Thus, build-up of physical infrastructure alone is insufficient to promote clusters. Rather, he calls for a strategy that stresses co-ordinated investment in infrastructure, technology and human capital, as done in Singapore.

ICTs are fast-flowing phenomena, with rapid and successively overlapping waves of technical advancements and market transformations. Yet, certain underlying structural continuities persist obstinately. One such chasm is the digital divide that characterizes the patterns of diffusion of ICTs between the rich and the poor, whether across or within nations, sectors, cities and communities. Vital as this theme is, it does not constitute a central preoccupation of this volume or the papers contained in it. Nor are issues pertaining to the downstream uses of ICTs in government and governance, in the provision of social services, or in enabling knowledge dissemination and related empowerment, picked up for specific analysis here. These themes are addressed separately in an independent companion volume (Saith et al. forthcoming) that highlights the various dimensions of diffusion, societal transformation and poverty reduction.

Notes

1. These concerns, in addition to the interaction between ICTs, civil society and governance, formed the backdrop of the three-day international seminar on *ICTs and Indian Development*, organized in December 2002 in Bangalore by the Institute of Social Studies, The Hague, and the Institute for Human Development, New Delhi. This volume is one of two being published based on the revised and updated papers and proceedings of the conference. It consists of a selection of papers that address issues relating to the production and diffusion of ICTs in user industries, micro-impacts on industrial organization, performance and labour use, issues of regulation and macro-economic implications.
2. http://www.nasscom.org/artdisplay.asp?cat_id=314.

References

Brynjolfsson, E. and L.M. Hitt. 2003. 'Computing Productivity: Firm-level Evidence', *Working Paper* No. 139, MIT Sloan School of Management, Cambridge, MA.

Gadrey, J. 2002. *New Economy, New Myth*. London: Routledge.

ILO. 2001. *Life at Work in the Information Economy: World Employment Report*. Geneva: ILO.

Joseph, K.J. and K.N. Harilal. 2001. 'Structure and Growth of India's IT Exports: Implications of an Export-Oriented Growth Strategy', *Economic and Political Weekly*, 36 (34): 3263–70.

Lash, S. and J. Urry. 1987. *The End of Organized Capitalism*. Cambridge: The Polity Press.

Lessig, L. 1999. *Code and Other Laws of Cyber Space*. New York: Basic Books.

O'Connor, D. 2003. 'Of Flying Geeks and O-Rings: Locating Software and Services in India's Economic Development', *Working Paper* No. 224, OECD Development Centre. Paris: OECD.

Perez, C. and L. Soete. 1988. 'Catching up in Technology: Entry Barriers and Windows of Opportunity', in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory*. London: Pinter.

Saith, Ashwani, M.Vijayabaskar and V. Gayathri (eds). Forthcoming. *ICTs and Indian Social Change: Diffusion, Poverty, Governance*. New Delhi: Sage Publications.

Singh, N. 2003. 'India's IT Sector: What Contribution to Broader Economic Development?' *Technical Paper*. No. 27, OECD Development Centre. Paris: OECD.

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The Diffusion of Information Technology and Implications for Development: A Perspective Based on the Indian Experience

C.P. Chandrasekhar

The growth of India's information and communication technology (ICT) sectors, especially the IT component, has attracted attention for a number of reasons. To begin with, the pace of growth has been rapid, albeit from a low base, tallying with the dynamism seen as typical of the industry and captured by the oft-quoted Moore's Law.[1] Thus, according to data provided by *Dataquest* (Table 1.1) over the 12-year period (1990–91 to 2001–02), the annual compound rate of growth of output was 37.4 per cent (Figure 1.1). That is, output was doubling every 2.2 years.

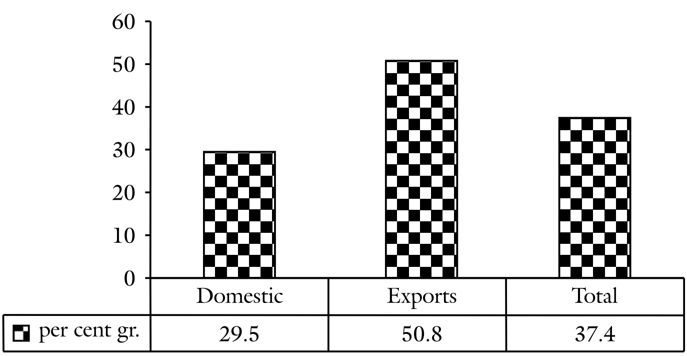
Second, this rapid growth has essentially been the result of a rapid expansion of exports. During the period 1990–91 to 2001–02, exports have been growing at 54 per cent per annum or doubling every 18–24 months. As Figure 1.2 shows, there has been a trend shift in the rate of expansion of IT sector output in 1996–97, driven by exports.

TABLE 1.1 ***Dataquest*'s Estimates of India's IT Industry Output (Rs bn)**

	Domestic Segment	*Export Segment*	*Total*
1990–91	17.62	4.52	22.14
1991–92	20.41	6.76	27.17
1992–93	25.24	9.31	34.55
1993–94	33.56	14.05	47.61
1994–95	49.59	18.82	68.41
1995–96	70.32	26.81	97.13
1996–97	85.87	48.47	134.34
1997–98	108.35	71.80	180.15
1998–99	132.04	107.52	239.56
1999–2000	170.02	160.50	330.52
2000–01*	246.70	298.96	545.66
2001–02*	242.88	378.46	621.34

Note: * ITES included in software exports.
Source: *Dataquest* 2001a, 2002a.

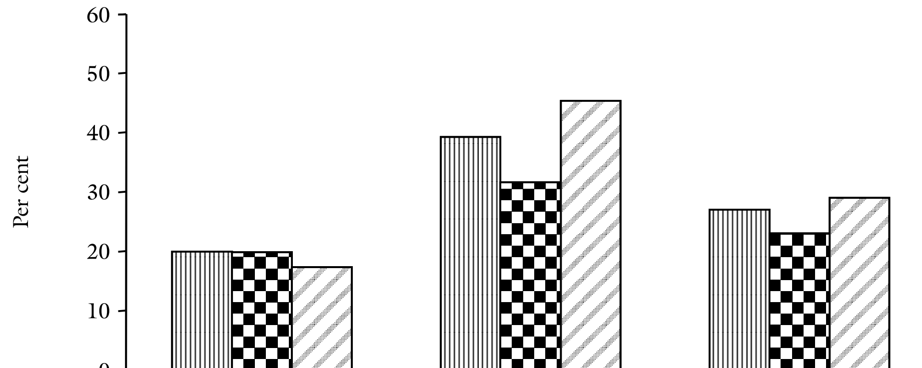
FIGURE 1.1 **Compound Annual Rate of Growth of Output**



Source: *Dataquest* 2001a, 2002a.

While the trend rate of growth of output valued in dollars rose from 23.7 per cent during 1990–91 to 1996–97 to 29.8 per cent during 1995–96 to 2001–02, the rate of growth of exports rose from 32.5 per cent to 46.6 per cent during these two periods. As a result, the share of exports in IT industry output, which rose from 20 to 28 per cent between 1990–91 and 1995–96, touched a remarkable 61 per cent in 2001–02 (Table 1.2 and Figure 1.3).[2] The net result has been that the ratio of gross IT sector output to GDP rose from 0.38 per cent in 1991–92 to 1.88 per cent in 1999–2000 and 3 per cent in 2001–02 (Figure 1.4).

FIGURE 1.2 Compound Annual Trend Rates of Growth of Output ($ mn)



	Domestic Segment	Export Segment	Total
1990–91 to 2001–02	20.5	40.3	27.8
1990–91 to 1996–97	20.4	32.5	23.7
1995–96 to 2001–02	17.8	46.6	29.8

Source: Computed using data in Table 1.1. *Dataquest* 2001a, 2002a.

TABLE 1.2 **India's IT Exports ($ bn)**

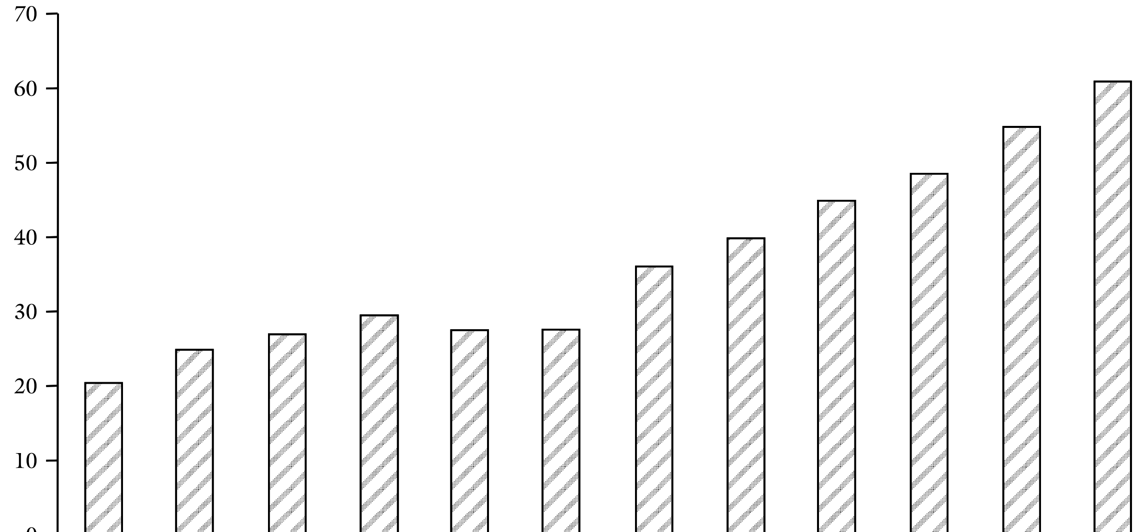
1990–91	0.25
1991–92	0.28
1992–93	0.30
1993–94	0.45
1994–95	0.60
1995–96	0.80
1996–97	1.37
1997–98	1.93
1998–99	2.56
1999–2000	3.70
2000–01*	6.54
2001–02*	8.04

Note:* ITES included in software exports.
Rupee figures converted using average annual exchange rates reported by Economic Survey and RBI.
Source: *Dataquest* 2001a, 2002a.

The third notable feature of the IT sector's growth is that it has been driven largely by the private sector on both the supply and demand sides, though government support in terms of IT infrastructure investments, duty free access to hardware for software exporters and zero taxation of export profits played a role. Almost all IT firms producing for the domestic and international markets are private firms, and as Figure 1.5 shows the private sector has accounted for a dominant and rising share of domestic IT spending since 1995–96 and contributed as much as 73 per cent of the total in 2001–02, compared to 15 and 12 per cent by the government and public sectors, respectively.

These features are remarkable for two reasons: (*a*) they have occurred in a policy environment very different from those which characterized the import substitution years, and have therefore been taken as indicators of the positive effects that policies emphasizing private initiative and a minimalist state can have on growth; and (*b*) since they have resulted in a noticeable increase in India's share of world software and IT services production and export, they lend credence to the view that the IT sector, besides being among the most dynamic areas in the global economy, is one where new opportunities afforded are available to small firms, including small firms from developing countries.

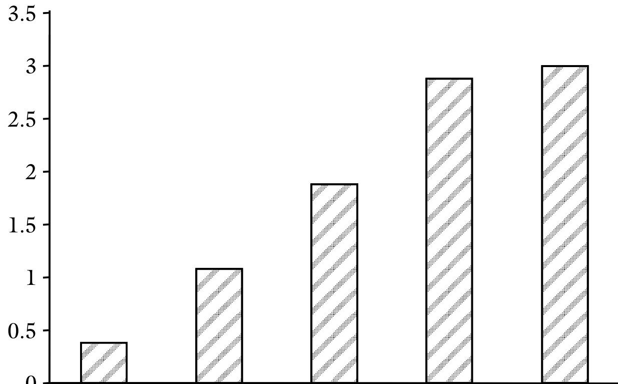
FIGURE 1.3 **Share of Exports in IT Industry Output**



	1990–91	1991–92	1992–93	1993–94	1994–96	1995–96	1996–97	1997–98	1998–99	1999–2000	2000–01*	2001–02*
per cent	20.4	24.9	26.9	29.5	27.5	27.6	36.1	39.9	44.9	48.6	54.8	60.9

Note: ITES included in software exports.
Source: *Dataquest* 2001a, 2002a.

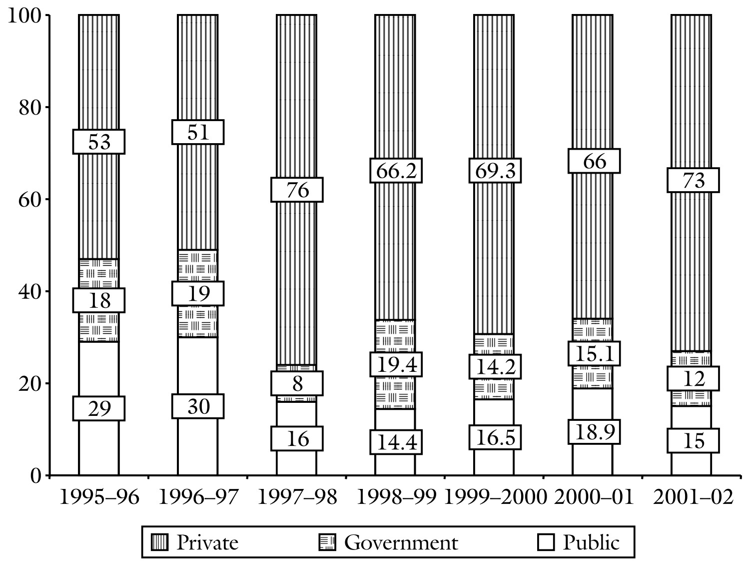
FIGURE 1.4 Ratio of IT Sector Output to GDP



	1991–92	1995–96	1999–2000	2000–01	2001–02
Per cent	0.38	1.08	1.88	2.88	3.00

Source: IT output from *Dataquest* (2001a, 2002a); GDP figures from GOI (2003).

FIGURE 1.5 Trends in Domestic Sectoral Spending



Source: *Dataquest* 2001a, 2002a.

Technological Opportunity

This notion of new opportunities that are not limited by the current level of inter-firm and inter-country inequality is grounded in the perception that unlike the 'routinized' technologies that dominated industry during the post-World War II years, new 'entrepreneurial' technologies typical of the IT sector are characterized by entry conditions that favour rapid international and domestic diffusion of the industry (Brunner 1995). Easy entry conditions are seen to result from two features of the technology. First, levels of investment required for entry are low and often easily afforded by private investors in developing countries. Second, the knowledge required for entry is in the public domain and is transmitted through open sources such as journals, seminars and universities.

Routinized technologies, such as those characteristic of the 'older' steel and chemical industries, were embodied in large continuous process plants requiring lumpsum investments in innovation, commercialization, capacity creation and market acquisition. This made access to a critical size of capital crucial for entry, queering the pitch for the big players from the developed industrial countries. Moreover, dramatic innovations in these sectors were few and far between, with much technological development consisting of marginal changes that were cumulatively, rather than instantaneously, significant. These marginal changes were, in turn, very often stimulated by knowledge gained in the act of production, which led up to expensive R&D exercises that created new commercially usable knowledge. Thus, not only were these industries dominated by big firms created with lumpsum investments, but much of the technological change that occurred in the industry originated within or as a result of the activity of these big firms themselves. Entry into the industry by new, especially small new, players, was rare. Competition was restricted to that among dominant oligopolistic firms straddling domestic and world markets. To the extent that technological change could trigger a competitive challenge from outside the industry, this was largely the result of the emergence of substitute products or wholly new industries that rendered older industries less significant or even irrelevant. And to the extent that growth occurred in new locations within late-industrializing countries, it occurred behind strong protectionist walls.

Compared with this, the IT sector can be seen as characterized by low costs of entry and an easily accessible and almost universally available knowledge base for innovation. What is of special significance is that the sources of this knowledge in a significant segment of hardware and software industries are conventional routes such as journals, conferences, seminars and publicly or privately financed training programmes. This makes it easy for wholly new entrants to acquire the knowledge base required for cutting-edge technological contributions to the industry, as was and is true of at least some of the myriad start-ups in Silicon Valley.

Benefit of Heterogeneity

In the hardware segment, manufacture of a range of products varying from components like printed circuit boards to peripherals like modems, on the one hand, and the assembly of personal computers, on the other, do not require large investments for entry. Many of these are heterogeneous products that can be put together by combining of internally produced and externally sourced intermediates and components. There are no doubt some components entering into ICT hardware—such as the microprocessor, the production of which is capital intensive in nature—that are dominated by a few global players like Intel, Motorola and AMD. But this does not preclude the presence of smaller players in important 'downstream' industries, since such components can be sourced from outside producers, even if located abroad, as is the norm in the computer industry worldwide. The real 'technology' in these downstream areas is a system architecture that maximizes the benefit derived from an appropriate combination of sub-systems, components and peripherals. That is, the heterogeneous nature of the product allows a producer to restrict his own production activity to a sub-set of the total elements that enter the product and/or just the design and assembly of the final product.[3] This requires that the technology in the sense of the knowledge for system design is freely available and is easily appropriated. But once such technology is available, the investment required for entry can be kept to the minimum, with labour intensive assembly often involving negligible investment in capital equipment and outlays on inventories kept to a minimum by employing innovative versions of the just-in-time method. This allows for easy entry even on the part of small developing country producers and partly allows for the emergence of international brands from the developing world, as is true of Acer from Taiwan. What is crucial here is access to outsourced components ensured, *inter alia*, by a liberal import regime. Thus, the rapid growth of the PC hardware segment is seen as facilitated by the removal of quantitative restrictions and the reduction of tariffs imposed on imported components, even while restricting and keeping expensive end product imports. As the domestic markets for PCs expands, domestic production of components will become viable, resulting in the emergence of an IT production 'complex' and reduction in import intensity. However, while convincing as an idea, this process can be subverted by developments in the software sector, as has already happened in India.

Implications of Skilled Labour Intensity

The logic of easy entry is even truer of the software sector, where knowledge is easily acquired and innovations easily replicated, which is skilled labour intensive and requires little by way of capital investment. Not surprisingly, over the years the software segment of the IT sector has come to dominate the industry in India. Entry into this sector requires access at competitive prices to very basic equipment such as networked PCs, suitable high-speed connectivity infrastructure and appropriate personnel. An easy way to ensure the first is to remove restrictions on hardware imports and reduce import duties on the same. The difficult way would be to build an internationally competitive hardware sector catering to domestic buyers. With the sudden and dramatic success on the software export front in countries like India, the pressure to liberalize hardware imports, including complete branded systems, increases substantially, and the government finds this route an easy option. Access to imported equipment is combined with public investments in the infrastructure required for connectivity and in training to generate the required personnel, as well as relaxed regulations with regard to private entry into these sectors.

Opportunity in Services

Another area where the ICT revolution has opened up whole new opportunities for developing countries is in the services sector. Prior to the digital revolution's transformation of service activity, the provision of most services required the presence of a service provider at the point of delivery of the service. As a result, services export took the form of migration of personnel to the location where the service was provided, as epitomized by the migration of skilled technicians, doctors and nurses to the US and of semi-skilled and unskilled workers, including carpenters, masons, chauffeurs and housemaids to the Gulf countries from India. Benefits to the home country came in the form of remittances of hard currency earnings by these migrants to their families, which augmented the scarce pool of foreign exchange available to these countries. But the magnitude of such income was limited by restrictions on the movement of skilled, semi-skilled and unskilled personnel set by immigration laws and practices of countries where the relevant service demand originated.

The digital revolution has changed all that. Now there is a range of services being provided by workers located in a country different from the one in which the service is actually delivered. These services are delivered via telecommunication or data networks, and are either *outsourced* or organized by agents in the country of origin of the service to whom the provision of these services are contracted out, or *outlocated* by subsidiaries of corporations from the country of delivery of certain services. When categorized by origin and focus, it is possible to identify four types of IT-enabled services (ITES): in-house or captive centres, units that were originally spin-offs, business process outsourcing (BPO) units and broad-based service providers who offer consulting or IT services in addition to BPO. The growing importance of the last of these blurs the distinction in the data between software and IT-enabled service exports. Examples of services outsourced/ outlocated include customer interaction services; the processing of credit card accounts, insurance claims and business payrolls; the creation and maintenance of information bases in the form of networked data centres and their use in the provision of information services such as help desks; and the generation of digitized records as in the case of medical transcription.[4] Other examples of outlocation include investment in design subsidiaries and back office facilities.[5]

The possible range of IT-enabled services in an environment where the service sector's role is growing worldwide is immense. The reasons that such relocation occurs are obvious. It substantially reduces the cost at which such services are obtained or provided, and so long as an appropriate location in terms of the availability of personpower with the requisite skills (say, basic computer literacy) and the necessary characteristics (for example, knowledge of English) is chosen, the quality and efficiency of the service can also be ensured.

Estimates made by the National Association of Software and Service Companies (NASSCOM) suggest that revenues from IT-enabled services increased from Rs 24 bn in 1999–2000 to Rs 41 bn in 2000–01 and Rs 71 bn in 2001–02 increasing the share of IT-enabled services in the total revenues from IT services and the whole IT sector, respectively, to 10.2 and 6.8 per cent in 1998–99, 11.3 and 7.5 per cent in 2000–01 and 16.2 and 11.4 per cent in 2001–02.[6] As a share of exports, NASSCOM estimates suggest that the contribution of ITES rose from 14 per cent in 1999–2000 to 14.5 per cent in 2000–01 and 19 per cent in 2001–02 (Table 1.3).

TABLE 1.3 **Contribution of IT-enabled Services to Total Exports**

Years	*IT-enabled Services*	*IT Services*
1999–2000	14%	86%
2000–01	14.5%	85.5%
2001–02	19%	81%

Source: www.nasscom.org.

Expectations are that ITES would account for a much larger share in the future. As Table 1.4 shows, the IT-enabled services sector is highly diversified. However, except for medical transcription, which records abysmally low revenue per worker, there is not too much difference in the revenue per worker, which averages Rs 600,000 (or around $12,200) per year. This points to the fact that low wages do drive the industry.

TABLE 1.4 Employment and Revenues from IT-enabled Services

	1999–2000		*2000–01*		*2001–02*	
	Employed	*Revenue (Rs bn)*	*Employed*	*Revenue (Rs bn)*	*Employed*	*Revenue (Rs bn)*
Customer Interaction Services include Call Centres	8,600	4.0	16,000	8.5	33,800	17.9
Back Office Operations/Revenue Accounting/Data Entry/Data Conversion including Finance and Accountancy/HR services	15,000	9.5	19,000	13.5	35,000	28.5
Transcription/Translation services	5,000	1.2	6,000	1.6	6,200	1.5
Content Development/Animation/ Engineering and Design/GIS	15,000	8.2	27,000	16.0	30,000	21.0
Other Services include Remote Education, Data Search, Market Research, Network, Consultancy and Management	1,400	1.1	2,000	1.4	3,000	2.1
Total	45,000	24.0	70,000	41.0	107,200	71.0

Source: www.nasscom.org.

Software Provision Advantages

The advantage that India has in the IT-enabled services sector is obvious. But India's competitive advantages in the software export area are also many. To start with, outsourcing of IT services is a dominant international business practice. According to the consulting firm International Data Corporation (IDC), out of a global market of $220 bn for computer services in 1995, as much as $68 bn was outsourced. Outsourcing totalled $16 bn in the case of customized software development, $32 bn in systems integration, $11 bn in IT consulting and $9 bn in business services. Compared with this, India's 2001–02 exports of $8 bn of software services and IT-enabled services appears small. The opportunities are therefore substantial. In January and February of 2002, Gartner Dataquest conducted phone interviews with 917 US-based companies (with 1,000 employees or more) to gauge their interest in offshore IT services. According to the survey, the top opportunities for growth in offshore services included enterprise application integration (EAI) services, applications outsourcing, packaged application implementation and integration with legacy applications beyond applications development and maintenance services. India was the primary country of choice for IT service spending with 70 per cent of survey respondents acquiring offshore services from India. Eighty-three per cent said they plan to outsource to India within 2003. Canada, Ireland, Singapore, Mexico and China were also cited as countries to outsource to.[7]

Second, till the slowdown in the IT sector in 2001–02, the shortage of software professionals in the developed countries was expected to result in an increase in the share of computer services outsourced. According to OECD (2000: 131),

> A recent study based on responses to a telephone survey of 532 IT and non-IT companies with more than 100 employees found that there were some 346,000 IT positions currently vacant in the United States in three core IT occupational clusters (programmers, systems analysts, computer scientists and engineers). In addition, there were 240,000 vacancies in areas such as technical writing, training and sales. An earlier study estimated a shortfall of nearly 1 million software professionals in Japan. Even if these figures are high, most observers agree that, in developed countries, demand for skilled software professionals has grown rapidly and may exceed supply.

Even though this would no longer be true, many argue that the need to cut costs during the downturn would accelerate outsourcing to countries like India.

Third, software professionals can be hired at a much lower cost in India. Even before the downturn, wage costs in India had been estimated at one-third to one-fifth of US levels for comparable work (Tables 1.5 and 1.6). Taking all costs into consideration, some estimates suggest that the cost of software development in India is half of that in the US. Relative to outsourcing competitors like Ireland, wages in India are estimated at a half to a third.

Finally, the rapid growth of software services exports from India noted earlier suggests that India has the managerial ability to exploit its competitive edge. The number of Fortune 500 companies that are outsourcing their software requirements to India steadily grew to 185 by 2002. The number of software exporting companies also grew to 1,250.

TABLE 1.5 Salaries of Software Professionals in the United States and India (1997)*

	United States (USD per annum)	*India† (USD per annum)*
Help-desk Support Technician	25,000–35,500	5,400–7,000
Programmer	32,500–39,000	2,200–2,900
Network Administrator	36,000–55,000	15,700–19,200
Programmer Analyst	39,000–50,000	5,400–7,000
Systems Analyst	46,000–57,500	8,200–10,700
Software Developer	49,000–67,500	15,700–19,200
Database Administrator	54,000–67,500	15,700–19,200

Notes: *Figures are starting salaries for large establishments employing more than 50 software professionals. They may be marginally lower for smaller firms. Salaries for particular designations vary owing to factors such as educational and experience profile of the professional; platform of operation; nature of the assignment (contract/full-time); location of the employer; and additional technical/ professional certification.

†Converted at an exchange rate of INR 41.50 per USD.

Source: Cited in OECD (2000).

The Promise

The rapid expansion of revenues from IT hardware, IT software and ITES resulting from these factors holds out the promise of substantial change in the nature of economic activity and the pace and pattern of growth in developing countries like India. By triggering the diffusion of information technology across nations and within individual nations this is expected to substantially alter the position of individual developing countries within the international economic order.

Overall, the promise that the ICT revolution holds for development in poor countries takes three forms. First, it is expected to result in the growth and diversification of the ICT sector itself, leading to the rapid expansion of output and employment in the production of currently available ICT products as well as myriad new products the technology can deliver because of the rapid pace of product innovation in this sector. The consequent income and employment growth, it is argued, cannot but have positive development implications (direction I). Second, the use of ICT in the agricultural, non-ICT manufacturing and services sectors is expected to fundamentally transform the nature of production in these sectors with major implications in terms of labour productivity, growth and employment (direction II). Third, penetration of ICT into activities outside of production is expected to reshape the way work, markets and leisure will be organized and the way in which individuals and communities can trade and access information and services, leading to changes in the structure of markets, improvements in the quality of life, a deepening of democracy and major advances in terms of human development indicators (direction III).

TABLE 1.6: Comparison of Annual Wages in the Software Industry

	Computer Programmer		*Systems Analyst*	
Country	*US$*	*Index (India=100)*	*US$*	*Index (India=100)*
India	4,002	100	5,444	100
USA	46,600	1,164	61,200	1,124
Japan	51,731	1,293	64,519	1,185
Germany	54,075	1,351	65,107	1,196
France	45,431	1,135	71,163	1,307
Britain	31,247	781	51,488	1,287
Hong Kong	34,615	865	63,462	1,166
Mexico	26,078	652	35,851	658

Source : Cited in Joseph (2002).

Needless to say, each of these routes through which ICT is expected to affect development is predicated on a certain kind and degree of diffusion of the technology within the country. The first presumes a process of *cross-country* diffusion, whereby the technologies and the industries that constitute the ICT sector move from early to late entrants. It is here that India's success has indeed been noteworthy.

The second route through which ICT is expected to impact on growth and development is predicated on a *horizontal intra-country* diffusion process, whereby ICT begins to be used (*a*) in the manufacturing sector, transforming the production process and the organizational structures of firms, and raising productivity, investment, growth and employment; and (*b*) in the services sector, changing the structure of markets and the extent and ease of access to and delivery of a range of services. It is here that India's progress has been limited, even negligible.

The third route by which ICT is expected to impact on development is crucially dependent on a *vertical intra-country* diffusion process that results in an increase in the level of penetration of the technology, leading to increased community and individual access to the benefits of the technology affecting human development by making these devices the means of service delivery, ensuring transparency and enhancing participation.

ICT Growth and Economy-wide Productivity

Experience from the developed industrial countries suggests that the growth of the ICT sector in terms of output and employment need not necessarily be accompanied by any equivalent diffusion of information technology into other sectors, especially manufacturing. As a result, the existence of a large information technology sector need not imply that production processes elsewhere have been transformed resulting in substantial productivity gains. This 'productivity paradox' was put on the agenda by the 1987 remark of Nobel laureate Robert Solow that 'You can see the computer age everywhere but in the productivity statistics' (Solow 1987: 36). While there are numerous problems associated with total factor productivity (TFP) measures, they have provided the evidence for the debate on the productivity paradox. To quote a summary of the evidence provided by Paul David (2000: 51–52):

> The long-run perspective on US productivity performance . . . shows a refined measure of the TFP growth rate (adjusting for composition-related

quality changes in labour and capital inputs) having been maintained in the near neighbourhood of 1.4 per cent per annum throughout the era from 1890 to 1966. From its 1.45 per cent level over the 1929–1966 trend interval, the annual growth rate plummeted to 0.04 per cent during 1966–1989.... More worrisome still, the post-1966 retardation was extended and intensified until the very end of the 1990s. Estimates of real gross output and inputs from the Bureau of Labour Statistics (USDL News Release 98-187, May 6, 1998) enable us to follow the path of measured productivity gains in the US economy well into the 1990s. The figures relating to the private *nonfarm business* economy are generally regarded as providing a more accurate picture of recent movements, because the deflation of the current value of output has been carried out by using price indexes that reweight the prices of component goods and services in accord with the changing composition of the aggregate. These 'chain-weighted' output measures lead to productivity growth estimates that reveal two notable things about the 'slowdown'. The first point is that the productivity growth rate's deviation below the trend that had prevailed during the 1950–72 'golden age' of post-World War II growth became even more pronounced during the late 1980s and early 1990s, instead of becoming less marked as the oil shock and inflationary disturbances of the 1970s and the recession of the early 1980s passed into history. Measured labour productivity rose during 1989–1996 at only 0.83 per cent per annum, half a percentage point *less* rapidly than the average pace maintained during 1972–1988, and thus fully 2.25 percentage points below the average pace during 1950–72. Second, concerning the magnitude of the slowdown, the TFP growth rate estimate of the Bureau of Labour Statistics for 1988–1996 sank to 0.11 per cent per annum, which represented a further drop of 0.24 percentage points below the pace of TFP advance that had been achieved during the post-World War II golden age.

Thus, while the much more recent revival in TFP growth has reduced scepticism regarding the ability of ICT innovation to raise economy-wide productivity, the least which can be said is that the lack of correspondence between high rates of innovation and slow growth of TFP suggests that the process of diffusion is time consuming, gradual and even painful from an output and employment growth perspective. There are, in fact, even more sceptical views on the matter. According to Robert Gordon (1999), a new economy sceptic:

When the period since 1995: 4 is compared to 1950–72 and 1972–95, growth in output per hour in the most recent (third) period has recovered

> more than two-thirds of the productivity growth slowdown registered between the first and second periods. *All* of this productivity rebound can be explained by three factors, (1) improved methods for measuring price deflators, (2) the normal procyclical response of productivity in periods like 1997–99 when output grows faster than trend, and (3) the explosion of output and productivity growth in durable goods, entirely due to the production of computers.
>
> There has been *no* productivity growth acceleration in the 99 percent of the economy located outside the sector which manufactures computer hardware, beyond that which can be explained by price remeasurement and by a normal (and modest) procyclical response. Indeed, far from exhibiting a productivity acceleration, the productivity slowdown in manufacturing has gotten worse; when computers are stripped out of the durable manufacturing sector, there has been a further productivity slowdown in durable manufacturing in 1995–99 as compared to 1972–95, and no acceleration at all in nondurable manufacturing.

This dissociation between ICT-sector growth and overall productivity performance can be all the greater in developing countries like India, where IT growth is predominantly targeted at export markets. Therefore, the advance of ICT growth along the first direction, that is, through the growth of the IT sector itself, need not imply diffusion that implies advance along the second direction, or through the diffusion of information technology into the non-ICT sector, which transforms production processes and increases productivity. It needs to be noted that recent studies have pointed to a substantial slowing of the rate of growth of TFP in Indian manufacturing during the years in which ICT sector expansion has been rapid.

Vertical Diffusion

Further, if expansion along directions I and II is not accompanied by the widespread diffusion of ICT across firms and households, the process need not be accompanied by the transformation of economic activity and markets that the growth of business-to-business and business-to-consumer e-commerce is required to effect (direction III). Thus, there need not be any diffusion and development along the lines suggested by the third direction, that is, through the utilization of the IT network by producers and consumers to undertake online transactions which would reduce transaction costs and alter market structures.

Even if there is substantial expansion along directions I, II and III, that along direction IV need not occur. The latter refers to the widespread diffusion of the information and communication technologies required to encourage the utilization of the IT network by governments, communities and individuals to share/provide information and offer various services. Such diffusion is, however, a prerequisite for the use of IT for meaningful e-governance and for improved service delivery that could have an impact on human development.

If all-round diffusion of this nature occurs, the consequences would indeed be revolutionary. It would create and massively expand industries catering to the market for a range of computing devices, especially personal computers, that would now be accessories in the home and not just at the workplace. It would also transform the nature of a whole range of products varying from televisions and microwave ovens to automobiles and aircrafts, as well as stimulate many new product innovations, such as cellular telephones and palm-sized personal organizers. The stimulus to innovation in sectors completely outside the computing business itself, resulting in the emergence/creation and servicing of a host of new needs, makes the employment consequences of the new technologies virtually impossible to calculate.

Third, it would substantially transform industrial processes, since firms can now use the capacity to store information and execute instructions to automate and change the manner in which they conduct and manage their operations. Information technology is in part revolutionary because it ensures and necessitates the transformation of productive capacity in almost all sectors. Finally, the resulting computing revolution would lead to a dramatic expansion of the size and scope of the services sector (across a wide spectrum including finance, banking, trade, entertainment, health and education). This results partly from associated technological developments that find new uses for the massive computing power that is cheaply available, partly from the huge market that developments in communications and networking technology create, and partly from the fact that the increasingly ubiquitous PC becomes the vehicle to deliver a range of services, besides being a device in its own right.

The Constraints

The Connectivity Barrier

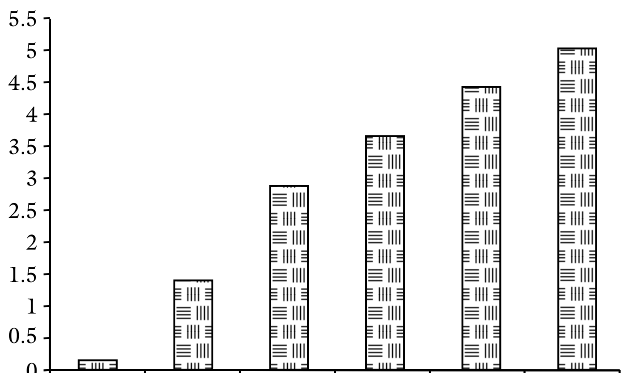
Crucial to the realization of this many-sided potential is connectivity. Unfortunately, India's communications infrastructure is still limited in size and spread, and though it is witnessing rapid growth in recent times, that growth is much lesser than in China, which has the wherewithal to undertake huge public investments.

There are many who argue that the entry of private operators made possible by the National Telecom Policy statements of 1994 and 1999 promises acceleration in telecommunications infrastructure growth. This view has been influenced by the experience with television penetration, driven in significant measure by private initiative. Till 1991, the spread of even television in India was limited, with broadcasting reach ensured by the much lower cost radio. Television programming, delivered through terrestrial channels, was dominated by the state-owned Doordarshan. A combination of factors, such as the government's decision to make television sets available in time for the 1982 Asian Games, the interest generated by coverage of the Gulf War in the early 1990s, the availability of a number of free-to-air, private channels in English and Indian languages beamed out of foreign locations such as Hong Kong and Singapore, and the rapid and unregulated growth of local cable operators, helped increase the demand for and reach of television. Yet the progress achieved must not be overstated. In 2001, only 31.5 per cent of rural Indians and 74.1 per cent of urban Indians had access through home-based or community TV sets to Doordarshan's network. Figures on cable television access in 1999 indicated that less than 10 per cent of rural India's television viewers had access to cable television and the percentage of rural homes with cable television was less than 1 per cent. In urban areas figures for cable television access varied from 10 to 50 per cent depending on location (Franda 2002: 107).

In the case of ICT, since connectivity is a core element of the new technology, a simple measure used to assess the degree of such diffusion is teledensity or the number of telephones per hundred inhabitants in the country. Going by that measure, there is evidence that suggests that India may be on track to realizing the required degree of diffusion, if at a slow (but accelerating) pace. Recently released figures indicate that telephone density has touched five per 100 inhabitants as on 31 March 2003, compared with only 1.39 per 100 at the end of March 1994, when the shift to a new, more liberal telecom policy began. Since then the rate of expansion of connectivity has indeed been rapid, with teledensity touching 2.86 lines per 100 people on 31 March 2000, 3.64 in 2001, 4.4 in 2002 and five in 2003 (Figure 1.6).

This growth in connectivity is expected to substantially increase interactive communication between distant centres, permit improved governance through more efficient delivery of information and a range of social services in rural areas as well as expand access to the internet and the benefits it can provide. Assuming that the government is able to put in place the IT infrastructure needed to exploit the benefits of such connectivity, it is argued, the country seems to be well on its way to realizing its goal of delivering IT to the masses, thereby supplementing the benefits from the autonomous growth of IT use in urban areas epitomized by the burgeoning revenues from the 'production' and export of IT-enabled and software services.

FIGURE 1.6 **Trends in Telephone Density (Lines per 100 people)**



	1951	1994	2000	2001	2002	2003
Teledensity	0.03	1.39	2.86	3.64	4.4	5

Source: www.dotindia.com/networkstatus.htm, accessed on 24 May 2003.

The difficulty is that a closer examination of the data suggests that aggregate teledensity may not be a good measure of the extent of diffusion. To start with, the aggregate figure conceals the low penetration of telecommunications capacity (Table 1.7) and a high degree of urban

TABLE 1.7 Indicators of Telecommunications Capacity in India

Description	*As of 31 March 2001*	*As of 31 March 2002*
Switching capacity in public sector (million)	39.90	47.40
No. of DELs (million)		
Public sector	32.40	37.90
Private sector	0.27	0.50
Cellular mobile phones (mn)	3.58	6.40
Village public telephones (mn)	0.41	0.47
Rural DELs (mn)	6.69	9.02
Public call offices (mn)	0.80	1.10
Internet subscribers (mn)	2.97	3.20

Source: www.dotindia.com/networkstatus.htm, accessed on 24 May 2003.

and regional concentration. Rural teledensity in India in 1999 was just 0.4 lines per 100 people. It crossed one per 100 in 2002 and stood at 1.49 in 2003, when urban teledensity was placed at 15.49. Further, inter-regional variations were also substantial. As of 31 March 2003, while total teledensity in the state of Delhi was 26.85, while that in Bihar was as low as 1.32 (Table 1.8).

TABLE 1.8 State-wise Teledensity (as on 31 March 2003)

	Teledensity (per 100 persons)		
State	*Urban*	*Rural*	*Total*
Andaman and Nicobar	14.98	7.71	9.60
Andhra Pradesh	16.45	2.03	5.56
Assam	11.54	0.50	1.94
Bihar	9.30	0.48	1.32
Chhattisgarh	5.55	0.40	1.39
Delhi	30.18	0.00	26.85
Gujarat	17.81	2.48	7.44
Haryana	16.46	2.32	6.06
Himachal Pradesh	39.63	5.43	8.40
Jammu and Kashmir	8.34	0.52	2.48
Jharkhand	6.11	0.40	1.57
Karnataka	15.84	2.37	6.45
Kerala	23.70	7.85	11.13
Madhya Pradesh	10.15	0.56	2.88
Maharashtra	19.27	2.16	8.99
North-east	9.17	0.88	2.70
Orissa	11.33	0.87	2.22
Punjab	25.66	4.60	11.60

(*Table 1.8 contd*)

(*Table 1.8 contd*)

State	*Teledensity (per 100 persons)* *Urban*	*Rural*	*Total*
Rajasthan	11.34	1.25	3.40
Tamil Nadu	15.20	2.12	7.82
Uttaranchal	12.57	1.30	3.95
Uttar Pradesh	8.82	0.56	2.13
West Bengal	11.53	0.89	3.72
Total	**15.16**	**1.49**	**5.00**

Source: MCIT 2003.

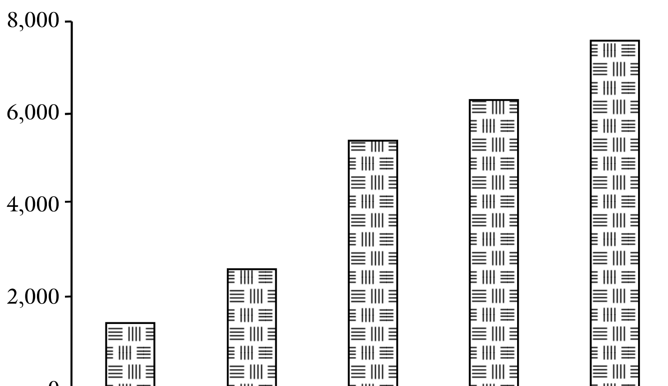
Besides the huge rural–urban divide and the substantial inter-regional variations in teledensity, the figures also appear to be substantially influenced by the recent growth of the mobile telephony sector. As of end-March 2002, while there were 37.9 million DELs being provided by public sector companies (VSNL and MTNL) and 0.50 million DELs by private operators, the number of cellular phone subscribers was placed at 6.4 million or close to 16 per cent of all DELs. Since a very large proportion of cellular phone subscribers were those who subscribed to the service in addition to holding a regular landline, so as to benefit from the mobility that cellular telephony allows, the rise in telephone density as a result of an increase in cellular telephone connections can hardly be taken as indicative of the diffusion of telecommunications technology among those who were thus far deprived of it.

To assess the latter, we need other indicators of mass access such as the presence of public call offices (PCOs) in rural and urban areas and DELs and village public telephones (VPTs) in rural areas. These indicators are by no means encouraging. The number of PCOs that could be converted into telecom kiosks or centres with internet connectivity stood at just 1.1 million at the end of March 2002. This figure amounted to less than 3 per cent of the total number of DELs in the country. Further, while the population in rural areas amounted to more than 70 per cent of the total, the number of rural DELs worked out to just 23.5 per cent of the total. Finally, despite the government's efforts to reach a telephone connection to each of India's 600,000 villages, the total number of village public telephones at the end of March 2002 amounted to 469,000. These figures are clearly indicative of a digital divide driven by asset and income inequalities, such that there are a few at the top who are connected, while the majority, preponderantly in rural areas, are marginalized in terms of connectivity.

Internet Connectivity

Even if connectivity in the form of a communications link is established, there is no guarantee that this can be viably expanded to connect India's villages to the world through the internet. Despite its large population, the success of its IT industry and the government's stated intent of wiring India's villages, India today lags far behind many other developing countries in terms of the bandwidth (or the pipe) necessary for people to simultaneously access information flow through the internet. The International Telecommunications Union estimated bandwidth availability in India in 2001 at 1,475 Mbits/sec, compared to 2,639 in Singapore, 5,432 in South Korea, 6,308 in Hong Kong and 7,598 in China (Figure 1.7).

FIGURE 1.7 International Internet Bandwidth (2001)



	India	Singapore	South Korea	Hong Kong	China
Mbits/s	1,475	2,639	5,432	6,308	7,598

Source: www.itu.int/itunews/issue/2002/10/indicators.html, accessed May 2002.

This, however, was not a problem because internet spread is also limited. The International Telecommunications Union (ITU) estimates that in 2001 India had a total of 3.2 million internet subscribers and 7 million internet users (Table 1.9). In terms of internet spread or the number of users per 100 inhabitants, India with 0.7 was behind China (2.6) and way below Hong Kong (38.5), Korea (52.1) and Singapore (36.3) (Figure 1.8).

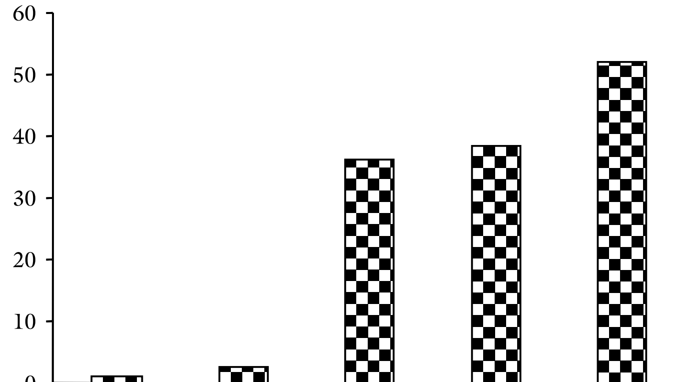
TABLE 1.9 **Asia-Pacific Internet Economy (2001)**

		Number of Users		*Number of Sub-scribers (in thousands)*		*Inter-national Internet Bandwidth (Mbit/s)*
	Number of ISPs	*Total (in thousands)*	*Per 100 in-habitants*	*Total*	*Broad-band*	
Australia	603	7,200	37.1	4,181	123	7,000
Bangladesh	60	250	0.2	100	–	40
China	936	33,700	2.6	17,364	203	7,598
Hong Kong, China	258	2,601	38.5	2,631	623	6,308
India	90	7,000	0.7	3,200	50	1,475
Indonesia	60	4,000	1.9	600	15	343
Japan	4,000	55,930	43.9	24,062	3,835	22,705
Korea (Republic of)	99	24,380	52.1	8,956	7,806	5,432
Malaysia	6	6,500	27.3	2,115	4	733
New Zealand	80	1,092	28.6	660	17	1,900
Pakistan	70	500	0.3	200	–	225
Philippines	51	2,000	2.6	600	10	237
Singapore	42	1,500	36.3	927	151	2,639
Sri Lanka	29	150	0.8	62	–	18
Taiwan, China	185	7,820	34.9	6,316	1,130	7,228
Thailand	18	3,536	5.8	1,500	2	642
Vietnam	4	1,010	1.2	252	–	34
Asia-Pacific	6,654	160,217	4.6	74,290	13,979	64,955

Note: Local internet access rates in Afghanistan and the Democratic People's Republic of Korea are not available.
Source: www.itu.int/itunews/issue/2002/10/indicators.html, accessed May 2002.

However, users are geographically extremely concentrated. In August 2000, when there were an estimated 1.6 million subscribers and 4.8 million users (0.37 per cent of the overall Indian population), more than three-fourths (77 per cent) of these users were from New Delhi and the capitals of Indian states. Two cities—Delhi and Mumbai—alone accounted for more than one-third of all users. Maharashtra with 453,000 accounted for 28 per cent of the total. On the other hand, two of India's most populous states—Uttar Pradesh and Bihar—had only 20,000 and 8,000 respectively (Franda 2002). Clearly, the inadequate spread of connectivity, the perceived benefits of connectivity and the cost at which it is available are working against as rapid a spread of the internet as seen in the case of radio.

FIGURE 1.8 Internet Users per 100 Inhabitants (ITU, 2001)

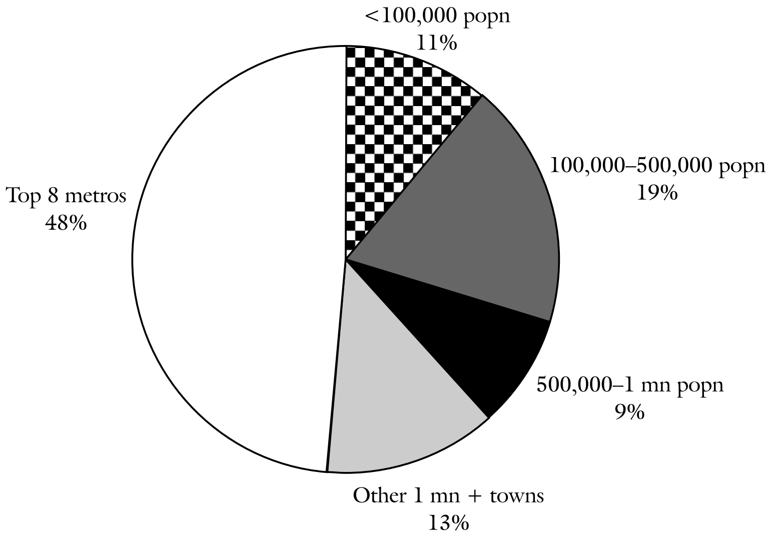


	India	China	Singapore	Hong Kong	South Korea
Number	0.7	2.6	36.3	38.5	52.1

Source: www.itu.int/itunews/issue/2002/10/indicators.html, accessed May 2002.

A useful source of information on the internet is the National Readership Survey (NRS) conducted by the National Readership Survey Council, a body of industry providers and users for advertisement of the media. NRS 2002 figures indicate that among 6.6 million adult internet users, besides the urban concentration noted earlier, there is a high degree of geographical concentration even among these urban users. Close to half of them (48.6 per cent) were located in the top eight metros, with smaller towns accounting for the remaining (Figure 1.9). Interestingly, however, while towns with populations of more than 1 million and 500,000–1 million accounted for 13.1 per cent and 8.5 per cent of internet users respectively, those with populations in the 100,000–500,000 and less than 100,000 ranges were home to 18.8 per cent and 11 per cent respectively. That is, these are signs of some diffusion of internet use among smaller Indian towns, providing a glimmer of hope to those who see an opportunity in the new technology.

FIGURE 1.9 Distribution of Urban Internet Users by Category of Location

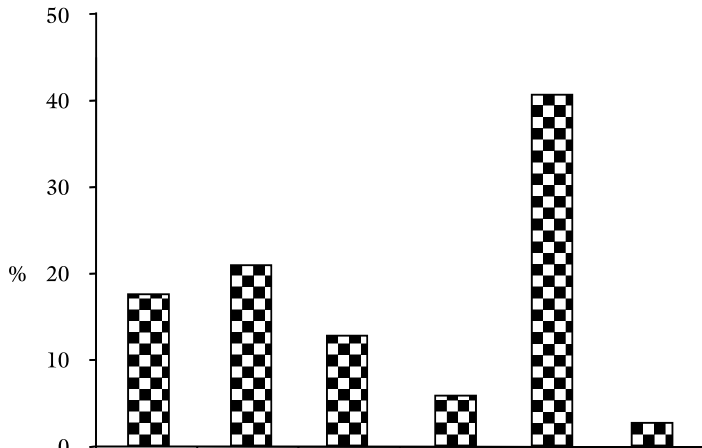


Source: NRS 2002.

Such signs of diffusion at the 'lower end' of the user spectrum are visible elsewhere as well, as in the data on the place of access (Figure 1.10). While 17.5 per cent of urban users in 2002 accessed the internet from their homes, 20.84 per cent had access from their place of work and another 12.7 per cent from their place of study. What is noteworthy is that a huge 40.56 per cent accessed the net through cybercafes. This lends credence to the view that the conversion of PCOs and STD/ISD booths that are indeed ubiquitous across India now could help expand internet use over time.

This picture of a combination of extreme concentration at the top accompanied by a more diffused access to the technology among users at the 'lower end' is also supported by figures on the distribution of users in terms of hours of usage (Figure 1.11). Those who had used the internet for five hours or more in a week accounted for 29.3 per cent of the total of internet users, whereas those who used it for one hour or less accounted for as much as 40 per cent. That is, there were a large number of users who were using the net to a limited extent, principally for e-mail and restricted surfing. It is likely that this large chunk of low-frequency users belonging to the 'lower end'

FIGURE 1.10 Distribution of Users by Place of Internet Access



	Home	Place of work	Place of study	Friend's place	Cyber cafe	Other
Place of access	17.50	20.84	12.71	5.77	40.56	2.62

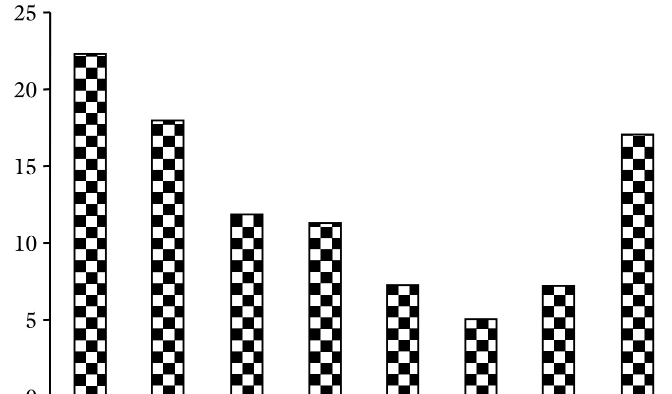
Source: NRS 2002.

of the user spectrum restricted use to what were seen as absolutely necessary operations. That is, the internet is not just concentrated among those who surf the net for entertainment, besides information and communication. It shows signs of diffusion among those whose usage pattern suggests that their use is much more purposeful, even if limited in terms of time.

Thus, while the use of the new technology is still extremely limited in India, and diffusion of the benefits of IT that can make a difference to the quality of life must wait, there are signs of change. Besides being concentrated among a set of top-end users, the technology does seem to be in the process of diffusion among a set of lower-end, low-frequency users.

This dual nature of the diffusion of the technology suggests that there are two routes through which the technology can impact on quality of life. Elite users, who use the technology to transact through business-to-business or business-to-consumer websites and share information and analysis can begin to take advantage of some of the benefits that the vertical diffusion of the technology is expected to

FIGURE 1.11 **Distribution of Internet Users by Hours of Access**



	<1 HR	1 HR	2 HR	3 HR	4 HR	5 HR	6 HR	7 HR
Per cent	22.30	17.98	11.85	11.29	7.26	5.04	7.22	17.06

Source: NRS 2002.

deliver. This would be the trickle-down means for the technology to influence development. The other would be for the technology to be diffused, leading to the participation of the less advantaged in initiatives that ensure direct provision of services that affect the quality of their lives. This is the more democratic face of the technology and the best manner in which it can be used to advance larger development goals. Unfortunately, the current extent and pattern of diffusion of the technology in the country is such that it is the first of these which predominates overwhelmingly and is likely to continue to do so in the foreseeable future.

Structural Constraints

In understanding the constraints to the realization of this promise by advancing along the four routes of diffusion, besides connectivity there are three features of the structure of the ICT industry which are of relevance. These are: (*a*) private sector dominance in IT investment and spending; (*b*) export dominance over IT revenues; and (*c*) software sector dominance over IT revenues. Private sector dominance in IT investment and spending suggests that the nature of the capital stock and infrastructure generated and the pricing of most services that are offered would be largely governed by profit considerations. This would mean that infrastructure generation for provision of e-governance and IT-enabled social services delivery is not likely to result from the current dynamics of the IT sector, but would need substantial state intervention. Evidence from other countries, such as South Korea, which leads the world in terms of the spread of broad-band connectivity, point in two directions: besides the benefit of a very much higher per capita income, there is need for substantial state investment or state support for private initiative; and there must exist a 'killer application' (in this peculiar case, gaming) if private initiative is likely to deliver such connectivity, even with state support. Since the level of per capita income and the experience with cable penetration suggests that such a killer application is unlikely to emerge in India in the near future, a major role for the state becomes crucial if widespread diffusion is to occur at all.

The setback to domestic diffusion is all the greater because of the fact that India's IT sector growth has been characterized by the dominance of export revenues over revenue growth. This does make the development of the sector take on an enclave-like character, with limited even if not negligible domestic linkage effects. It is not just that exports account for more than 60 per cent of IT sector revenues today, but the fact that exports from software technology parks account for 70 per cent of software exports from the country. This would suggest that ICT expenditure would be concentrated in a few locations, rendering the diffusion effects of ICT growth limited. In fact, an examination of the adoption of IT by Indian industry based on the Annual Survey of Industries (ASI) data indicates that only 35 per cent of factories covered in 1997–98 claim to use computers in offices, only 1.1 per cent have networked computer systems, just 3.7 per cent were connected to the internet and a meagre 1.8 per cent used robotics or computerized processes in production (Joseph 2002).

Transnational Dominance

Diffusion is also limited by the fact that IT sector growth in India is increasingly dominated by software revenues. It is not just that software revenues have tended to grow faster than hardware revenues, but the rapid growth of the software sector has generated a perverted form of the Dutch disease, adversely affecting hardware sector growth.

Initially, the Indian hardware sector—which because of protection was more or less limited to domestic firms—consisted of three segments. Premium producers like Wipro controlled the market consisting of quality-conscious customers who demanded a large and reliable after-sales service network and were willing to pay a higher price for these features. Large volume retailers like Sterling Computers and HCL kept prices down by pushing volume sales while limiting overhead costs and accepting lower per unit margins. And finally, a large number of assemblers with low overheads, a small employee base and virtually no after-sales service, catered to price-conscious customers willing to take quality risks. According to IDC (India), very small assemblers selling less than 200 units annually accounted for close to 50 per cent of the market for assembled PCs in 1998–99 (Table 1.10). According to *Dataquest*, units other than the top 12, including the assemblers accounted for 65 per cent of PCs sold in 2001–02 (*Dataquest* 2002c).

TABLE 1.10 **Units of Assembler Type Sold per Year (1998–99)**

Size	*Share of the Market in Unit Terms*
A (more than 1,000)	21.60%
B (401–1,000)	14.30%
C (201–400)	15.60%
D (up to 200)	48.50%
Total	100.00%

Source: IDC (India) website.

These small producers most often used inputs obtained from suppliers who had managed to evade customs duties. This reduced their costs substantially. Besides, these firms were satisfied with extremely low margins. As a result, their prices were much lower than that of the large domestic suppliers. Not surprisingly, the market catered to by the assemblers as a group was by no means small.

The large premium producers defended their prices on the grounds of being technologically superior, of offering better quality and of providing far more reliable after-sales service facilities. In practice, having invested much in marketing to build their brand images, these large suppliers used the protection afforded by the government to garner large margins on their sales, but did little to build brand loyalty in the domestic and international market. Neither did the government intervene to ensure that the period of protection was used to build technological capability and viable sales volumes.

When the domestic market for PCs and peripherals is relatively protected and component imports are highly taxed, the few large players co-exist with the large number of smaller suppliers. It should be obvious that all segments of the domestic industry benefited substantially from the quantitative restrictions on PC imports, with premium producers garnering high margins and the lower-end assemblers surviving despite high costs and poor service support. Needless to say, the small assemblers with low margins were in no position to use the opportunity afforded by protection to build capabilities of a kind that would allow them to compete with large international suppliers as and when protection was withdrawn. On the other hand, with the government not enforcing R&D-based competitive production in the premium segment, and premium producers choosing to encash the large margins rather than plough them back into production, even the latter did not concentrate on developing indigenous sources of supply of components and accessories and on reducing costs and developing significant product innovation capabilities.

The effects of this history were seen when the government, eager to exploit India's capabilities as a software and IT-enabled outsourcer decided to ease access to and lower duties on information and communication technology products. The first casualties were producers in the premium segment who, when faced with the abolition of quantitative restrictions and the reduction of duties on a range of PC products, decided they could not face up to the competition. Some chose to become domestic sales agents for international brands. But almost all leading producers have substantially diversified out of PC production into software generation.

As a result, in the wake of liberalization the industry has seen significant changes in structure. Liberalization has resulted in the gradual conversion of some premium producers into domestic sales agents for international firms. Wipro, for example, has virtually discontinued its own range of products and become a supplier of Apple and Acer products. This has also resulted in the closure of at least some large volume retailers such as Sterling, though some other large producers like HCL have remained in the PC business. Finally, as the volumes sold by multinational brands are increasing and duties on imported components being reduced, there has been a growing threat of erosion of the market share of assemblers by these international suppliers.

As Table 1.11 shows, in 1999–2000, about a half of the top 15 PC brands in India were known international brands, there were only two major domestic players who were involved in retailing volumes larger than 50,000 PCs a year, and these producers were falling behind in the competition with transnational producers. To quote *Dataquest*:

> Gone are the days of PCL, DCM and ECI—the erstwhile heroes of the domestic IT market have long vanished or have been relegated to history books. Today's domestic market is run by MNCs. Look around at any of the IT segments in India and the frontrunners are likely to be MNCs. Think servers and you think Sun, IBM, Compaq and HP. Think printers, you have little option but to think HP, Epson and Samsung. Think networking products and who can you think of but Cisco and 3Com? Sure, there are some lone Indian rangers, for instance HCL Infosystems in desktops and TVSE in impact printers, but even their numbers are fast dwindling. This is a domestic scene that is nearly monopolised by MNCs (*Dataquest* 2001b: 194).

TABLE 1.11 Major PC Vendors in the Domestic Market (1999–2000 and 2000–01)

Vendor	*Units 1999–2000*	*Units 2000–01*
Compaq	79,484 (2)	151,568
HCL	101,500 (1)	149,500
Hewlett-Packard	63,000 (3)	91,200
IBM	40,534 (6)	67,644
Wipro	49,000 (5)	66,699
Zenith	59,685 (4)	60,646
DELL	15,500 (12)	38,000
PCS	17,500 (10)	36,350
Vintron	20,598 (8)	30,575
Minicomp	27,260 (7)	29,271
Visualan	16,570 (12)	23,746
Acer	18,000 (9)	22,100
Apple	9,000 (14)	12,000
SNI	10,000 (13)	10,000
CMS	5,000 (17)	8,000
Computech	5,893 (16)	8,000
Accel	6,480 (15)	7,000
Others+assembled	580,321	892,736
Total	1,125,235	1,705,335

Source: *Dataquest* 2001a, 2002a.

The tendency for these transnational suppliers to source virtually knocked-down kits from production facilities abroad is known, resulting in a high and growing import intensity in the industry. This implies that the output and employment implications of the rapid growth of domestic hardware spending would be far less than suggested by the gross revenue figures.

This reflects the unusual situation in the PC market in developing countries like India, where despite a long record of PC production even by international standards, there are increasingly international brand names like Compaq, IBM, Dell and HP dominating the market.

The core of the computing business is dominated by a capital-intensive and oligopolized product like the microprocessor, the market for which is dominated by a few producers like Intel, Motorola and AMD. And the technologies driving a range of peripherals like printers and networking products, for example, are proprietary and are not replicated without a licence. If we take hardware as a whole, according to *Dataquest* (2002c), the only Indian company which featured among the top five domestic vendors in 2001–02 was HCL Infosystems, with the top four slots being taken by Compaq, Intel, Samsung and Hewlett-Packard, in that order. This implies that hardware production in developing countries like India amounts largely to assembly of components, much of which is imported. Indigenous content is restricted to certain of these components and indigenous technological input is confined to system architecture and design. As a result, value added domestically tends to be small.

Further, while capital investment requirements for production may be small, production for geographically and quantitatively large national and world markets require high sunk costs. This takes the form of initial expenditures on marketing, retailing and the creation of an after-sales service network. Deep pockets and/or access to large sums of capital are therefore a prerequisite for entry into this segment of the hardware sector.

This also has implications for the linkage effects of the growth of the PC industry and for net foreign exchange earned by the information technology sector. Needless to say, with imported components accounting for a substantial share of the value of PCs assembled by both the international players and domestic assemblers, the domestic linkage effects of the growth of PC sales could only be limited. Much more employment is likely to be created by the growing demand for maintaining and servicing the installed PC base (estimated at 7.5 million in 2000). In the PC segment itself whatever value is added domestically would accrue in the hands of large international firms.

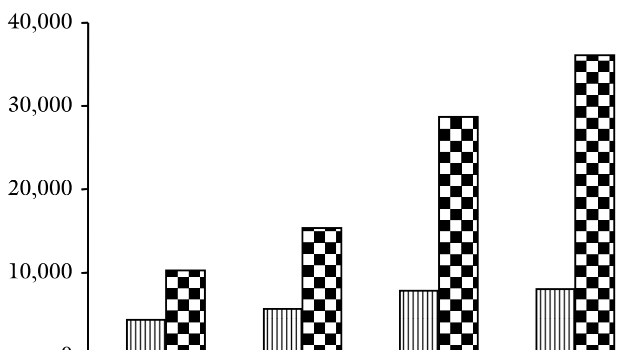
Given the sourcing practices of these firms it is likely that the import intensity of PC production in India would remain high, resulting in the leakage of at least some of the revenues earned from exports of software and IT-enabled services.

These features of the PC market, which would be even truer of the peripherals market, indicate that in the wake of liberalization, the emergence of a strong indigenous industry that engages world markets is not likely in the hardware segment. This substantially dilutes the argument that there is likely to be a substantial restructuring of the international industry in favour of developing countries such as India, at least so far as hardware production is concerned.

The Software Story

Thus, if the case that India is likely to emerge as an IT powerhouse which invades developed country markets and challenges developed country players is valid at all, it can only be true of the software segment. In IT-related services it is the export market that provides the real opportunity. As Figure 1.12 shows, revenues from services in the domestic market were close to a fifth of that from the export market in 2002.

FIGURE 1.12 Revenues from Services

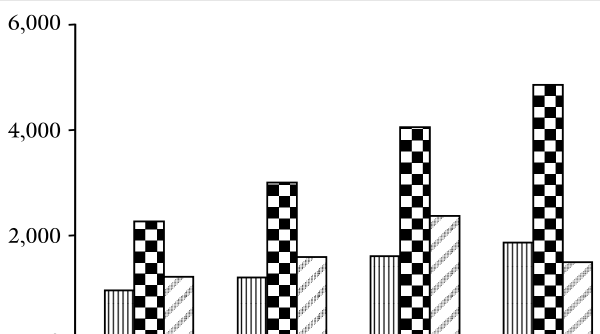


	1998–99	1999–2000	2000–01	2001–02
Domestic	4,358	5,690	7,885	8,065
Export	10,306	15,387	28,730	36,153

Source: *Dataquest* 2001a, 2002a.

There are three broad categories into which domestic IT-related services fall. Hardware services, including maintenance of the growing installed base of computers; educational services, which generate the skilled and semi-skilled personnel needed to sustain IT sector growth; and software services, including the production of software packages, generation of customized software and the provision of a range of IT-enabled services. In the domestic market, revenues from software services, at Rs 47.67 bn in 2001–02, was only about 1.5 times the combined revenue from hardware and educational services totalling Rs 27.43 bn (Figure 1.13). That is, not only were domestic service revenues small, but revenues from areas such as maintenance and the creation of basic IT skills generated as much as 70 per cent of the revenue garnered from the production of IT-enabling software. This is of significance because a large domestic software services market provides the workplaces of training for software personnel and the base for generating the skills necessary to meet the higher demands of the export market and to graduate to the higher end of the software value chain. That base is crucial since a substantial part of revenues from IT-related educational services is known to accrue to teaching shops that do not develop adequate skills among its students. A growing disproportionality between the market for domestic and export

FIGURE 1.13 Structure of Revenues from Services: Domestic



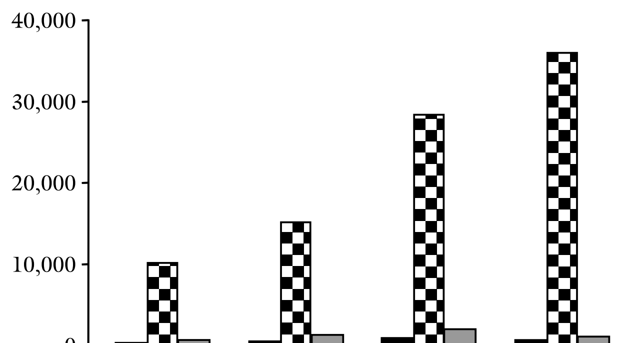
	1998–99	1999–2000	2000–01	2001–02
Hardware	940	1,182	1,578	1,830
Software	2,224	2,947	3,978	4,767
Education	1,194	1,561	2,329	1,467

Source: *Dataquest* 2001a, 2002a.

software services, therefore, constrains the ability of the system to generate the wherewithal in terms of the personnel needed to service the export market. This is the first factor to take account of while making judgements about India's potential in the export of software services.

To return to the point made earlier, the ability of the IT sector to unleash growth that will change India's economic fortunes depends largely on revenues from exports of services. As is to be expected, software services and ITES dominate the export of IT services, accounting, at Rs 360 bn for more than 99 per cent of such exports (Figure 1.14). This is where the income and employment gains are going to be registered, as suggested by the fact that such exports grew by nearly 50 per cent in 1999–2000.

FIGURE 1.14 **Structure of Revenues from Services: Export**



	1998–99	1999–2000	2000–01	2001–02
Hardware	18	26	73	40
Software	10,148	15,169	28,393	36,006
Education	139	191	265	107

Source: *Dataquest* 2001a, 2002a.

There are three prerequisites for the potential suggested by these factors to realize itself. First, Indian software exports need to diversify in terms of sources and destinations. Of the 1,250 companies exporting software services in 1999–2000, those exporting more than Rs 1 bn (about $22.5 mn) stood at just 37. The top 25 exporters accounted for 61 per cent of export revenues. And the US market dominated in terms of destination accounting for 62 per cent of exports compared with Europe's 23.5 per cent (*The Economic Times* 2000). Second, Indian software service providers should be able to sustain the quality of services offered by inducting appropriately qualified and skilled personnel to not merely write codes but design systems. Third, Indian firms should be able to migrate up the value chain, so as to ensure a growing share of the market as well as enter into segments that offer higher value per employee.

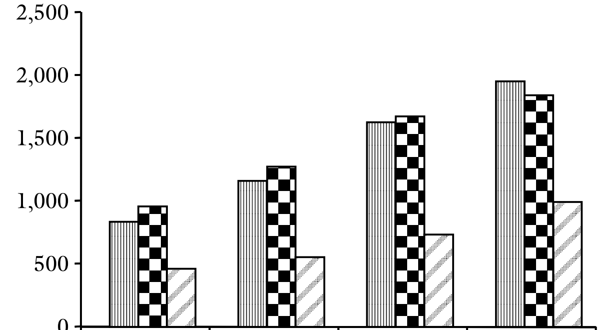
In all these areas, the availability of personnel is bound to be a constraint. The inadequacy of training services resulting from the proliferation of poorly staffed, profit-hungry teaching shops, and the limited base for training and skilled development in the domestic software services segment has already been noted. As a result even as an outsourcer India still remains a lower-end software supplier and a supplier of IT-enabled services. As Figures 1.15 and 1.16 show, unlike in the domestic market, generation of customized software or codes for systems specified by clients dominates both the domestic and the export software services market. As has been repeatedly emphasized, this often involves some body-shopping in the form of temporary export of software professionals to undertake specific jobs in large projects designed and executed in the West and enclave-type offshore supply.

What is noteworthy is that even the big exporters obtained little by way of revenues from frontline software products or higher end consultancy and software generation services. To quote a senior executive from the Indian software sector:

> India, somewhere down the line, has to make up its mind whether it would be a quality software developer or concentrate on quantity…. If you look at the typical structure of the IT services provided to any of the global companies—on the bottom layer is outsourcing, above it software development, on top of that is technology development and higher up is networking services and, finally, IT consulting. As you move up, you get higher billing rates, higher revenues, higher gross margins and, thereby, high profitability because the complexity of the transaction is higher.

According to industry insiders like Narayana Murthy of Infosys, this move up the value chain has hardly occurred and is not India's priority. In an interview, Murthy said that Indian software expertise in customized services has a long way to go in quantity and quality before

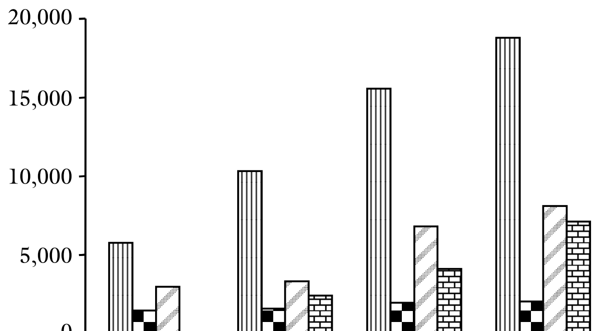
FIGURE 1.15 Structure of Software Services: Domestic



	1998–99	1999–2000	2000–01	2001–02
Customized software	825	1,145	1,603	1,924
Turnkey projects	944	1,255	1,650	1,815
Consulting/others	456	547	725	979

Source: *Dataquest* 2001a, 2002a.

FIGURE 1.16 Structure of Software Services: Export



	1998–99	1999–2000	2000–01	2001–02
Customized software	5,751	10,301	15,547	18,789
Turnkey projects	1,447	1,563	1,943	2,023
Consulting/others	2,951	3,305	6,802	8,094
ITES		2,400	4,100	7,100

Source: *Dataquest* 2001a, 2002a.

focusing entirely on other fields. 'Yes, moving up the value chain is a good idea. We are at it ourselves—about Rs 20 crores (200 mn), which is just 8 per cent of our total business and not the main', he said (Mohan 1998: 7). He said that India's share of the service industry—'customised software provision'—was only $2 bn, while the market is a staggering $25 bn. India needs that kind of money, while there is no stopping it from reaching out to higher levels of technology. There are others, like Vinay Deshpande of NCore, who feel that while software services should not be sneered at, the contract should be properly designed.

> If the job is just another cover for body shopping, then there is little technology that accrues to the contractor.... Except a few, such contracts mainly mean deputing engineers from here. The parent company does not get any fresh infusion of technology in this case. I strongly believe that even in service industries, contracts should be such that there is technological upgradation (quoted in Mohan 1998: 7).

He feels technology thus acquired could then be leveraged to develop indigenous products, for in the long run, the money is in developing products.

Further, it is clear that a growing share of this export revenue is little more than the sale of cheap skilled and not-so-skilled IT-enabled labour services whose output is transmitted via modern communication technologies to sites where those services are required. According to NASSCOM, its annual survey on the performance of the Indian software and services exports industry has estimated that IT softwares and services exports grew by 26.3 per cent in 2002–03 to garner revenues of Rs 461 bn (US$ 9.5 bn). IT services, products and technology services have grown by 18.3 per cent to reach Rs 348 bn ($7.2 bn) while the ITES–BPO segment registered a growth of 59 per cent to reach Rs 113 bn (US $2.3 bn).[8] This takes the share of ITES in total software and service exports to 25 per cent. That is, a large part of software exports is not very different from the exports of nursing, carpentry, masonry and other such services, except for the fact that unlike those exports, the presence of the service provider at the point of sale is not required in the case of IT-enabled services. The possibility of such service delivery has helped India circumvent the obstacle to service exports created by immigration laws in developed countries.

Thus, conceptually, India's software thrust of the last decade is not as spectacular as it appears. It substantially involves the export of lower-end software and IT-enabled services facilitated by the availability of cheap skilled labour. And it is in large part a technology-aided extension of the earlier waves of migration by service providers of different descriptions: doctors, nurses and blue-collar workers of various kinds. An expansion of that kind cannot be self-sustaining. Even in quantitative terms, the development is not spectacular. The 'net foreign exchange revenue' to the country from migration of the old kind, captured by the volume of remittances into India, is in the range of $10–12 bn. The gross foreign exchange revenue from software exports, even after the boom, is placed at $8 bn.

Barriers to Entry in Software

The difficulty is that the move up the value chain may not be a matter of pure choice, but might be structurally limited. While there have been instances of Indian companies delivering high-end products—like the banking and e-commerce software product, BankAway, from Infosys—the industry generally accepts that much of the export from India consists of low-end outsourcing and IT-enabled services. This limited success in terms of the composition of exports may be because there indeed are barriers to entry into higher-end software, resulting from the fact of increasing returns in the form of sharply reducing costs as volumes increase, helping to create and strengthen oligopolistic positions.

What could be the source of barriers to entry in the software sector? Consider, for example, the packaged software segment, mass-producing branded products for large national and international markets. Knowledge products like software packages have the public good characteristic of non-rivalry in consumption, since making the product available to one user does not preclude its availability without much additional cost to another. This essentially implies that so long as the producer and seller of that knowledge can ensure that sale of the product to one does not lead to the replication of that package for free use by another, there are substantial increasing returns in the software sector. Producing the first unit of a software product requires large investments in its generation, whereas producing an additional unit is almost costless. The larger the sales, therefore, the lower is the average cost and the higher the return.

But that is not all. When large sales imply a large share of the market as well, scale becomes a means of ensuring consumer loyalty and strengthening oligopolistic positions. This is the result of 'network externalities' stemming from three sources. First, consumers get accustomed to the user interface of the product concerned and are loath to shift to an alternative product which involves some 'learning' before the features of the product can be exploited in full. Second, the larger the number of users of a particular product, the greater is the compatibility of each user's files with the software available to others, and greater the degree to which files can be shared. The importance of this in an increasingly networked environment is obvious. Finally, all successful products have a large number of third party software generators developing supporting software tools or 'plug-ins', since the applications programme interface of the original software in question also becomes a kind of industry standard, increasing the versatility of the product in question without much additional cost to the supplier. These 'network externalities' help suppliers of a successful software package to 'lock-in' consumers as well as third party developers and vendors, leading to substantial barriers to entry.

Appropriating the Benefits of New Technology

Take the case of software products for mass use, for example. Creating such a product starts with identifying a felt need (say, for a browser once the internet was opened up to the less computer savvy, or for a web publishing programme once the internet went commercial). The persons/firms identifying such a need must work out a strategy of generating the product by hiring software engineers at the lowest cost in the shortest possible time. Once out, the effort must be to make the product a proprietary industry standard. This involves winning a large share of target consumers, so that the product becomes the industry standard in its area. Once done, the product becomes a revenue generating profit centre. The investment required is the sum involved in setting up the company, in investing in software generation during the gestation period, and in marketing the product once it is out so as to quickly win it a large share of the market. Needless to say, while entry by individuals or small players are not restricted by technology, they could be limited by the lack of seed capital. This is where the venture capitalists enter, betting sums on start-ups which if successful could give them revenues and capital gains that imply enormous returns.

There are, however, three problems here. The first is one of maintaining a monopoly on the idea during the stage when the idea is being translated into a product. The second is that of ensuring that once the product is in the public domain competitors who can win a share of the market before the originator of the idea consolidates her/his position do not replicate it. It is here that a feature of 'entrepreneurial technologies'—the easy acquisition and widespread prevalence of the knowledge base needed to generate new products—considered an advantage for small new entrants actually proves a disadvantage. Third, no software product is complete, but has to evolve continuously over time to offer more features, to exploit the benefits of increasing computing power and to keep pace with developments in operating systems and related products. Thus, large and financially strong competitors, even if they lag in terms of introducing a product 'replica', can in time lead in terms of product development and erode the pioneer's competitive advantage.

There are two aspects of technology that are crucial in this regard: its source, and the appropriability of the benefits of a technology. As mentioned earlier, in industries with routinized technologies the source of technology was in significant part the activity of incumbent firms themselves. On the other hand, in the case of entrepreneurial technologies the sources were in the public domain. This was where the advantage lay for the small operator. But once a technology is generated based on some expenditure in the form of sunk costs, there must be some way in which the innovator can recoup these costs and earn a profit as incentive to undertake the innovation. In the Schumpeterian world this occurred because of the 'pioneer profits' that the innovator obtained. The lead time required to replicate a technology itself provides the original innovator with a monopoly for a period of time that generates the surplus required for innovation.

Most often this alone is not enough to warrant innovation and in the software sector lead times can be extremely low, especially if the competitor invests huge sums in software generation, reducing the lead time substantially. It is for this reason that researchers have defended and invoked the benefits of patents, copyright and barriers to entry in production, which allow innovators to stave off competition during the period when sunk costs are being recouped. Unfortunately, neither is the status of patents and copyrights in the software area clear (as illustrated by the failure of Apple to win proprietary rights over icons in user interfaces), nor are there barriers to entry into software production.

This has had two implications. First, the importance of secrecy in the software business: the 'idea' behind the product must be kept secret right through the development stage, if competitors are not to begin rival product developments even before the original product is in the market. A feeble attempt to institutionally guarantee such secrecy is the now infamous 'non-disclosure agreements' which prospective employees, financiers and suppliers are called upon to sign by the innovator who is forced to partially or fully reveal her/his idea. Second, even after the product is out, since the threat of replication remains, it is necessary to strive to sustain the monopoly that being a pioneer generates. This is where the possibility of locking in users with the help of an appropriate user interface—to which they become accustomed and are reticent to migrate away from—and locking in producers of supportive software with an appropriate 'applications programming interface' becomes relevant. It should be obvious that sustaining monopoly to recoup sunk costs can indeed be difficult.

Such strategies did help the early start-ups, resulting in the jeans-to-riches stories (Microsoft, Netscape, etc.) which abound in Silicon Valley. But more recently, it has become clear that start-ups undertake innovative activities only to create winning products that the big fish acquire. This is because of the possibility of easy replication and development of an original product, which can be done by dominant firms with deep pockets that allow them to stay in place and spend massively to win dominant market shares. In the event, the likelihood that a small start-up would be able to recoup sunk costs, clear debts and make a reasonable profit is indeed low. Selling out ensures that such sums can indeed be garnered. And selling out is often a better option than investing further sums in developing a product faced with a competitive threat, in keeping with industry and market needs.

Given this feature of the software products market, it is not surprising that small players (such as Netscape with its Navigator and

Vermeer technologies that delivered FrontPage) are mere transient presences in key areas even in the developed countries. To expect developing country producers to fare better is to expect far too much. The latter can merely be software suppliers or outsourcers for the dominant players. This implies that given the current trends in the industry, even on the software front the promise of ICT contributing to a redressal of national, let alone international, inequalities in technology and income is unlikely to be realized. The digital world seems to adding to and even worsening the existing divide.

Impact on Growth and International Inequality

It is against this background that we should assess the implications of the new opportunities promised by the diffusion of information and communication technologies in the hardware, software and IT-enabled services sectors. It would be useful to recall the nature of these opportunities. To start with, they offer a whole new range of income-generating sources of employment for labour surplus economies where there are definite signs of a decline in the employment elasticities of output in the conventional commodity producing sectors such as agriculture and manufacturing. In fact, in these sectors, the available evidence seems to suggest that trade liberalization in the form of removal of quota restrictions and reductions in tariffs, necessitated in part by WTO norms, are resulting in the displacement of workers from traditional activities rather than creating opportunities in newer activities. Further, the promised expansion in exports as a result of the restructuring of commodity production by liberalization has not been realized despite 10 years of reform in India. In the circumstances, the fact that the new sectors offer a combination of employment opportunities and export revenues from hardware, software and IT-enabled services renders them leaders in the effort to make globalization the appropriate means to enhance growth in output and employment as well as to reduce balance-of-payments vulnerability.

As mentioned earlier, in the past, the special characteristics of the IT sector, which substantially reduce technological and financial barriers to entry by small players, were seen as underlying the success of small Silicon Valley start-ups. Those start-ups not only challenged traditional giants like IBM, but have also grown to become major players in their own right and changed the structure of the industry.

The growth of the IT industry in India and elsewhere in the developing world and India's success as a software exporter seem to suggest that these characteristics hold for firms in developing countries as well. Not surprisingly, it is now being argued that what was true for the Silicon Valley start-ups in terms of their ability to break through barriers to entry should be true for the developing countries. It is this perception that underlies the optimism that information technology heralds a new era of reduced international inequality.

However, our argument would lead us to suggest that the rapid rates of growth of turnover in the industry should be treated with caution. Gross revenues are obviously misleading in the domestic industry segment characterized by substantial dependence on imported capital goods, components and software, especially in the hardware and packaged software sectors. With hardware and packaged software accounting for a significant share of domestic IT, their high import intensity would substantially reduce the domestic multiplier effects of such spending.

There are a number of reasons to expect import intensity to be high. The domestic industry does not generate much packaged software, so that a substantial part of spending on this account would amount to leakage from the domestic economy. According to *Dataquest*, Indian companies launched 92 software products and updates in the domestic market in 2000–01. However, MNCs launched 152 and dominated the market in most segments. Microsoft's Office suite for example, occupied over 80 per cent of the market. Even in the case of hardware, import intensity tends to be high, especially in the case of servers, workstations, networking hardware and peripherals. Finally, in the case of single-user systems, two developments are likely to have increased import intensity over time: Liberalization of component imports and reductions in import tariffs would have encouraged all producers to increase the share of components outsourced from abroad. Second, import liberalization and the relaxation of regulations on foreign firms have increased the share of major international players in the domestic PC market.

However, it is not only in the domestic segment that there is a case for caution, if not scepticism, when assessing the larger international and national consequences of IT growth. Our discussion of the dominant export segment also suggests that there are not only difficulties in ensuring the appropriate 'diffusion' through growth of this kind, but also that the sustainability of such growth is not altogether certain.

IT Growth and the State

These features of IT growth not only suggest that the high expectations from the IT sector were in part misplaced but that private responses to market incentives do not ensure the requisite changes in terms of technological development and brand building in the hardware sector, the spread and appropriate diversification of software export activity, the adequate generation of software skills and the much-needed migration up the software export value chain. This points to the need for some intervention by the state not merely to facilitate such changes but to enforce compliance along these lines on the part of the private sector. Unfortunately, the prevailing perception is that ICT-based industries are best left to private initiatives and responses to market signals. Any attempt at regulation has been interpreted as an effort to throttle the dynamism of private sector-led growth. Accepting that perspective, the Indian government has increasingly withdrawn from the regulation of this sector and has even offered substantial fiscal incentives and tax concessions, especially to the exporters of software and IT-enabled services. Besides implementing and proposing to implement a zero-duty regime on a range of IT products, the government has exempted software service and IT-enabled service export profits from the payment of income tax.

On the other hand, in its role as facilitator, the government has taken on a range of responsibilities including that of ensuring the expansion of educational services so as increase the supply of IT professionals and investing in and creating conditions for the rapid expansion of the IT infrastructure, especially the availability of high speed links and international gateways with sufficient bandwidth.

This policy slant has had three consequences: (*a*) it has meant that the government has not been able to ensure adequate technology absorption and development in the hardware sector; (*b*) the government has not been able to intervene to ensure the migration up the value chain of India's software industry; and (*c*) the government has not been able to mobilize adequate revenues from what is a rapidly growing sector, even though it is required to undertake expenditures and investment to facilitate the growth of the sector, especially its export segment, as well as widen access to ICT. This is crucial given the fact that ICT is not all benign. As one analyst puts it, there is

> ... a clear risk that, without policy intervention, ICT will intensify social divisions rather than close them. The unregulated market is likely to develop ICT to address the needs of the better educated, wealthier, and more technology literate individuals, communities and countries, since these are the people who want and will be prepared to pay for the development of new and more sophisticated products and services (McNair 2000: 9–10).

Case for Caution

With the government failing to guide the sector in the appropriate direction, the persistence of current growth trends in the industry depends on India continuing to exploit the possibilities of arbitrage generated by differences in custom software and IT-enabled service costs between onsite sources and offshore centres. There is, however, some uncertainty as to whether India can do so. That possibility is threatened not merely by the emergence of alternative offshore centres in countries like the Philippines and Israel, but also by a reduction in the onsite–offshore cost differential. There are two tendencies driving that reduction in differential. First, an inadequate pace of generation of additional appropriately skilled software professionals, for reasons delineated earlier.

Second, the 'suction effect' exerted by software centres in the developed metropolitan countries. Learning from the success of Indian software engineers in Silicon Valley and elsewhere in the US, the United States government itself and governments in other developed countries like Germany, France and Japan are selectively relaxing their immigration laws and rules and quotas regarding the provision of work permits, to facilitate the flow of the best Indian software engineers to their countries. The attraction of better salaries, lifestyles and work conditions in these environments ensures the rest. This has had some adverse consequences for India. To start with, it has raised the salaries paid out to top-end software professionals to close to international levels, reducing the cost advantage India had in this area.

Second, it has created an acute shortage of highly qualified, top-end experienced and skilled professionals in the Indian market for software engineers. The prognosis with regard to India's migration to the higher end of the software supply chain based on its knowledge advantage is, therefore, not altogether positive. That movement is possibly as structurally constrained as the effort to increase sophisticated manufactured exports from the developing to the developed world was. It is for such reasons that optimistic projections of the kind emanating from the McKinsey/NASSCOM stable should be taken with a pinch of salt.

Implications for Policy

In brief, the earlier analysis of constraints to the realization of the potential of ICT leads us to conclude the following:

- Despite its rapid growth, the information technology sector in India is small and the effect of its growth on the rest of the economy is limited.
- There are signs that barriers to entry outside the realm of production in both the hardware and software segments are substantial. This has adverse implications for sustaining the growth of both output and employment in this sector, unless the disproportionality in growth between the domestic and export segments is addressed and firms strive to strengthen domestic hardware production and move up the value chain in software. This requires the state to play a more proactive role in influencing the pattern of growth of this sector, rather than leave matters to the market which drives firms to the lower end of the value chain, where entry is easier and profits quick to come by.
- Despite the rapid growth and high profitability of leading firms in the software and IT-enabled services sector, the notion that this is a sector whose growth is best left to the market has resulted in fiscal concessions of a kind that substantially reduce the revenues garnered by the state. This substantially erodes the latter's ability to sustain even its role as facilitator (which involves large investments in the communications infrastructure), let alone providing funds to expand its role in the area. The industry must contribute

out of its large profits a part of the revenues to meet the much-needed expenditures by the state in this area.

- The state's role is all the more crucial when we examine the prospect of a sharply widening digital divide within the economy. Even beginning to provide access to the new technology to the overwhelming majority who cannot access it for technological reasons would impose a large financial burden. But the more difficult task is to prepare the disconnected to develop the competence to participate, however marginally, in the emerging digital economy. This alters priorities completely. With literacy and schooling achievements still at indefensibly low levels, the first task of the government would be to rapidly advance the pathetic reach of literacy and school education in the country. In terms of priority this should be placed above the target of providing a minimum degree of ICT access to those who are completely disconnected. However, the nature of the challenge of overcoming backwardness is such that a degree of syncopation is inevitable, necessitating large resources which in part must come from the surpluses being garnered by the rapidly growing and highly profitable IT services sector. Thus, the growing dilution of the state's role in the growth in the IT sector could result in the persistence and widening of the 'digital divide' between India and the developed industrial countries, especially the US, and within India itself. This strengthens the argument that the buoyant and highly profitable private sector has to be treated on par with the 'brick and mortar' economy and taxed to generate resources for such expenditures.
- This need to push for greater expenditure by the state is in the interests of the industry as well for two reasons. To start with, a widening digital divide can only widen social divisions and tensions. To quote McNair (2000: 10):

> Easy access to ICT enables people to become richer and therefore more able to afford still newer technology; it is moreover the already educated who—disproportionately—take up lifelong learning activities and who, in general, get better services. In short, the educated *information rich* become richer and the less educated *information poor* become poorer.

No democratic society can tolerate growing divisions of this kind, making state intervention an effective policy option for the industry as well. As the infrastructure and the capacity to participate in the transformation being wrought by ICT expands, it simultaneously expands not only the market for the domestic industry but also allows it to use the large domestic market as the base to generate the skills and develop the capability to move up the value chain in both hardware and software production. Thus, a greater interventionist role for the state rather than an emphasis on the free play of private initiative, with the state as mere facilitator, is what is required to even begin to meet the challenge that the IT revolution sets for a developing country like India.

Notes

1. This refers to the observation made by Gordon Moore as early as 1965 that newer chips that entered commercial production every 18–24 months incorporated twice the number of transistors as their predecessor.
2. This includes exports of IT-enabled services (ITES) in the values for 2000–01 and 2001–02.
3. In India, for example, the Centre for Development of Telecommunications (C-DOT) designed, developed and patented a switching system more suited to environments characterized by low telephone densities and low call densities than is the case with switching systems imported from abroad. Much of the hardware needed for these rural automatic exchanges was sourced from other domestic producers or imported from abroad.
4. Medical transcription meets at low cost the need set by the medicare system in the US for detailed patient treatment records. Doctors dictate the relevant entries and the spoken word is digitized and transmitted to locations in India, where they are immediately transcribed into word-processed files that, given the time difference between the two countries, are available to the doctor concerned the very next morning for correction and finalization.
5. The McKinsey–NASSCOM report lists 10 processes as attractive opportunities—telesales/telemarketing, web sales and marketing, database marketing/customer analysis, benefits administration, payroll services, engineering and design, inbound call centre, claims processing, billing services and credit/debit card services.
6. According to *Dataquest*, the ITES market in India is restricted to call centres. Even if some activity has taken place in other areas such as medical transcription, engineering and design or other web services, this is seen as too little to make a significant impact on the overall market or growth (*Dataquest* 2002b).
7. http://www4.gartner.com/5_about/press_releases/2002_09/pr20020909a.jsp, accessed July 2003.
8. www.nasscom.org/artdisplay.asp?Art_id=1836, accessed on 5 July 2003.

References

Abramovitz, Moses and Paul A. David. 1999. 'American Macroeconomic Growth in the Era of Knowledge-Based Progress: The Long-Run Perspective', *Discussion Paper Series*, Stanford Institute for Economic Policy Research, Stanford University, December.

Brunner, Hans-Peter. 1995. *Closing the Technology Gap: Technological Change in India's Computer Industry*. New Delhi: Sage Publications.

Brynjolfsson, Erik and Brian Kahin (eds). 2002. *Understanding the Digital Economy: Data, Tools and Research*. Cambridge, MA: MIT Press.

Dataquest. 2001a. 'A Mixed Bag of Tricks', 19 (13): 49–64.

———. 2001b. 'Multinationals in India: Domestic Champions', 31 July.

———. 2002a. 'The Year of Survival', 20 (13): 31–44.

———. 2002b. 'IT-enabled Services: Indian IT's Lone Crusader', 15 July: 131–38.

———. 2002c. 'The Giants: Survival of the Fittest', 30 July.

David, Paul. 2000. 'Understanding Digital Technology's Evolution and the Path of Measured Productivity Growth: Present and Future in the Mirror of the Past', in Erik Brynjolfsson and Brian Kahin (ed.), *Understanding the Digital Economy*: *Data, Tools and Research*. Cambridge, MA: MIT Press.

Franda, Marcus. 2002. *China and India Online: Information, Technology Politics and Diplomacy in the World's Two Largest Nations*. Oxford: Rowman & Littlefield Publishers.

Gordon, Robert J. 1999. 'Has the "New Economy" Rendered the Productivity Slowdown Obsolete?', available at http://faculty-web.at.northwestern.edu/economics/gordon/researchhome.html.

Joseph, K.J. 2002. 'Growth ICT and Harnessing IT for Development' (background paper prepared for the OECD-IPS Workshop on *Promoting Knowledge-based Economies in Asia*), 21–22 November, Singapore, mimeo.

MCIT (Ministry of Communications and Information Technology). 2003. 'Teledensity Reaches Five as on 31st March 2003', press release dated 23 May, http://pib.nic.in/archive/lreleng/lyr2003/rmay2003/23052003/r23052003.html, accessed on 24 May 2003.

McNair, Stephen. 2000. 'The Emerging Policy Agenda', in *Schooling for Tomorrow: Learning to Bridge the Digital Divide*. Paris: OECD.

Mohan, R. 1998. 'Products vs Services: The Argument Continues', *Business Line*, 17 December.

OECD. 2000. *OECD Information Technology Outlook 2000: ICTs, E-Commerce and the Information Economy*. Paris: OECD.

Solow, Robert M. 1987. 'We'd Better Watch Out,' *New York Review of Books*, 12 July.

The Economic Times. 2000. 'Software Sales on Hard Drive', 4 July.

Websites

www.dotindia.com
www4.gartner.com
www.itu.int
www.nasscom.org
www.nic.in

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Indian Software Industry Development: National and International Perspectives*

Nagesh Kumar

Introduction

The rise of the IT software and services industry (henceforth, software industry) over the 1990s represents one of the most spectacular achievements for the Indian economy. The industry has grown at an incredible rate of 50 per cent per annum over the past few years, is highly export oriented, has established India as an exporter of knowledge-intensive services in the world, and has brought in a number of other spillover benefits such as creating employment and a new pool of entrepreneurship. The evolution of India as an exporter of these knowledge-intensive services has also created much interest in the development community worldwide. Encouraged by the Indian success, a number of other developing countries are trying to emulate her in entering the industry. There are also questions on the sustainability of high growth rates of Indian exports in view of emerging competition, growing scarcities of personpower in the country, eroding cost advantage and the recent technology slowdown in the US and other markets of Indian software.

This paper attempts to analyse Indian software industry development in this context. First, the capability and strengths of the software industry are evaluated taking an international perspective to surmise the relative strength of the Indian achievement. Then the achievement of the industry is evaluated vis-à-vis national development agendas. Next, the paper examines challenges to the sustainability of software exports in the coming years and briefly overviews the steps taken by the government and the industry to respond to them. Finally, the paper concludes with a recapitulation of the main findings and a few remarks for policy.

Indian Software Industry Development in a Global Perspective

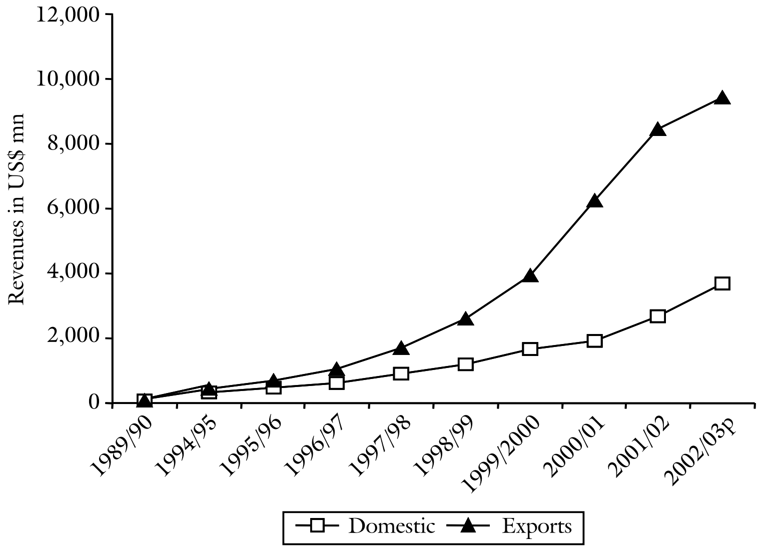
The Indian software industry has grown at a phenomenal compound annual rate of more than 50 per cent through the 1990s, from a modest revenue of US$ 195 mn in 1989–90 to evolve into an over $ 13 bn industry by 2002–03. Furthermore, the industry has earned 72 per cent of its revenue (totalling $ 9.5 bn) from exports.

It is clear from Figure 2.1 that the annual export growth rate has been higher than 50 per cent since 1995. However, the growth rates of exports started to fall in 2002–03 due to the slowdown in the US, and the growth rate of overall revenues and of exports have tended to converge over the past couple of years as a result of the growth rates of the domestic software market also picking up.

To put this growth performance in an international perspective, the Indian software industry accounts for roughly about 2 per cent of the US$ 400 bn global software industry. However, India's share in the global market for customized software that is outsourced across borders was significant at 18.5 per cent in 1999 compared to 11.9 per cent in 1991 (NASSCOM 2000a: 4). The growth rate of the Indian software industry has been substantially higher than the global software industry. Apparently, India is the only country in the world to register a growth rate of around 50 per cent in the software industry.

Based on a vision document prepared by McKinsey for the industry body, NASSCOM (NASSCOM–McKinsey 1999), the government-appointed National Taskforce on IT and Software Development

FIGURE 2.1 **Revenues and Exports of the Indian Software Industry**



Source: Adapted from Hanna (1994) and Heeks (1996).

(NTITSD) has projected the Indian software industry as growing to US $85 bn in revenue by 2008, of which $50 bn should be coming from exports, including $8 bn from export of software products. The recent slowdown of the technology sector in the US, which consumes the bulk of Indian exports, however, has tempered some of the assumptions that underpin these projections. The effects of slowdown in the US were felt by Indian companies in the year 2001–02 in terms of slower growth of revenues than they had become used to over the past few years.

Indicators of Capability

Although the magnitudes of exports of software and services from India have grown rapidly over the past decade, the general perception is that these exports comprise low-value services. That perception emanates from the fact that in the early years, the bulk of the software export activity of Indian enterprises consisted in lending their software professionals to their clients to deliver their services 'onsite'. It was considered to be a rather lower level of skill intensity compared to software product designing and development, and has been derisively termed as 'body-shopping' (Heeks 1996). However, the Indian software industry has since come of age in terms of capabilities, sophistication, range of expertise and worldwide reach. In what follows, we briefly review the performance of the industry in terms of certain indicators of growing capability.

Moving Away from Body-Shopping

As observed earlier, the bulk of the software export activity of Indian enterprises in the early period comprised body-shopping or onsite delivery. The advantage of Indian enterprises in the onsite work emanated largely from the lower salaries of Indian software professionals compared to those available in developed countries. However, Indian companies have progressively demonstrated their technological and project management skills by successfully completing turnkey projects for large companies. As a result, the proportion of onsite exports has begun to come down in India's software exports, from 90 per cent in 1988 to 56 per cent by 2000–01, as shown in Table 2.1. An increasing proportion of India's software is being developed 'offshore' at the home bases of exporters in India and exported. The 'offshore development', as it is called in the industry, has been partly facilitated by improved communication links in the software technology parks (STPs) set up by the government that allow teams of professionals at vendors' and clients' ends to be in constant touch on a real-time basis, and by the growing visa restrictions in the US and Europe. It also turns out to be cheaper for the clients. Besides, the 12-hour time lag between India and the US virtually doubles the working time per day and hence cuts the development lifecycle by half. The share of off-shore development declined slightly to 44 per cent in 2000–01, compared to 44.4 per cent in 1998–99. This rise in the share of onsite development has been attributed to rising focus on e-commerce-related jobs in recent years, which require a greater presence of software developers at the clients' sites.

TABLE 2.1 **Locational Division of Labour in Indian Software Development**

Location of Work	*1988*	*1995*	*1998–99*	*2000–01*
Onsite (at client's site abroad)	90	66	54.4	56
Offshore (at vendor's site in India)	10	33	44.4	44

Source: Adapted from *Dataquest* (various issues); Heeks (1996); NASSCOM (various issues).

Increasing Focus on High-Value Consulting and Packaged Software

So far, Indian software enterprises have generally focused on services that are considered to be low value adding. Having got themselves established as suppliers of these services, Indian companies are now making a conscious effort to increase exports of high-end consulting with the development of domain expertise and export of packaged software. Infosys, for instance, is focusing on the export of end-to-end services. As Indian software enterprises establish their credentials and competence, they consciously seek fair value for their work. This, however, may be applicable for leading companies such as Tata Consultancy Services (TCS), Infosys, Hindustan Computers Limited (HCL) Technologies, Wipro, Satyam Computer Services, that are providing higher-end programming solutions to their clients. Infosys has successfully renegotiated its person-hour charges with its clients, and reportedly commands $90 per hour.

Over the past few years, Indian companies have also managed to develop and launch a number of proprietary software products. A niche market has been created in banking, financial and accounting software. These include, for instance, I-Flex that has been used by over 240 financial institutions in 69 countries. Polaris has developed a proprietary retail banking software, Polaris Point, and is tying up with Bull, France, for its marketing in Europe. Banking solutions from Infosys (Financle, BankAway and PayAway) have been adopted by 22 domestic and 16 overseas banks across 12 countries. TCS has launched packaged software for banking insurance, securities, accounting and health-care industries. It is currently developing industry-specific software products for several manufacturing industries such as cement, steel, chemicals, petrochemicals and refineries in collaboration with industry firms. It has also launched its branded integrated suite of software tools—Mastercraft—which is claimed to have been well received in the US and Europe and carries a price tag of US $ 150,000. Wipro Technologies has recently launched two branded products, namely, Teleprodigy, a billing system for ISPs and Web-Secure, an internet security package. It is focusing on global brand building and plans to come up with a branded product every year. NIIT and Pentamedia are developing multimedia products on CD-ROMs in large numbers. A number of even smaller software companies have developed packaged software which are sold in domestic markets.

For example, Tally, a popular accounting package for small and medium enterprises which is being used by 50,000 companies and has been approved by accountants' professional bodies in India and the UK, has been developed by a smaller highly specialized software company (Kumar 2000b, on the basis of company sources and media reports). Despite these efforts, the share of products and packages in the Indian exports of software is still low at 7.9 per cent (NASSCOM 2000a). However, given the high entry barriers in the packages market, the entry of Indian companies in their exports is nevertheless significant. Furthermore, success in markets, such as those of software products, is a cumulative process. Once the image or brand value of India as a reliable supplier improves with growing exports of products and services, given the current trend, and as leading companies augment the requisite scale of operations, global reach and financial clout to sustain large marketing efforts, it would be easier for companies to make a serious impact in markets for products.

Broad and Expanding Supply Base

An interesting feature of the Indian software industry is the relatively large and growing number of companies participating in development and export activity. One indicator of the supply base is the membership of the industry body—namely, NASSCOM—that has grown from just 38 members in 1988 to 850 members in 2001. NASSCOM members are generally medium and large companies (those with 20 employees or more). There are numerous small and informal sector enterprises as well that have displayed considerable dynamism (see Kumar 2000a). As expected, larger firms do account for a disproportionate share of revenue and exports, with the top 25 companies accounting for 60 per cent share and the top five for 29 per cent share of exports in 2000–01(NASSCOM 2001). However, the vendor concentration is not as high as in many other industries.

Locally Anchored Capability

There is a qualitative difference between export success of a country dominated by national subsidiaries of MNEs and that of another based on indigenous enterprise in terms of local anchoring of capabilities. Indian export success is primarily driven by local enterprise, resources and talent. The role played by MNEs in software development in India is quite limited. Although all the major software companies have established development bases in India, their overall share in India's exports of software is rather small. MNEs do not figure among the top seven software companies in India, ranked either on the basis of overall sales or the exports. Among the top 20 software companies too, no more than six are MNE affiliates or joint ventures. Seventy-nine of the 572 member companies of NASSCOM are reported to be foreign subsidiaries. Some of these are actually subsidiaries of companies promoted by non-resident Indians (NRIs) in the US, such as Mastech, CBSI, IMR, Syntel, rather than being associated with US MNEs (Arora et al. 2000). Some others were Indian companies to begin with, but have subsequently been taken over by foreign companies, such as Hinditron, which has been taken over by TAIB Bank E.C., Bahrain, or IIS Infotech which has been taken over by the FI Group of the UK. Foreign subsidiaries include software development centres of software MNEs and also subsidiaries of other MNEs that develop software for their parents' applications. The latter include subsidiaries of financial services companies, such as Citicorp, Deutsche Bank, Churchill Insurance, Phoenix Life Mutual; telecommunication MNEs, such as Hughes, Motorola, among others. In addition, MNEs have set up 16 joint ventures with local enterprises, such as British Aerospace with Hindustan Aeronautics, Bell South with Telecommication Corporation of India (TCIL), British Telecom with the Mahindra Group, and so on. In all, 95 companies have controlling foreign participation.

Table 2.2 summarizes the shares of these 79 foreign subsidiaries in the total sales and exports of the software industry. It would appear that MNE subsidiaries have a higher degree of export orientation, with 94 per cent of their earnings coming from exports, compared to local companies. This is because they often exclusively cater to the demand of their parents. Collectively, however, they accounted for less than 19 per cent share of exports in 1998–99.

Another aspect of the role of FDI and MNE subsidiaries in development of the Indian software industry is apparent from the pattern of their entry. Table 2.3 shows that the bulk of the entries took place after 1994, by which time India's potential as a base for software development was already established, and not the other way round.

TABLE 2.2 **Share of Foreign Subsidiaries in the Indian Software Industry**

Share of 79 Foreign Subsidiaries in	*1997–98*	*1998–99*
Total Revenue	12.27	13.7
Total Exports	16.77	18.66

Source: Kumar 2000b.

TABLE 2.3 **Time Profile of Entry of MNEs in the Indian Software Industry**

Period	*Entries of MNEs as Subsidiaries or Joint Ventures*
Up to 1987	11
1988–90	14
1991–93	15
1994–96	39
1997–99	16

Source: Kumar 2000b.

Increasing International Orientation of Indian Companies

Indian software exporting companies themselves are sufficiently global in their outlook. As many as 212 Indian software companies have set up 509 overseas offices or subsidiaries; 266 of these 509 offices had been set up in North America, 122 in Europe, 59 in Asia, excluding India, 25 in Australia–New Zealand, 25 in Africa and 12 in Latin America (NASSCOM 2000a). A few leading companies have established extensive networks of offices and subsidiaries all over the world to tap opportunities in different markets similar to the operations of a multinational corporation. These firms include TCS, HCL Technologies, Infosys Technologies and NIIT. Four Indian companies have got themselves listed on American stock exchanges and more are planning such moves.

International Quality Accreditations and Process Maturity Levels

International orientation and the increasing professionalism of Indian software enterprises have prompted them to align their processes with global best practices and to obtain international certifications. For instance, 250 Indian companies had obtained the International Standards Organization 9000 (ISO 9000) certification by March 2001

(NASSCOM 2001). Furthermore, as many as 38 Indian companies have received SEI-CMM (Software Engineering Institute, USA's Capability Maturity Model) Certification at Level 3 or above. India's lead in high maturity levels is quite clear with 29 of 31 non-US companies which have been certified at high maturity levels, namely, Levels 4 and 5, in terms of SEI-CMM being Indian. Of the 31 companies certified at Level 5 worldwide, 16 that are outside the US are in India (Table 2.4). Level 5 represents the optimizing level of process maturity and is the highest stage to be reached. Outside the US, Australia and Israel have one organization each qualifying for Level 4. This shows that Indian software enterprises, especially the leading ones, have strived to attain excellence in their professionalism and best practices.

TABLE 2.4 High Maturity Organizations

Level	*Number of Organizations Certified Worldwide, May 2000*	*Of which non-US*	*Of which in India*
Level 4	45	15	13
Level 5	31	16	16
Total High Maturity	76	31	29

Source: Kumar 200b, based on SEI 2000.

Geographical Reach

Indian software services are exported worldwide. However, the bulk (62 per cent) is concentrated in North America, mainly the US, which is also the largest market for software. Europe accounts for 23.5 per cent of India's exports, and the Asia-Pacific for a further 10 per cent (Table 2.5). Language also contributes to a high concentration in the US.

TABLE 2.5 Geographical Distribution of Indian Software Exports (1999–2000)

Region	*Share of India's Exports*	*Share of Global Software Market*
North America	62.0	45.1
Europe	24.0	27.6
Japan	4.0	16.9
South East Asia	3.5	2.8
Australia & NZ	1.5	2.1
West Asia	1.5	1.8
Rest of the world	3.5	3.7

Source: Kumar 2000b, on the basis of NASSCOM (2000b, 2001) and OECD (1997).

Range of Domain Expertise and Applications

Indian companies have developed expertise in a wide range of domains and industries. Banking, insurance and finance have emerged as areas in which they have developed particular expertise and have even launched packaged software (Table 2.6). They are also able to undertake a variety of tasks, as listed in Table 2.7.

TABLE 2.6 Major Domain Specializations of Indian Software Companies

Domains/Sector	*Number of Companies Offering Expertise*
Banking, Insurance, Stock Exchange, Financial Accounting	247
Manufacturing, Retail, Trading & Distribution	331
Transport/Airlines/Railways/Ports	157
Web Applications/Online Information Services	295
Engineering, Electronics, Design Automation/Robotics	224
Medical & Health	163
Education, Training/Entertainment	115
Telecommunications	174

Source: Kumar 2000b.

An evidence of the growing ability and expertise of Indian software companies was provided by their ability to manage the transition from Y2K-related projects successfully. In 1998–99, 16.5 per cent of the export earnings of Indian companies were derived from Y2K-related projects. Over 1996–99, Indian companies are reported to have earned $2.5 billion from Y2K projects (NASSCOM 2000a). Hence, it was widely expected that the loss of these projects with the turn of the century would lead to a decline in the growth rates of exports. However, it is quite clear by now that the Y2K transition has been managed successfully. The industry had, in fact, clocked a 51 per cent rise in exports in 1999–2000 and a 57 per cent rise in the following year. This transition has been managed because of the ability of companies to quickly diversify into internet and e-commerce-related technologies and applications that are now booming. Evidently, web-based revenue increased its proportion from 4.8 per cent to 15.6 per cent over 1998–99 to 1999–2000. In fact, Y2K projects provided Indian companies with an opportunity to know new potential clients and display their competence. According to surveys conducted by the Carnegie Mellon University (CMU), the expertise levels of Indian companies on UNIX and Windows NT platforms is considered to be at par with US firms. Indian companies have also grown in their ability to handle larger and more complex projects than in the past (Arora et al. 2000). Now 300–500 person-year projects are not a rarity any more.

TABLE 2.7 Major Areas of Specialization of Indian Software Companies

Areas	*Companies Offering Expertise*
Web Technologies/Intranet/Internet/e-Commerce	319
Euro Currency Solutions	132
Software Product Development	286
Software Maintenance and Migration	233
RDBMS/Data Warehousing/Data Mining	215
ERP/MRP Solutions	200
GIS/Imaging	55
System Integration/Networking	192
Business Process Consultancy/Reengineering	168

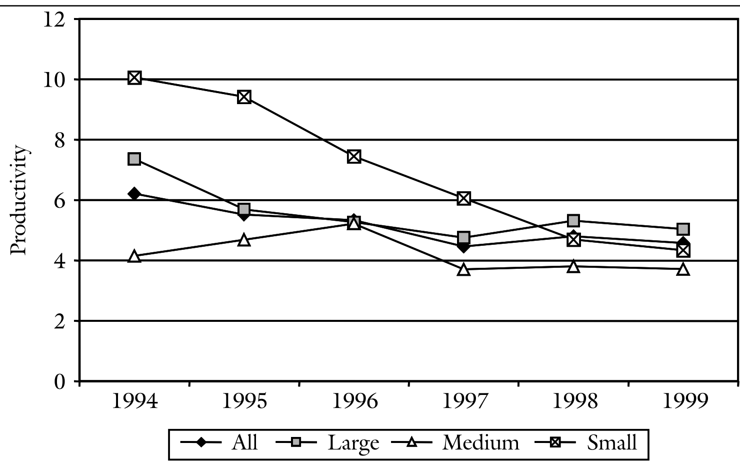
Source: Kumar 200b.

Moving up the Value Chain? Recent Trends in Enterprise Performance

An important issue concerning the technological upgrading, international competitiveness and the ability to move up the value chain of Indian software enterprises is whether they are able to constantly improve their productivity, reduce the unit cost of production and improve profit margins. An attempt has been made to examine the performance of Indian software enterprises in terms of these indicators with the help of an exclusive panel dataset covering a sample of 66 Indian software companies with a fair representation of small, medium and large companies for the period 1994–99 (see Kumar 2000b for details). The patterns emerging from this analysis are summarized here.

Labour Productivity Productivity performance in the software industry has to be judged with respect to the key resource in the industry, that is, human resources. Labour productivity has been measured in terms of revenue per unit of wage bill to take care of possible differences in the quality of personpower and to capture the overall efficiency in use of labour, keeping in mind the rapidly rising salaries of the workforce. Figure 2.2 summarizes the patterns with respect to productivity measured in terms of revenue per unit of wage bill. The productivity measured this way declines over the period 1994–97 for the full sample, as well as for different groups of firms. Since 1997, however, the Indian software industry has been able to improve the productivity even after taking care of rising wage costs. It would appear that since 1997, the Indian industry has made an effort to improve efficiency in the use of its key resource, that is, personpower. This effort might have been prompted by the rising costs and growing scarcity of trained personpower. Between the groups, smaller firms had the highest ratio of revenue per unit of wage bill in 1994, probably owing to lower rates of employee compensation. However, the tight labour market conditions that have prevailed in the subsequent years due to increasing competition for knowledge workers have led to a converging trend in productivity levels of larger and smaller firms. The productivity of medium-scale firms had roughly converged to the levels of larger firms in 1996, nevertheless declining later. Thus, larger firms have the best levels of efficiency in utilization of human resources in the industry.

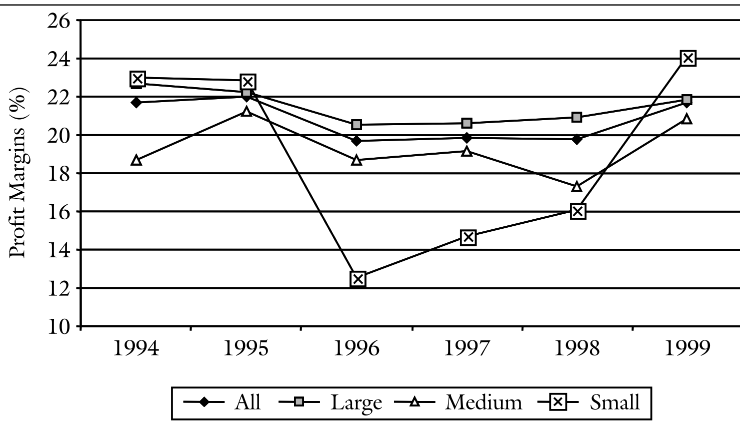
FIGURE 2.2 **Trends in Labour Productivity**



Source: Kumar 2000b.

Profit Margins Besides indicating overall efficiency, profit margins of firms competing on the basis of costs are generally under pressure because of rising competition. On the other hand, firms moving up the value chain may be able to improve their margins. Figure 2.3 summarizes the trends pertaining to profit margins for the sample firms. Here, profit margins have been measured in terms of proportion of profit before tax in revenues. Like productivity indicators, profit margins also showed a shift in 1996. The margins revealed a declining trend in the period 1994–96, and a rising trend since 1996. It may have something to do with the effort of the industry towards improving the efficiency in resource use and rising export-orientation after 1996. Between the groups, smaller firms reveal lower margins during the period. However, they have improved their margins sharply since 1996. In fact, in 1999, profit margins of smaller firms have exceeded those of the other two groups. It is to be seen whether this performance will be sustained in the future. Medium-sized firms also have somewhat lower margins. However, the margins of these firms have tended to converge with those of larger firms.

FIGURE 2.3 **Trends in Profit Margins**



Source: Kumar 2000b.

The overall conclusion emerging from the analysis of enterprise performance suggests that 1996 (that is, the financial year 1995–96) was a year of transition for the industry. A number of indicators showed changing trends from this year. This includes rise in export orientation, rising net exports, rise in profit margins and decline in unit cost of production. These trends got reflected in terms of improved productivity since 1997. Small-scale firms are quite different from medium- and large-sized firms with a greater focus on domestic markets. However, they are fast catching up with the larger ones. Finally, the analysis also indicates the presence of economies of scale in utilization of foreign exchange and human resources. Hence, some consolidation of the industry may lead to improvement of overall competitiveness.

Development Implications of India's Participation in International Division of Labour in Software

India's participation in the global division of labour in software services industry has created much interest worldwide. What does it imply for the parameters of economic development of the country? An overview of the implications of the software industry development for different macro parameters is presented in this section. In addition, the development of export-oriented software industry also has important externalities that constitute its indirect impact on India's development, as will be seen here.

Direct Developmental Impact

National Income and Growth Rates The software industry still accounts for a rather marginal share of India's GNP, but it has been rising fast. In 1998–99, the industry accounted for just 1 per cent of India's GNP. Its share nearly doubled by 2000–01 (Table 2.8). Even with marginal shares in income, the sector contributed nearly 12 per cent of the growth of national income. Given the rate at which it is growing, it is bound to emerge as an important sector of the Indian economy in future. The NASSCOM–McKinsey Report (1999) projects a 7.7 per cent share of the sector in the overall economy by 2008.

Exports and Foreign Exchange Generation The share of software exports to India's exports of goods and services has risen from a negligible 4.4 per cent in 1998–99 to nearly 8 per cent in 2000–01, as is clear from Table 2.8. The NASSCOM–McKinsey Report and National Taskforce on Information Technology and Software Development

(NTITSD) project that by 2008, software and services exports would account for 35 per cent of India's exports.

TABLE 2.8 Software Industry in Relation to India's Macro Parameters (in billion US$)

	1998–99	*1999–2000*	*2000–01*
India's GDP	379.70	404.70	427.00
Indian Software Industry Revenues	3.90	5.70	8.30
Share of Software Industry in the GNP (%)	1.03	1.41	1.94
India's Exports of Goods & Services	60.07	67.85	79.76
Exports of Software Services	2.65	4.00	6.30
Share of Software in Exports (%)	4.41	5.89	7.89

Source: Adapted from NASSCOM (2001).

The magnitude of exports would be a poor guide, however, of the amount of actual foreign exchange earned by the country in view of the expenditure of foreign exchange by software companies in the process of implementing the contracts for their clients, which often involves sending their personnel at clients' sites. Net export earnings are usually much smaller than the overall export magnitudes that are publicized. Therefore, net exports of foreign exchange expenditure would be the more appropriate indicator of the generation of domestic value addition or net foreign exchange. The movement in proportion of foreign exchange utilization per unit of exports over time could also indicate some trends in terms of efficiency in foreign exchange conservation or in domestic value addition. The figures of foreign exchange utilization by the industry are not provided by NASSCOM or the government. However, data compiled for a representative sample of 58 companies for the 1994–99 period to examine the trends summarized in Table 2.9 show that foreign exchange utilization per unit of exports by the sample industry firms is quite substantial compared to some manufacturing industries. Hence, the total exports figure gives a highly exaggerated picture of the industry's contribution to foreign exchange earnings. However, the foreign exchange utilization of the industry has declined in a steady manner since 1996, from 62 per cent in 1996 to 48 per cent in 1999. This suggests that the proportion of net exports in total exports has gone up since 1996 from 38 per cent of total exports to 52 per cent of total exports. It is a healthy sign and suggests that the proportion of domestic value added has gone up in Indian software export activity. To some extent, it reflects the increasing importance of off-shore development, and hence savings of foreign exchange on travel, etc.

TABLE 2.9 **Net Exports of Sample Software Companies**

	1994	*1995*	*1996*	*1997*	*1988*	*1999*
Foreign Exchange Utilization per Unit of Export	57.41	56.39	61.66	54.65	51.11	48.01
Net Exports per Unit of Export	42.59	43.61	38.34	45.35	48.89	51.99

Source: Kumar 2000b.

Employment and Job Potential According to NASSCOM surveys, the software industry employed some 340,000 professionals on 31 March 2000, including software professionals working in software user organizations compared to 160,000 professionals in 1996. Therefore, the industry generates about 60,000–70,000 more jobs every year and may have created so far no more than half a million jobs, including ancillary jobs such as those of data entry operators, despite so much rhetoric about its expansion and job potential. The compound annual growth of employment at 28.5 per cent recorded over the past three years, though impressive from the standards of growth of jobs in the national economy, is only half of the growth of the revenues in the industry. However, the potential of the industry to sustain its growth momentum does suggest its potential to emerge as a source of significant employment in the Indian industry in times to come. The NTITSD has projected that the software industry will employ 2.2 million workers by 2008. Half of these jobs, that is, 1.1 million, will be created by an expansion of IT-enabled services in the country by the year 2008 compared to 23,000 in 1998–99. Of these, nearly 560,000 jobs are expected to be in back office operations and in content development.

Other characteristics of the jobs created by the software industry can be seen from Table 2.10. The industry is creating job opportunities for highly qualified (the majority with an engineering degree) young graduates with relatively short experience. The salary levels here are among the best across industries within the country and have been growing at a healthy rate of 16–21 per cent. In addition, companies have begun to offer stock options to their employees to retain employees. Despite this, the attrition rate is quite high, although it has shown a decline over the past few years. The industry loses quite a substantial proportion of its brightest professionals every year as they migrate to better paid jobs in other countries.

TABLE 2.10 Key Characteristics of Employment in the Software Industry

Parameters	*1996*	*1999*	*2000*
Software Professionals (Including Those in Non-commercial Organizations and User Organizations)	160,000	280,000	340,000
Software Professionals in Software Development (%)	70	67	63
Marketing and Relationship Development (%)	10	11	14
Median Age (yrs)	28.4	26.2	25.7
Proportion of IT Degree Holders (%)	75	NA	NA
Proportion of those having 5 yrs of Experience (%)	60	50	60
Rise in Basic Salary over Previous Year (%)	21	21+ESO*	16+ESO*
Attrition Rate (%)	17.2	16	14

Note: *Supplemented by Employee Stock Options; 41 companies have offered ESOs to their employees.
Source: Kumar 2000b, based on respective NASSCOM surveys.

Besides the organized segment of the software industry, employment opportunities are fast expanding in the smaller or the so-called informal or micro-enterprise segment in software and services. In a recent study, I (see Kumar 2000a) found smaller enterprises in software customization, data entry and internet bureau to be growing in terms of numbers and size at a very fast pace. As a result, employment in these enterprises is expected to grow between 50 and 100 per cent per year. Although the salaries in these enterprises are relatively low to begin with, the sector provides opportunities for fast vertical mobility of personnel. While the larger and more organized enterprises are driven largely by external demand, the informal establishments cater to rising demand of domestic industry, especially the SMEs, for their official automation and customization needs. The sector also provides opportunities for self-employment to trained personnel who work as data entry operators at the lower end of the skill spectrum, to web page designers, and to software consultants at the upper end.

Quality of Jobs Created—The Gender Dimension: The jobs created in the software industry are generally physically less demanding than those in other manufacturing and are white-collar ones. Hence, they are also well suited to women. NASSCOM surveys reveal that although the share of women in software professionals was low at 19 per cent at the turn of the century, it had increased steadily from just 10 per cent in 1993 (NASSCOM 2000a). In the IT-enabled services segment, women account for 37 per cent of jobs, and their participation has been projected to rise to 35 per cent by 2005. Earlier studies on the industry had reported an even higher domination of the industry by men with a share of women ranging between 5–10 per cent (see Heeks 1996; Mitter and Pearson 1992). The domination of the workforce by men, however, does not seem to be due to a gender bias. Even the early surveys, such as those conducted by Jayanthi and Madhavan in the mid-1980s (cited in Heeks 1996) and another by Mitter in 1990 (cited in Mitter and Pearson 1992), do not report any overt discrimination against women in the industry. Both these studies have reported that the industry offered a more relaxed and less discriminatory atmosphere than most other occupations and that women stand a better chance of reaching a position of seniority in this industry than others. Among the reasons cited in those surveys for women's observed under-achievements, are a lack of international mobility due to family commitments, social sanctions against night work, preventing companies from hiring them for round-the-clock contracts, and some international clients' reluctance to hire women consultants, especially in the Middle East. The declining dependence of the industry on onsite contracts may help it to remove some biases against women.

Furthermore, the IT-enabled services that are projected to expand in the coming years will also create more job avenues for women and will increase their share in employment. The call centres and back office services, especially data entry operations for instance, are predominantly staffed by women worldwide. Quite a large part of these services can be delivered from home. For instance, a home-based worker answers a call from her home or enters data that are transmitted electronically to the client. These types of 'teleworking' opportunities, as they have begun to be called, are particularly well suited for self-employed women workers who wish to stay at home for family reasons or because of young children (see Hoon et al. 1999 for details).

The bulk of the jobs created in the sector by 2008 according to the projections of the McKinsey Report and the NTITSD, will be in IT-enabled services, such as back office operations, medical transcriptions, call centres, etc., in a significant manner. Given a rather low skill content of these jobs, they will be of footloose nature and may move to other destinations as and when a cheaper competing location is available, as it happened in the case of other low skill export-oriented manufacturing, such as garments. Hence, the move from export-oriented manufacture to export-oriented services may not alter the basic pattern of the international division of labour for developing countries (Mitter and Efendioglu 1999). Finally, these activities, having a rather low skill content provide limited scope for knowledge spillovers in the host country.

Externalities or Indirect Effects on Development

The rise of the software industry in the country since the mid-1990s has also generated a number of important externalities, many of which are of a favourable kind. These include development of entrepreneurship and reversal of brain drain. Some are less desirable ones, such as lack of linkages with the domestic economy and a possible neglect of the domestic software sector in the process of pushing exports, and perpetuating urbanization and concentration.

Expanding the Base of Domestic Entrepreneurship The rise of the software industry has provided opportunities for expanding the local base of entrepreneurship. The initial start-up costs in the sector are rather low and economies of scale are not particularly significant, especially for service enterprises. Hence, the entry barriers are low. This has helped a number of technical professionals to start on their own. Many of the leading software enterprises of today have been started by first generation entrepreneurs. Infosys, Satyam, Mastek, Silverline, Polaris, among numerous others, for instance, were started by software professionals and engineers with small savings and loans at very modest scales to begin with. At a smaller level too, the boom has provided opportunities for the development of entrepreneurship among relatively less qualified professionals as well. A study of smaller or informal sector enterprises in the software and services industry in India corroborated the rewarding opportunities for entrepreneurship with little initial set-up costs. The rates at which even these smaller enterprises have been growing means that they do not stay small for very long (Kumar 2000a).

Software Industry Development and Brain Drain: Counteracting Influences Brain drain has been a major problem facing the country with respect to highly trained personpower. According to a study conducted by the Institute of Applied Manpower Research (IAMR 1999), 58.5 per cent of graduates in computer science from IIT, Madras during the period 1964–86 migrated abroad. Thus, India has been losing highly valuable IT human resources, created at considerable cost to the country, on a regular basis to the western world. The rise of the software industry in India is associated with two counteracting trends with respect to the extent of brain drain. The first is positive in that the emerging opportunities in the industry have helped to stem the outflow of personpower from India to some extent. The other is the possiblity of losing more talent to the outside world in the near future, given the rising shortages of IT-trained personpower in the western world.

Reversal of Brain Drain: The rapid rise of the software industry in the country has helped to reduce the extent of brain drain by creating rewarding employment opportunities within the country, a trend also supported by the availability of venture capital to implement new ideas. According to a partial database maintained by the IIT Delhi Alumni Association (IITDAA), the rate of brain drain declined from 21 per cent during the 1990–92 period to 18 per cent during 1997–99 (Sachdev 2000). Besides the rewarding job opportunities coming up within the country in the software industry, a number of graduates of IITs are assisted by the on-campus incubation centres in implementing their ideas and in getting them funded by venture capital funds.

The rise of the software industry has also prompted a number of non-resident Indians to return to the country to start software ventures. According to some estimates, the rate of returning of professionals increased from 2 per cent in 1991 to 8 to 10 per cent in the late 1990s, with several senior software professionals returning to India to set up their own companies here. Apparently in Hyderabad alone about 100 companies have been set up by returning software professionals (*Express India* 2000). Furthermore, the export orientation of the Indian software industry benefited from the presence of a substantial number of non-resident Indian engineers working in US MNEs. Lateef (1997) and Arora et al. (2000) observe that some of them have played an important, though yet to be documented, role in facilitating the contacts between buyers in the US and the potential suppliers in India. Nonresident Indians in the software industry in the US have also invested back home in subsidiaries that develop software for their US operations. These include investments in subsidiaries of Mastech, CBS Inc., IMR, among others.

Fresh Spurt In Brain Drain?: The software export industry has also contributed to brain drain in the course of executing projects on-site or through 'body-shopping'. A number of software personnel who went to other countries for assignments of their employers have stayed on. For instance, 10,000 of the total 100,000 software professionals in Australia are Indians, who stayed on after completing their assignments for Tata Consultancy Services (TCS) there (Lateef 1997). Although the proportion of onsite work is now decreasing, the rapid growth of the software industry worldwide has created fresh possibilities of a further and potentially sizeable wave of brain drain. The recent emergence of India as a centre of software development has focused attention on the country as a potential source of trained personpower for IT industries to meet the growing shortages in other countries. According to the International Data Corporation (IDC), half of all IT jobs in the US now go 'begging'. In Western Europe, the shortfall of IT workers rose from 6 per cent in 1998 to 14 per cent in 2000. Subsequently, it was expected to rise to 23 per cent (IDC 2000). As a result, a large number of countries have been planning to import software engineers from India. These include Germany's offer of 20,000 green cards for software workers; Japan seeking 10,000 IT workers from India between 2002 and 2005; apart from projections like 32,000 by 2005 to Ireland; 10,000 to France; 8,000 to Italy; and another 10,000 to Korea (Kumar 2000b, based on media reports). There are other countries like Belgium, Syria, Iran, Singapore and Spain, which have also shown interest in importing Indian talent, although precise figures are not indicated. The British government has recently enacted a special fast-track work permit system to allow IT workforce into the country to meet an estimated demand for about 150,000 professionals. This system will reduce the time needed to issue a work permit for IT professionals from six to eight weeks to only two weeks. In the US too, the gap between demand and supply of IT personpower has been increasing and this shortfall has been bridged with imports from India among other countries (ESA 2000). Due to growing pressure from the industry, the administration has recently raised the annual cap on H1B visas from 115,000 to 195,000.

This trend raises the prospect of a further rise in the rates of brain drain of software personpower from India. It is not clear how many of Indian personnel will leave the country to take advantage of these opportunities. There are some media reports that in response to an offer of 20,000 green card visas by Germany to IT workers, it has already received 10,000 applications, including 2,000 from Indians. However, an outflow will certainly add to the growing scarcity of software talent, thereby pushing up the salaries of software professionals in India. That in turn may have an adverse bearing on the external competitiveness of software exports from India. Thus, it has the potential of adversely affecting the domestic software industry and its export performance. Much will depend on the ability of the country to increase the supply of software personpower quickly. In the meanwhile, however, slowdown in the US has led to retrenchment of a large number of Indian knowledge workers who have returned home after being served with the 'pink slips'.

Creating a Brand Value for the Country in Knowledge-based Industries Despite the large pool of trained engineering personpower, India's image in the world has been that of a poor and underdeveloped economy having a comparative advantage only in low-skill and low-technology industries. As a result, the country has suffered from a disadvantage in exporting knowledge-intensive goods. The emergence of the country as a centre for outsourcing a highly knowledge-intensive service such as software is helping to change the public perception about India and is focusing attention on the potential of the country in knowledge-based industries. Perhaps, as a related development, a significant number of MNEs in other knowledge-based industries have set up global or regional R&D centres in India to benefit from the expertise available in the country much in the same way as software houses (see Kumar 1999 for illustrations).

Improving India's Bilateral Relations A recognition of India as the leading source of expertise and talent in the industry has also contributed to the improvement of bilateral relationships of India and the US and also other industrialized countries. President Clinton's visit to India in 2000 came after a nearly two decade gap of any US President's visit to the country at that level from the US. The agenda of his visit was heavily loaded in favour of IT-related issues. Several other top leaders from different parts of the world have visited the country in 2000, all of them seeking India's trained personpower and expertise in high-tech education. These include the Japanese Prime Minister, Mori and Singapore's Prime Minister, among others.

Facilitating Capital Inflows? Development of the software industry has led to an increased flow of capital to the country in three forms: foreign direct investment (FDI) by outside MNEs in their subsidiaries and joint ventures in India; foreign institutional investments (FIIs) in the stocks of software companies in India; and capital raised abroad by Indian software companies.

FDI Inflows and Distribution of Gains from MNE Entry: Despite the entry of all major IT MNEs into the country and the forming of subsidiaries and joint ventures for software development, the FDI inflow has not been substantial. The total subscribed capital of 79 foreign subsidiaries set up in the country by 1999 was about Rs 4.7 bn (or US$ 115 mn at the Rs 41 to a $ prevalent exchange rate). So the total inflow of FDI by MNE subsidiaries over the past one-and-a-half decades of development of industry was no more than $115 mn, not a considerable amount in comparison to the annual inflow of about $3 bn worth of FDI that India has received in the past few years.

Furthermore, the distribution of gains from the activity of MNE subsidiaries in the software industry between home and host countries seems to be grossly in favour of the former. Apparently, some of the MNE subsidiaries in software development are doing pioneering work for their parents. For instance, Oracle Software Development Center located in Bangalore has been solely responsible for designing the 'network computer' introduced by Oracle (Arora et al. 2000; *Dataquest* 1999). Many other design centres of MNEs in India are doing highly valuable development work for them. However, the Indian subsidiaries of these MNEs do not share the revenue streams generated by their developments worldwide. MNEs tend to invoice the exports of their subsidiaries to them at cost plus 10–15 per cent (Mehta 1996: 44). Therefore, the distribution of gains is grossly in favour of the home country of MNEs and against the host country, that is India, in this case.

FII Investments and ADRs: FII investments in IT stocks, including in some software companies in India, has been considerable. However, these investments have been highly unstable given the volatility of Indian stock markets in recent years. The rise of some Indian software companies has enabled them to get listed at the American stock exchanges and raise capital abroad. Infosys became the first Indian software company to get listed at Nasdaq on 11 March 1999 and to raise US$ 70.38 mn through the issue of American depository receipts (ADRs). Subsequently, Silverline Technologies raised $101 million at the New York Stock Exchange on 20 June 2000. The success of these two companies in raising capital abroad has prompted a number of others to plan US listings. These include HCL Technologies that is planning a US$ 500 issue of ADRs. The ADRs by Indian software companies may become a significant source of capital inflow to India. A US listing helps the company in many ways. These include their ability to offer ADR-linked stock options to their employees as a part of their strategy to retain talent, as is being pursued by both Infosys and Silverline, thereby making the option more attractive than the ESOPs of their competitors in the labour market. It helps them fund acquisitions abroad to widen their client base. It also helps them in their marketing and in creating a brand value.

In addition, the rise of the software industry has attracted the attention of foreign venture capital funds and angel investors to the country. According to NASSCOM, the investments made by venture capital funds in high-technology firms in India (and not just software ventures) in 1999–2000 amounted to US$ 370 mn, rising from just $20 mn in 1996–97. A considerable part of this investment, however, has gone into e-commerce start-ups and dotcom companies. The software industry may have received a relatively small part of this amount. This channel of investments may grow in future.

Opportunity Cost of Exports and Domestic Linkages The opportunity cost of software exports could be considerable. On the one hand, India's best talents and capabilities are employed for exporting software services, and software for domestic use is largely imported from abroad. Inadequate attention being paid to the domestic market by the industry has stunted the diffusion of ICTs. For instance, the availability of software in local languages could have facilitated a widespread diffusion of IT in the country. The lost opportunity of productivity improvement through the diffusion of IT in India could be substantial. On the other hand, the contribution of Indian software companies to productivity improvements in the US industry over the past five years that has resulted in an average rate of growth of over 5 per cent over the second half of the 1990s could be significant. To some extent, the prevailing fiscal incentive regime, that is, the availability of tax incentives for export profits, diverts attention towards exports by making them more rewarding activity compared to serving the domestic market. There is need for rethinking on the relevance of tax incentives to the software industry.

Most of the export-oriented software companies operate as 'export enclaves' with little linkages with the domestic economy, if at all. MNE subsidiaries in software development, in particular, derive almost all of their income from exports to their parents. Hence, hardly any vertical linkages are developed with the domestic software market or the rest of the economy. The enclave nature of operation generates very few knowledge spillovers for the domestic economy. The bulk of the work done is also of a highly customized nature, having little application elsewhere. Given the high salaries and perks of foreign travel, the movement of personnel from these companies to domestic firms too does not take place. The employees of export-oriented firms are generally lured by foreign companies. However, there is considerable movement of personnel from domestic market-oriented firms to export-oriented firms or foreign subsidiaries. A survey of the software industry in 1995 suggested that 45.6 per cent of the professionals were recruited by software firms from other companies (Rajeswari 1995). The domestic market also supports the exports of products that are first tried locally and are improved on the basis of feedback data generated before being exported (Heeks 1996). In terms of technological complexity and sophistication, some projects in the domestic market are more advanced and challenging than export projects (Arora et al. 2000).

The engineers employed by the software industry need not possess exceptional ability but are generally trained extensively by their employers in software development (Balasubramanyam and Balasubramanyam 1997). However, the rise of the software industry has suddenly caused a general scarcity of engineers in all disciplines and this has led to a sharp rise in their salaries. The engineering industry in the country is finding it difficult to recruit an adequate number of engineers for their requirement. The impact of rising salaries on the competitiveness and bottomlines of engineering and other industries that compete for engineering talent with the software industry is not yet clear. However, the situation has certainly been made more difficult.

Spatial Agglomeration and Regional Distribution Software industry development in different parts of the world is characterized by a strong tendency of clustering because of agglomeration economies. In India, the software industry developed initially in Mumbai. Subsequently, especially after the entry of Texas Instruments in the mid-1980s, Bangalore emerged as a centre of software industry development. Bangalore enjoyed several attractions for the industry. These included the availability of a pool of trained personpower given the existence of Indian Institute of Science, Indian Institute of Management, and many high-technology industrial complexes, such as Bharat Electronics, Hindustan Aeronautics, Bharat Heavy Electricals, among others. Besides, the mild climate also made it attractive. The development of infrastructure under the aegis of software technology parks (STPs) and subsequently, private IT parks, helped in the agglomeration of the industry in and around Bangalore (see Kumar 2001; Lateef 1997). Besides Bangalore and Mumbai, Delhi along with its suburbs, namely, NOIDA and Gurgaon, has emerged as the third most popular concentration of software units (Table 2.11). Hyderabad and Chennai have started to provide alternative locations in the south after the saturation of Bangalore in terms of available infrastructure and scarcity of space. The state government's promotional role has also contributed to the emergence of Hyderabad as the fourth most important centre of concentration of software companies. The five major cities together account for 80.5 per cent of the 600 top companies. But other cities such as Kolkata, Pune, Thiruvanantapuram, Ahmedabad and Bhubaneswar are coming up as increasingly popular locations. One important factor is the availability of high-speed data communication links and built-up space provided in the STPs.

The development of the software industry is therefore largely concentrated in select major urban centres and their suburbs. This pattern of concentration owes itself to the clustering tendencies of knowledge-based industries because of the high economies of agglomeration. In India, the availability of communication infrastructure and personpower and other facilities have also contributed to it. Since all these centres have already been well developed compared to other parts of the country, possible spillovers of software industry development for balanced regional development have not accrued. The concentration of the industry in particular cities has in fact added to the congestion. For instance, real estate prices have reportedly risen in cities like Chennai because of the growth of the software industry that accounted for 70 to 80 per cent of all industrial space taken up in the city between 1999–2000.

TABLE 2.11 **Patterns of Clustering of Top 600 Software Companies**

City	*Number of Company Headquarters*	*Percentage Share*
Mumbai	131	21.83
Bangalore	122	20.33
Delhi and suburbs	111	18.50
Hyderabad	64	10.67
Chennai	55	9.16
Kolkata	25	4.16
Pune	23	3.83
Thiruvananthapuram	14	2.33
Others	55	9.16

Source: Adapted from NASSCOM (2000a).

Challenges for Strengthening India's Position in the International Division of Labour

A number of favourable factors have helped in the rise of the Indian software industry so far. These include the availability of a large pool of talented English-speaking personpower at low wages, past investments by the government in national innovation systems and building capability in the computing and networking technologies (see Kumar 2001 for a detailed analysis), availability of infrastructure and communication links, favourable policy regimes, networks of expatriate Indian technical and managerial personnel working in Silicon Valley who facilitated contacts with Indian companies, coupled with the growing scarcity of trained personpower in the West. The Y2K bug also created a valuable opportunity for Indian software companies. It will be a challenge to sustain the growth rates achieved in the past in the medium term and to fulfil the NASSCOM–McKinsey–NTITSD targets of exports and domestic industry. The factors that challenge the growth of the Indian industry include rising wage costs, growing scarcities of talent, emerging competition, etc., are summarized later.

Growing Scarcity of Trained Personpower India's comparative advantage for software industry development is primarily based on the availability of quality trained personpower. Although India has traditionally had a surplus of highly qualified engineering and technological personpower, with the rapid growth of the IT industry over the past decade, demand is outstripping the supply. In particular, experienced personnel and project managers are becoming highly scarce (Arora et al. 2000). The situation is further aggravated by a growing drain of trained personpower from India to other countries. With the growing shortfall in IT-trained personpower, a large number of countries and companies from the western world are turning their sights towards India to bridge the gap. A number of large IT MNEs regularly recruit engineers and managerial personpower in India through advertisements in the national media and even through campus interviews for their worldwide requirements. Recently, a number of countries such as Germany, Japan, Korea, Switzerland, France, among others, have announced their intention to import trained IT personpower from India, as observed earlier. All these attempts increase the demand for personpower in India and will make it more difficult for the local industry to attract and retain talent. A major challenge for policy makers is to increase the supply of trained personpower quickly enough so as to satisfy the growing demand of domestic industry as well as that of other countries. Increasing competition for knowledge workers means that management of human resources is becoming a key to corporate success in the industry.

Eroding Labour Cost Advantage With the growing scarcity of trained personpower, the salaries in the software industry have been rising at the rate of over 20 per cent per annum. In addition, employers are offering other incentives, such as stock options, and are spending on making the working environment more attractive for their workers. Rising salaries have reduced the margin of advantage in wage cost that Indian software companies initially enjoyed. The cost comparison figures, as given in Table 2.12 suggest that Indian salaries of comparable personnel ranged between 20–42 per cent of US levels and between 38–53 per cent of Irish levels for different personnel in 1995. Arora et al. (2000) find that after factoring in the associated costs of Indian workers, the cost of Indian workers comes to only half of US levels. Hence, the strategy of competing on the basis of cost will

TABLE 2.12 **Labour Cost Comparison for IT Personnel in 1995 (US$ per annum)**

	Switzerland	*USA*	*Canada*	*UK*	*Ireland*	*Greece*	*India*
Project Leader	74,000	54,000	39,000	39,000	43,000	24,000	23,000
Business Analyst	74,000	38,000	36,000	37,000	36,000	28,000	21,000
Systems Analyst	74,000	48,000	32,000	34,000	36,000	15,000	14,000
Systems Designer	67,000	55,000	36,000	34,000	31,000	15,000	11,000
Development Programmer	56,000	41,000	29,000	29,000	21,000	13,000	8,000
Support Programmer	56,000	37,000	26,000	25,000	21,000	15,000	8,000
Network Analyst/Designer	67,000	49,000	32,000	31,000	26,000	15,000	14,000
Quality Assurance Specialist	71,000	50,000	28,000	33,000	29,000	15,000	14,000
Database Data Analyst	67,000	50,000	32,000	22,000	29,000	24,000	17,000
Metrics/Process Specialist	74,000	48,000	29,000	31,000	NA	15,000	17,000
Documentation/Training Staff	59,000	36,000	26,000	21,000	NA	15,000	8,000
Test Engineer	59,000	47,000	25,000	24,000	NA	13,000	8,000

Note: Figures are averages for 1995. 5–10 per cent per annum rise can be assumed, with rates being slightly higher in lower-income countries.
Source: Heeks 1996.

become increasingly difficult for Indian enterprises, especially with emerging competition from other low wage countries. Indian enterprises will have to deal with this by moving up the value chain as salaries rise and will have to increase the overall efficiency of utilization of human resources or increase productivity faster than the wage cost.

Emerging Competition from Other Countries So far, the Indian software industry faced little competition from other countries, if at all. This is because India enjoyed the first mover advantage in software outsourcing. A survey conducted by the Carnegie Mellon University found that 82 per cent of competititors of Indian software firms were located within India (see Table 2.13). The second largest source of competition was US-based firms that 'extensively recruit Indian software professionals' (Arora et al. 2000). Firms based in Singapore, Israel, Ireland, Philippines, Russia and East Europe were mentioned as competitors for a relatively small number of cases. However, in future, Indian software companies may face more competition in high-end jobs from firms based in Israel, Ireland, Singapore and East Europe, among others; and from those in the Philippines, China, Malaysia and other South Asian countries in low-end routinized jobs. Hence, it will be important to strengthen international competitiveness through various measures, such as productivity improvement, maintaining the quality of services, and establishment of long-term relationships with important clients, marketing and after-sales service, and moving up the value chain, if India is not to lose her status as a preferred destination for software outsourcing.

TABLE 2.13 **Location of Primary Competitors of Indian Software Firms**

Location of Competitors	*No. of Firms*	*Percentage*
India	75	82
USA	58	63
Israel	12	13
Ireland	12	13
Singapore	19	21
Philippines	6	7
Eastern Europe/Russia	10	11

Note: N=92. Firms were asked to list up to three countries.
Source: Arora et al. 2000.

Infrastructural Bottlenecks The rapid growth of the software industry is also dependent upon the infrastructural development keeping pace with it. These include adequate bandwidth for data transfer, built-up space for software development and other facilities. According to industry association, available bandwidth, in particular, is not adequate and is becoming a bottleneck. Hence, it needs to be augmented soon.

Low R&D Thrust The Indian software industry has so far undervalued the importance of R&D, compared to the knowledge intensity and its international orientation. NASSCOM (2000b) finds that R&D spending in the industry has increased from 2.5 per cent of total spending on R&D in 1997–98 to about 4 per cent during 2000–01. Although leading companies such as TCS, Infosys and Wipro do have R&D labs, the proportion of revenue devoted to these is rather low compared to software companies in the developed world. For instance, Adobe Systems, Novell, Lotus Development, Microsoft, all reportedly spend between 14 to 19 per cent of their revenue on R&D (OECD 1997). Given their huge revenues the scale of R&D conducted is much larger. Compared to this, even a leading and fast-growing Indian software company Infosys Technologies reports R&D expenditure to form only a 0.89 per cent of its turnover. Furthermore, a declining output of engineering doctorates in India from 629 in 1990–91 to 298 in 1996–97 (GOI 1999), is also a damaging trend as it has implications for the availability of research personnel for the industry. A bigger R&D thrust will be necessary for Indian software enterprises to upgrade their export profile to higher value-adding services and products and establish themselves as innovators and developers of new products and technologies, rather than just providers of coding and programming services. Such an evolution of Indian software enterprises is important if they are to realize the target of generating revenues equal to $8 bn from export of products.

In order to deal with these challenges, a number of steps have been taken by the government. In particular, a number of steps have been taken as a part of the IT Action Plan formulated by the NTITSD accepted by the government. Some of these steps include:

- Initiatives to ease the supply of engineering personnel: expanding the capacity of IITs, upgrading the existing institutions and setting up new IIITs (Indian Institutes of Information Technology).

- Augmenting infrastructure for software development: steps to augment the bandwidth, setting up of technology parks and more STPs.
- Expanding the domestic software market: increasing PC penetration, tax incentives for IT investments, trade liberalization in IT equipment and software, checking software piracy, e-governance.
- Facilitating the availability of venture capital.
- Facilitating internationalization of Indian enterprises: assistance in overseas acquisitions, and for building indigenous brands (see GOI 2000a, 2000b; NTITSD 2000, for more details).

The leading Indian enterprises are also adopting strategies to strengthen their place in the industry. These include knowledge management strategies to recruit, train and retain talent; moving up the value chain by focusing on high-value consulting and packaged software; building long-term relationships with clients; and geographical diversification to reduce vulnerability to slow down in the US market, among others (see Kumar 2000b).

Concluding Remarks

The emergence of a developing country like India as a significant supplier of software services in the world market has attracted a lot of attention in developmental literature. The growth of exports of software from India at an over 51 per cent compound annual rate over the past decade has led policy makers within the country to view it as an engine of growth, a source of employment and foreign exchange, among other favourable effects. Indian software enterprises have been able to grow fast and expand exports at phenomenal rates and now account for a significant share of the world market in outsourced software services. Although MNE entry in the mid-1980s helped to demonstrate the potential India had as a base of software outsourcing, Indian development is largely driven by indigenous entrepreneurship, talent and resources. A large number of firms that have entered the industry have grown in their capability, demonstrated their commitment to international best practices in process quality, expanded their geographical reach and have progressively widened the range of products and services offered and domains served. Initially starting off as suppliers of personpower to undertake jobs at clients' sites, software development progressively takes place at exporters' home bases in India. There is also a conscious move from low value-adding coding and programming to the export of high-end consulting and packaged software. This performance over the past few years has led the industry and the government to set ambitious targets for the future, such as an annual export earnings of US$ 50 bn by 2008. The realization of these targets, however, is a challenge given the rising scarcity of trained personpower, eroding labour cost advantage, emerging competition from other countries, infrastructural bottlenecks and low R&D thrust. Furthermore, the recent US slowdown has tempered the assumptions underlying the projections and projected growth rates of the industry have been revised downwards. Nevertheless, the software industry is likely to continue its growth at a rapid pace in the medium term even if this pace is slightly lower than that of the past few years.

From a national perspective, software accounts for a marginal (nearly 2 per cent) share of India's GNP, but has contributed to nearly 12 per cent of her GNP growth. Software also accounts for nearly 8 per cent of India's exports of goods and services. The net foreign exchange realization, however, is much smaller because of substantial foreign exchange expenditure on onsite delivery of these services. Although foreign exchange utilization per unit of exports has decreased since 1996, net exports realization is still less than 52 per cent of gross exports. The industry, despite all the euphoria, creates jobs for only 60–70,000 highly talented engineering graduates per annum. The IT-enabled services such as back office operations, call centres and medical transcriptions could create over 1 million jobs by 2008 according to projections. However, these jobs are of a footloose nature, given the low skill content and routinized nature. They will move away from India as wages rise and other cheaper locations emerge. The jobs created in the industry, however, are physically less demanding and hence have great potential for women in the workforce. The software industry has helped in expanding the domestic base for entrepreneurship and has helped in creating a brand equity for the country in knowledge-based industries. Its development helped in reversing the trend of brain drain in the 1990s by creating rewarding career opportunities for professional personpower in the country. However, the growing scarcity of IT-trained personpower in western countries has led them to turn their attention to India as a source of supply of trained personpower. This trend threatens to lead to a fresh rise in brain drain from India, and in the process, to adversely affect the competitiveness of Indian industry by aggravating their growing scarcity for talent. The entry of MNEs in the industry has not resulted in a substantial inflow of capital. Furthermore, the distribution of gains from the export activity of MNEs in the industry has been grossly in favour of the home country. The export enclave nature of the industry has generated few, if any, vertical inter-firm linkages with the rest of the domestic economy. There is also evidence that by absorbing the bulk of engineering graduates, the industry has affected other industries using engineers adversely, although the precise impact is not yet clear. The industry is clustered around six to seven cities which have well-developed infrastructure and communication facilities, and its impact in reducing regional disparities is negligible.

The main resource that has attracted the industry to the country is the pool of trained personpower generated through investments in human resource development over decades. Subsequently, the government facilitated the development of the industry by providing dedicated high-speed data communication links and built up infrastructure in software technology parks. Several initiatives are being taken by the government and the industry in response to the challenge the country is facing in further strengthening its place in the international division of labour. These include steps to increase the supply of trained personpower and other promotional facilities. The enterprises themselves have responded to emerging challenges by adopting strategies for acquiring, upgrading and retaining the talent. There is clear evidence that human resource management is becoming a key aspect of the enterprise strategy in the Indian software industry. Companies are also attempting to move up the value chain by moving towards offshore development, by focusing on domain expertise, high-end consulting and proprietary packages, and value pricing strategies. These strategies have been reflected in the trends in enterprise performance. There is evidence of improvement in the proportion of net exports in labour productivity and profit margins over the past couple of years.

Despite the strong performance of the Indian software industry over the past decade, there is no room for complacency in view of competition from emerging countries, especially China and the Philippines. While Indian software enterprises have a headstart in terms of reaching international benchmarks of process maturity, the competition will become more intensive in the short and medium term, especially in low value-adding services such as coding, custom software, IT-enabled services, etc. The Indian industry, therefore, needs to consolidate its strengths and take advantage of the headstart over potential competitors to quickly move up the value chain and establish themselves as leading sources of software products. However, entry into the product market is full of high entry barriers that make it difficult for new entrants. In this respect, the following measures may be fruitful.

Paying Attention to R&D and Product Development

The Indian software industry needs to strengthen its thrust on R&D activity, especially for product development. India's domestic market is sizeable enough to provide a testing ground for these products. Increased thrust on R&D activity is important for sustaining their long-term comparative advantage. In this context, the declining output of doctorates in engineering and technology in the country is a matter of concern. Increasing emphasis on R&D by industry, establishment of industry–university/IIT linkages may help to improve the career prospects of researchers in engineering/technology and draw more talented people into Ph.D. programmes.

Strategic Acquisition of Global Marketing Channels and Brands

The global marketing and after-sales service networks and globally recognized brands act as barriers to the entry of new firms. To overcome these problems, Indian companies could plan to acquire stakes in a few Silicon Valley–based software companies that have established niche markets for their products. Leveraged buyouts of much larger enterprises are now possible (as demonstrated by the recent takeover of Tetley by Tata Tea). Governmental financial institutions may assist Indian companies in such strategic acquisitions. These acquisitions could serve as vehicles for the entry of Indian software in the markets for shrink-wrapped software and give them a fuller control over the value chain.

Industrial Restructuring and Consolidation

The analysis of firm size in enterprise performance suggests the presence of economies of scale in utilization of foreign exchange and human resources. Hence, some consolidation of the industry may lead to improvement in overall competitiveness.

Reorienting Governmental Promotional Measures

The Government of India has played an important role in evolution of the industry by creating a pool of trained personpower and by taking several important initiatives in setting up institutional infrastructure in computing and networking research since the late 1960s (Kumar 2001). The government has also assisted the industry by way of providing infrastructural facilities in STPs, along with other facilities. In addition, software exporters receive an income tax holiday for profits from software exports. There is need to rethink the relevance of these tax incentives. In an industry, where India enjoys a natural comparative advantage (on account of low-cost personpower), where exports have been growing at a rate of more than 50 per cent per annum, and where profit margins are around 22 per cent of revenue (much higher than any industry in the country), there seems to be little relevance of these tax breaks on a sustained basis. Furthermore, given the opportunity cost of software development for the domestic markets, the bias created by tax breaks in favour of exports is not desirable. The revenue loss on account of these tax breaks is substantial. Our back-of-the-envelope calculations suggest that the loss of revenue to the exchequer on account of these tax incentives to the industry could be to the order of Rs 20 bn. A part of this amount leaks out to foreign countries in the form of tax benefits absorbed by foreign MNEs, which relocate software development activity in the country to take advantage of availability of low-cost trained personpower. Besides strengthening the physical infrastructure for the industry, this amount would be better spent on supporting higher education and research in software technology that would be of long-term strategic interest to the industry, assisting the industry in product development, building brands and international marketing networks, foreign acquisitions and other strategic support.

Note

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References

Arora, Ashish, V.S. Arunachalam, Jai Asundi and Ronald Fernandes. 2000. 'The Indian Software Services Industry'. Pittsburg: Carnegie Mellon University (mimeograph).

Balasubramanyam, Ahalya and V.N. Balasubramanyam. 1997. 'Singer, Services and Software', *World Development*, 25(11): 1857–61.

Dataquest. 1999. 'The DQ Top 20 Giants', XVII (13).

ESA(Economics and Statistics Administration). 2000. *Digital Economy 2000*. Washington, DC: US Department of Commerce, ESA.

Express India. 2000. 'IT Industry May Face Shortage of Manpower', www.expressindia.com/infotech/0030051.htm.

GOI (Government of India). 1999. *Research and Development Statistics 1996–97*. New Delhi: Department of Science & Technology, GOI.

———. 2000a. *Annual Report 1999–2000*. New Delhi: Ministry of Information Technology, GOI.

———. 2000b. *Action Taken Report of the National Task Force on Information Technology and Software Development*, IT Action Plain: Part I, New Delhi: Ministry of Information Technology, GOI.

Hanna, Nagy. 1994. *Exploring Information Technology for Development: A Case Study of India*, World Bank Discussion Paper No. 246, Washington, DC: The World Bank.

Heeks, R. 1996. *India's Software Industry: State Policy, Liberalization and Industrial Development*. New Delhi: Sage Publications.

Hoon, Cheah Siew, Cecilia Ng and Swasti Mitter. 1999. *Teleworking in Malaysia: A Primer*. Maastrict: United Nations University (UNU/INTECH).

IAMR (Institute of Applied Manpower Research). 1999. *Manpower Profile, India, Yearbook 1999*. New Delhi: IAMR.

IDC (International Data Corporation). 2000. 'The IT Skill Gap: Price and Source of Success', *IT Forecaster*, 851, 23 May.

Kumar, Nagesh. 1999. 'Multinational Enterprises, Overseas R&D Activity and Global Technological Order', RIS Occasional Paper No. 56. New Delhi: Research and Information System.

———. 2000a. 'New Technology Based Small Service Enterprises and Employment: The Case of Software and Related Services Industry in India' (paper presented at the *National Seminar on Strategic Approach to Job Creation*), February, organized by ILO-SAAT and Ministry of Labour, at Surajkund, Haryana.

———. 2000b. *Developing Countries in International Division of Labour in Software and Service Industries: Lessons from Indian Experience*, background paper for the *World Employment Report 2001*. Geneva: ILO.

Kumar, Nagesh. 2001. *National Innovation System and the Indian Software Industry Development*, background paper for the *World Industrial Development Report 2002*, Vienna: UNIDO.

Lateef, Asma. 1997. *Linking up with the Global Economy: A Case Study of the Bangalore Software Industry*, NIOP, DP/96/97. Geneva: International Institute for Labour Studies.

Mehta, Dewang. 1996. 'Of Faults and Fruition', *Dataquest*, 31 July: 43–46.

Mitter, Swasti and Umit Efendioglu. 1999. 'Is Asia the Destination for "Runaway", Information Processing Work? Implications for Trade and Employment', in Swasti Mitter and Maria-Ines Bastos (eds), *Europe and Developing Countries in the Globalised Information Economy*. London and New York: Routledge.

Mitter, Swasti and Ruth Pearson. 1992. 'Global Information Processing: The Emergence of Software Services and Data Entry Jobs in Selected Developing Countries', Working Papers, SAP 4.14/WP.51 (rev. 1). Geneva: ILO, Salaried Employees and Professional Workers' Branch.

NASSCOM (National Association of Software and Service Companies). 1999. *Indian I.T. Software and Services Directory*. New Delhi: NASSCOM.

———. 2000a. *The I.T. Software and Services Industry in India: Strategic Review 2000*. New Delhi: NASSCOM.

———. 2000b. *Indian Software Export Grows by 57% in 1999-2000: NASSCOM Report*, Mumbai, 3 July. New Delhi: NASSCOM.

———. 2001. *NASSCOM Survey 2001*, www.nasscom.org.

NASSCOM-McKinsey 1999. *The Indian I.T. Strategy Summit: Beyond Y2K: Building a Dominant Position for India in IT Software and Services.* New Delhi: McKinsey & Co. for NASSCOM.

NTITSD (National Taskforce on Information Technology and Software Development). 2000. *IT Action Plan* (in 3 vols). New Delhi: NTITSD, http://it-taskforce.nic.in/.

OECD. 1997. *IT Outlook 1997*. Paris: OECD.

Rajeswari, A.R. 1995. 'Employment Characteristics of Software Personnel: Issues and Analysis', in *Advanced Technology Assessment System: Information Technology for Development*, Issue 10, New York and Geneva.

Sachdev, Radhika. 2000. 'Holding on to our "Brains"', *Times of India,* 26 June.

Websites

www.expressindia.com
www.nasscom.org
www.nic.in

3

Moving Up or Lagging Behind? An Index of Technological Competence in India's ICT Sector

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Introduction: The Background

One of the oft-cited achievements of the Indian economy during the 1990s has been the emergence of the ICT sector which has shown remarkable vibrancy in terms of output and export growth.[1] If the available statistics is any indication, the ICT software and service export from India recorded an annual compound growth rate of the order of

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over 60 per cent in rupee terms (at current prices) and around 45 per cent in dollar terms during the decade. This is unprecedented not only in terms of the magnitude of the observed growth rate but also in terms of its stability. As a result, the share of software export in total export earning of the country increased from 1.9 per cent in 1994–95 to about 16 per cent in 2000–01 and its share in GDP increased from about 0.6 per cent to 2.9 per cent during the same period (NASSCOM 2002). More importantly, the Indian ICT sector has established credibility in the export market and a large number of Fortune companies outsource software from India. The achievement becomes all the more striking when considered against the fact that it has been achieved almost entirely by local firms.[2]

Analytically, the contribution of ICT to an economy could be viewed at two different but interrelated levels: on account of ICT growth and on account of ICT diffusion. The former refers to the contribution in output, employment, export earning, etc., on account of the production of ICT related goods and services which are confined to just one segment of the economy (Kraemer and Dedrick 2001) and the latter refers to ICT induced development through enhanced productivity, competitiveness, growth and human welfare on account of the diffusion of this technology to the different sectors of the economy and society. India's attempt has been mainly to profit from ICT growth, through a series of institutional innovations and export-oriented policy measures.[3] The implicit assumption is that market-oriented ICT growth strategy will also result in the diffusion of new technology and ICT induced development. Hence, the oft-claimed achievements with respect to India's ICT sector have not been in terms of harnessing the new technology for enhanced efficiency and productivity growth; instead, these have been in terms of export earning for the economy. Harnessing of ICT for development calls for development of capabilities at different levels. This includes, among others, the capability to develop local content by taking into account the development needs of different sectors and also the ability to make effective use of the same. Thus, it may be argued that the presence of a vibrant ICT sector capable of addressing issues in other sectors may be a factor that facilitates diffusion of information technology.

However, studies tend to suggest that remarkable export performance notwithstanding, the Indian ICT sector presents a very low profile in terms of its technological capability. To substantiate the argument, it has been shown that very few well-known software products or proprietary packages have been developed by Indian firms. Further, the comparative advantage of Indian ICT firms has been in onsite export of services and related customized software development (Arora and Asundi 1999). Moreover, the focus of Indian firms has mostly been the lowest end of the value chain and low-level design, coding and maintenance (see D'Costa 2002, Kattuman and Iyer 2001). As a result, the revenue per employee in the Indian ICT sector ($ 16,000 in 1999) was found to be only about one-tenth of that of Israel and one-fourth of even Ireland (Arora et al. 2001). Above all, the net export earning has been only of the order of 50 per cent of the gross export (Joseph and Harilal 2001). The available evidence also indicates that the prime factor behind the current comparative advantage is the relatively low labour cost in India (Kumar 2001).

Reflections on the technological competence of India's ICT sector, however, are based on certain indirect indicators and hence the need for a direct measure of technological competence. Given the fact that the conventional measures of innovation, developed mostly in the context of goods producing sectors, have their limits in capturing innovation and technological competence in a service sector like ICT, we have developed an Index of Claimed Technological Competence (ICTC) using firm-level information on the areas of specialization. The theoretical base of the index has been drawn from the literature on technological opportunity.

The rest of the paper is organized as follows: the first section highlights the difficulties involved in adopting conventional measures on innovation in the context of ICTs and drawing from the literature on technological opportunity, develops an analytical framework for the index. The second section presents the method of the index estimation followed by empirical results in section three and concluding observations in the last section.

Innovation in ICT Sector: Some Conceptual and Measurement Issues

Studies have highlighted the role of innovation in sustaining competitiveness and growth in the context of a dynamic and technology-intensive sector like ICT software and services. The process of innovation, in turn, involves *inter alia* the ability to develop new products and new processes, new markets and to bring about organizational improvements. However, innovations are often location specific and hence the process that governs the dynamics of innovation in a developing economy might be inherently different from that of developed countries. During the last three decades a large number of studies have examined in detail the process underlying innovation in developing countries (Amsden 1989; Bell et al. 1982; Cooper 1980; Dahlman 1984; Dahlman et al. 1987; Enos 1991; Fransman 1986; Katz 1984; Kumar and Siddharthan 1997; Lall 1983, 1987; and Stoneman 1995, to cite a few). Drawing from the experience of Southeast Asian and Latin American countries and of India, these studies have analysed the process of innovation in terms of the capability to adapt and modify the imported technology to local conditions which in turn leads to incremental innovations. The cumulative effect of these incremental innovations, in contrast to the discrete random jumps of Schumpeterian type, facilitated by the import and adapt strategy generally followed by the developing countries get manifested in the long run in terms of altogether new innovations.[4]

Thus, in a general sense, innovation in a developing economy is viewed as an outcome of the combined effect of both the transfer and generation of technologies. The technology transfer could be either from external or domestic sources. It could take either embodied (in capital goods) or disembodied form (technical drawings, source codes, etc.). It has been argued that the technology transferred from an industrialized country is often not suited to local conditions in a developing country and has to be adapted to the local environment. Moreover, it is generally understood that strategic technologies are R&D and IPR intensive. What is more, such state-of-the-art technologies are very often also not available from the international technology market. All these considerations necessitate domestic R&D effort, both for adapting imported technology to local conditions and developing altogether new technologies. Using this analytical framework a large number of studies have analyzed the technology import and in–house R&D behaviour of firms with a view to understanding the innovation process in developing countries like India (Basant 1997; Basant and Fikkert 1996; Deolalikar and Evenson 1989; Desai 1985; Evenson and Joseph 1997; Katrak 1985, 1989; Kumar 1987; Subrahmanian 1988, to list a few). There is also a large body of literature not only on the role of different actors (Mani 1992) but also on the determinants of technological efforts (Kumar 1987;

Lall 1983, 1987; Siddharthan 1988, 1992). Substantial progress has also been made not only in conceptualizing the innovation process but also in measuring it. Commonly used measures of innovation performance used in the literature include the R&D expenditure, R&D employment, number of patents, technology balance of payments, exports of high technology products (Mani 2001) and so on.[5]

It may be noted that most of the studies cited here have focused on sectors producing tangible goods. When it comes to sectors like ICT, which essentially produce intangible services, there arise two interrelated issues: first, the extent to which the existing framework of analysis developed essentially in the context of goods producing sectors is helpful in understanding the process of innovation in sectors like ICT engaged in the production of invisibles. Scholars have already underlined the importance of developing a new theory of innovation in the service sector in contrast to the goods producing sector (Barras 1986). Second, and more important for the current discussion, is whether the conventional measures of innovation capture the underlying process of innovation in ICT and other sectors producing invisibles. Here we shall focus mainly on the second question.[6]

On Measuring Technological Competence[7] in ICT

Essentially, the process of innovation involves the production of knowledge that in turn calls for research and development.[8] In the case of commodity producing sectors there is a fairly clear distinction between those engaged in the production of goods and those engaged in the production of knowledge (R&D). Moreover, the skill profile of those engaged in the production of goods is distinctly different from those engaged in the production of knowledge. While the former generally comprises highly skilled personpower and work in R&D laboratories, the latter work on the shop floor and their skill profile is at a lower level compared to that of their knowledge producing counterparts. This is, however, not to ignore the importance of knowledge and experience generated on the shop floor termed generally as 'informal R&D' (Deolalikar and Evenson 1990). Thus, in the goods producing sectors, where there is a divorce between the generation of knowledge and production of goods, innovation becomes amenable to measurement in terms of R&D expenditure, patents obtained, R&D employment or any other conventional measures. In the case of sectors producing services like ICT, on the other hand, the distinction between those engaged in the production of knowledge and saleable service is rather blurred. This is because a large part of knowledge generation takes place as part of routine production process itself. This is however not to say that knowledge generation cannot be separated from that of the production of final saleable services. It is a known fact that leading firms in ICT like Microsoft Silicon Graphics and AMD spend over 10 per cent of their sales turnover on R&D (Richter and Banerjee 2002). However, in sectors like ICT, to the extent that there is a greater extent of simultaneity in the production of final saleable service and knowledge, conventional measures of innovation like patents and R&D become less appropriate in measuring innovation.

The limits to the conventional measures of innovation in ICT are evident from a recent study on the innovative behaviour of ICT firms viewed in terms of technology import and in-house R&D (Parthasarathi and Joseph 2002). The study found that the number of foreign collaborations in the Indian software industry has increased from eight in 1991 to 262 in 1999. The study also found that unlike the experience in other industries, more than 90 per cent of the collaborations involved neither royalty nor lumpsum payment.[9] In the case of R&D it was found that in 2000–2001, out of a sample of 217 firms, only 17 reported any expenditure and their R&D intensity was found to be around 5 per cent. At the same time, in terms of the mode of software export, we find a definite shift away from onsite to offshore development. In the early 1990s, almost 80 per cent of India's software took the form of onsite development. But by 2001, the share of onsite development declined and that of offshore development increased to 49 per cent. Given the fact that firms engaged in offshore development are likely to be more innovative compared to those engaged in onsite development, the observed trend may be an indication of the increased opportunity for firms to be innovative. Thus, it appears to be difficult to reach definite conclusions regarding the innovative performance of firms, either from conventional measures or from the observed trend in the industry's export structure. If conventional measures are not appropriate enough to represent the innovation process, is there any way out?

There is a growing body of literature that highlights the role of technological opportunity in understanding the inter-industry variation in innovative performance (see Cohen 1995).[10] In the framework of standard neo-classical theory of production, technological opportunity can be regarded as the set of production possibilities for translating research inputs into new techniques of production that employ conventional inputs. Another approach considers technological opportunity in terms of the responsiveness of unit cost with respect to R&D spending and therefore as a shift parameter determining the location of the innovation possibility frontier (Dasgupta and Stiglitz 1980; Levin 1978; Spence 1984). Rosenberg (1974) articulated the mechanism by which growth in scientific knowledge encourages innovation. He showed that as scientific knowledge grows, the cost of successfully undertaking any given science-based innovation declines. Evenson and Kislev (1976) and Nelson (1982) suggested that strong science affects the cost of innovation by increasing the productivity of applied research. According to this perspective the contribution of science is that it provides a powerful heuristic guiding the search process associated with technological change. Cohen and Klepper (1992) offer a complimentary view in which a more vital underlying science and technology may also increase the number of technological objectives to be pursued instead of increasing the number of approaches of pursuing any given objective.

In his pioneering work, Scherer (1965) classified industries on the basis of scientific and technological fields with which each was most closely associated. His classification of industries into technology groups produced powerful insights for understanding the variation in patenting activity and R&D intensity. Another empirical study by Levin (1987) based on the survey of executives in 130 manufacturing industries has also shown that technological opportunities have a powerful influence on understanding innovative performance. While the importance of technological opportunity has been widely recognized in understanding innovation potential, there is hardly any consensus on how to make the concept of technological opportunity precise and empirically operational (Cohen 1995). At the empirical level the difficulty arises in precisely categorizing different industries according to their scientific bases and in measuring technological intensity.

Drawing insight from this literature it may be argued that in a knowledge-intensive service sector like ICT, where production of knowledge and final saleable service coincide, and the nature of activities that the firm undertakes itself provides sufficient indication of the potential for innovation as well as actual innovation. The ICT service sector comprises a number of services: These can be activities requiring very limited skill, scientific base and hence less innovation potential (opportunity) like data entry, to ASIC (Application Specific Integrated Circuit) design, where the scientific base as well as the skill requirement are higher as also the potential for innovation. To illustrate, a field like ASIC design with high scientific and skill base is likely to have higher number of technological issues to be pursued and also much more different ways of pursuing any given objective as compared to another area with low scientific and skill base leading to differing levels of innovative performance.

Based on firm-level information on areas of specialization of Indian software firms, we have developed an index of firms' technological competence. We found onsiderable inter-firm variation in areas of specialization. It was also observed that very often firms focus on more than one activity and these activities vary in terms of their scientific base and skill requirements. Before proceeding further, it may be noted that while a firm that specializes in an area where the opportunity for innovation is high—like ASIC design—has the potential to be innovative, it need not necessarily be innovative. This is because the development of any software involves following the stages of requirements analysis, high-level design, low-level design, coding, installation, testing and post-production support. It is generally considered that about 60–65 per cent of value addition takes place in the first few stages (Schware 1987) which call for highly skilled personpower. In the final stages, like coding, testing and post-production supports, the value addition as well as the skill requirement is lower. Thus, a firm with specialization in an area with high innovation potential (like ASIC design) but with a focus on the end stages of development of software, like coding, installation, testing and post-production support, may have only limited potential for innovation.

Index of Claimed Technological Competence (ICTC): Method of Measurement

The index that we have prepared here is not based on firms' actual sales or export in different areas of competence. Instead, it is based on the information given by firms in terms of their claim regarding the capability to undertake tasks in different areas of ICT. Hence, the index may aptly be called the Index of Claimed Technological Competence (ICTC). We must also hasten to add that in a highly competitive world no firm can afford to send wrong signals by claiming competence in an area without actually having it.

Let us now briefly explain the method adopted in the construction of the index and the database. The directory of software companies in India published by NASSCOM provides information on different areas in which each of their members specializes. In a technologically dynamic area like ICT, with shorter product life cycle, the area of specialization by the firms changes from year to year. Nonetheless, there are a number of areas that remain unchanged over time. As a first step, we have divided different areas of specialization by the firms in terms of their innovation potential into three groups: high, medium and low. Such a classification has been made in consultation with experts in ICT. Though the nine experts who responded were engaged in different spheres of ICT, like software development, managing software firms and ICT training, there was hardly any difference in terms of their classification of the areas of specialization by the firms into high-, medium- and low-technology areas. Table 3.1A (please see the Appendix) presents the distribution of different activities into high-, medium- and low-technology activities in 1998 and 2001. Having divided the areas into three categories, we have assigned different weights (1 for low, 2 for medium and 3 for high) to them. Thus, we have a matrix of a_{ij} (where $a_{ij} \bullet 0, 1$), activities in which the firms actually specialize, and another matrix of w_j (where $w_j \bullet 1, 2, 3$), their weights. The total number of areas in which the firm could specialize is given by b_j. Then the estimated index is:

$$\mathrm{ICTC_i} = \frac{\sum_{j=1}^{3} a_{ij} w_j}{\sum_{j=1}^{3} b_j w_j} * 100$$

where

a_{ij} is the number of areas in the jth category where the ith firm reported specialization.

w_j is the weight assigned to the category (1 for low, 2 for medium and 3 for high category).

b_j is the number of areas in which the firms could specialize: $a_{ij} \leq b_j$

The value of the index will range from 0 to 100. $ICTC_i$ will be zero when $a_{ij} = 0$ and 100 when $a_{ij} = b_j$.

Before presenting the empirical results, it may be appropriate to state the limitation of the estimated index. As already stated, the index is based on the claim made by firms of their competence. Most of the firms were specializing in a number of areas and the data does not provide any information on the relative role of each area of specialization in their total sales turnover or export. In reality, whether the firm is actually engaged in an area where it has claimed competence cannot be made out from the dataset that we have. A more appropriate method would have been to generate an index by taking into account the sales turnover realized from different areas in which the firms specialize. Such an exercise is reserved for future work.

Empirical Results

For constructing the index we have made use of data on firm-level specialization provided by NASSCOM in its directory of software and service firms. The directory provides information on all its members, and in 2001 it was found that 854 Indian software and service companies were its members. These firms accounted for almost 95 per cent of the total revenue of the software industry in India in 2001. Though the total membership in 2001 was 854, the firm-level information on areas of specialization was available only for 630 firms. The corresponding number of firms in 1998 was 452. The directory also provides information on, among other things, exports, sales, software employment, other employment, year of establishment, etc. Table 3.1 presents the distribution of firms in terms of estimated ICTC in 1998 and 2001.

The table clearly shows an upward mobility of firms in terms of the estimated index. To illustrate, in 1998 over 56 per cent of firms were in the low index category (less than 30 per cent), whereas in a short span of three years the share of such firms declined to around 44 per cent. Similarly, in the higher index category (more than 60 per cent), the share of firms increased from 5.3 per cent in 1998 to 8.3 per cent in 2001. The estimated index of leading IT firms like Infosys, Wipro, TCS and Satyam were found to be more than 75 per cent. The increase in the share of firms was not confined to the high index category. In the middle index category as well the proportion of firms increased by 10 per cent. Thus, notwithstanding any significant increase in the R&D intensity of firms or any qualitative improvement in the nature of foreign collaboration, there appears to have been an upward mobility of firms in terms of the estimated ICTC.

TABLE 3.1 Distribution of Firms According to ICTC

ICTC	*1998*		*2001*	
	Number	*Percentage*	*Number*	*Percentage*
0–10	57	12.61	60	9.52
10–20	77	17.04	110	17.46
20–30	121	26.77	106	16.83
30–40	67	14.82	139	22.06
40–50	74	16.37	112	17.78
50–60	32	7.08	51	8.10
60–70	13	2.88	39	6.19
70–80	8	1.77	10	1.59
Above 80	3	0.66	3	0.48
Total	452	100.00	630	100.00

Source: Authors' calculations.

The change in the value of index is essentially a manifestation of the strategy adopted by firms in terms of the choice of their areas of specialization, which in turn could have been influenced mainly by demand and to a certain extent also by supply conditions faced by the firms. Analytically, one could conceive of seven choices that a firm could make in terms of selection of activities. They are: only low-technology areas, only medium technology areas, only high-technology areas, only low- and medium-technology areas, only medium- and high-technology areas, only low- and high-technology areas and lastly, in all three areas. Needless to say, the strategic choices adopted by firms in terms of their areas of specialization is bound to have a bearing on inter-firm variation in the estimated index. Table 3.2 presents a distribution of firms in terms of their choice of specialization in 1998 and 2001.

To begin with, it may be noted that between 1998 and 2001 there has been a decline in the share of firms opting for the first three strategies (only low, only medium and only high). Thus, the preferred strategy of firms appears to be not one of narrow specialization by focusing on any one group of activities. Another interesting finding relates to the fact that, in general, there has been a decline in those cases where the firms' choice involved high-technology areas. Thus, the share of firms with only high, medium and high and low and high strategies have shown a decline in 2001, compared to 1998. Given the fact that most of the firms are highly export oriented, the observed trend may be a reflection of the nature of export demand that Indian firms are faced with. The table also shows that the most preferred strategy (in terms of the percentage of firms) has been the last one, where firms have diversified into a wide range of activities. The share of such firms increased from over 62 per cent in 1998 to over 70 per cent in 2001.

TABLE 3.2 **Distribution of Firms According to Strategies Adopted**

Strategy	*1998*		*2001*	
	Number	*Percentage*	*Number*	*Percentage*
Low	7	1.55	8	1.27
Medium	25	5.53	27	4.29
High	28	6.19	19	3.02
Low and Medium	10	2.21	25	3.97
Medium and High	87	19.25	99	15.71
Low and High	12	2.65	9	1.43
Low and Medium and High	283	62.61	443	70.32
Total	452	100.00	630	100.00

Source: Authors' calculations.

Having observed the choice pattern of firms in terms of high- low- and medium-technology activities, it is pertinent to examine the relationship between the choice made by firms and their ability to increase their technological competence in terms of the estimated ICTC. Table 3.3 presents the matrix of distribution of firms in terms of their choice of areas of specialization and the level of ICTC.

The following observations may be made from the table: first, none of the firms with low, medium, high, medium and low, and low and high activities have recorded an index above 30 per cent. That is, almost 33 per cent of the firms in both of the years that adopted the above strategies have not been able to go beyond 30 per cent in terms of the estimated index. Firms recording estimated index above 30 per cent were the ones, which adopted a strategy of either medium and high or all three. Among these firms, those adopting the former strategy could go only up to 60 per cent whereas the latter recorded the highest index levels. From this one may be tempted to infer that the firms could go up the index level by diversifying into all the areas.

TABLE 3.3 Distribution of Firms Based on Levels of ICTC and Adopted Strategy

	Activity Choice of Firms													
	Low		*Medium*		*High*		*Low and Medium*		*Medium and High*		*Low and High*		*Low and Medium and High*	
Index Class ↓	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*
0–10	1.55	1.27	5.09	4.13	4.87	1.9	0.66	1.27	–	–	0.44	0.79	–	–
	(7)	(8)	(23)	(26)	(22)	(12)	(3)	(8)			(2)	(5)		
10–20			0.44	0.15	1.33	1.11	1.33	2.22	8.20	8.09	1.33	0.47	4.43	5.39
			(2)	(1)	(6)	(7)	(6)	(14)	(37)	(51)	(6)	(3)	(20)	(34)
20–30							0.22	0.15	7.53	5.23	0.88	0.15	18.18	6.51
							(1)	(1)	(34)	(33)	(4)	(1)	(82)	(71)
30–40								0.15	2.88	2.06	–		11.97	19.84
								(1)	(13)	(13)			(54)	(125)
40–50									0.44	0.15	–		15.96	17.62
									(2)	(1)			(72)	(111)
50–60									0.22	0.15	–		6.87	7.94
									(1)	(1)			(31)	(50)
60–70													2.88	6.19
													(13)	(39)
70–80													1.33	1.59
													(6)	(10)
Above 80													0.66	0.47
													(3)	(3)

Source: Authors' calculations.

The table however, shows that this may not be the case because in 1998 around 23 per cent of the firms, which opted for a strategy of high diversification obtained an estimated index of only less than 30 per cent. More importantly, only a very small proportion (4.87 per cent in 1998 and 8.25 per cent in 2001) with high diversification have a recorded index above 60 per cent. This suggests that diversification into a number of areas may not be a sufficient condition for firms to improve their ICTC.

It may be argued *a priori* that a firm with accumulated experience and larger size is more likely to go up the ICTC by diversifying into larger number of areas. The accumulated experience may be reflected in terms of age of the firm, and the sales turnover provides an indication of size. Now let us examine the bearing of these two factors on firms' choices and their observed ICTC.

Table 3.4 presents the age distribution of firms in terms of choices and observed levels of ICTC.

TABLE 3.4 **Mean Age of Firms According to ICTC and Strategy**

Index Class ↓	*Low*	*Medium*	*High*	*Low and Medium*	*Medium and High*	*Low and High*	*Low and Medium and High*	*Total*
0–10	6.25	9.11	7.66	10.44		12.00		8.25
10–20		8.00	8.42	7.50	7.41	12.00	8.14	7.84
20–30				7.00	7.87	3.00	7.09	7.30
30–40					4.00	8.92	7.46	7.57
40–50						2.00	7.46	7.41
50–60					26.00		8.42	8.76
60–70							8.55	8.55
70–80							11.40	11.40
Above 80							19.00	19.00
Total	6.25	9.07	7.94	8.40	7.89	6.77	7.82	7.88

Source: Authors' calculations.

It may be noted that the mean age of firms in the ICT sector in 2001 was found to be 7.88 years. Invariably, we find that the mean age of firms adopting a strategy of diversification (all the three areas) and that of firms adopting a strategy of specializing in high- and medium-technology activities are higher than the industry mean age and more importantly higher than those specializing in low-technology activities. The mean age of all firms with higher ICTC (higher than 60 per cent) is significantly higher than the industry mean age. This tends to suggest that a threshold level of accumulated experience may be called for if the firm intends to go up the ICTC index by adopting a strategy of diversification.

Data presented in Table 3.5 may be helpful to discern the bearing of the size of the firms on their choice of strategies and the observed level of ICTC.

It is evident from the table that hardly any firm with size below the industry mean has been able to record ICTC above 40 per cent. On the whole, it appears that a threshold level of size as well as accumulated experience may be necessary for firms to translate their diversification strategy into higher levels of ICTC.

Concluding Observations

Given the manifold ways in which information technology has the potential to contribute towards enhancing productivity, efficiency, competitiveness, growth and—more importantly—human welfare, developing countries have invested in ICTs as a short cut to prosperity (UNDP 1999; World Bank 1999). India is, in fact, one of the pioneering developing countries to undertake a series of initiatives to promote the ICT sector. However, the focus of attention has been to reap benefits from ICT export growth through a series of institutional interventions and export-oriented policy measures. These efforts seem to have paid rich dividends in terms of the sector emerging as one of the vibrant components in India's export basket and accounting for as high as 16 per cent of total exports. To the extent that the presence of a technologically dynamic ICT sector can be helpful in harnessing ICTs for development and technological capability is the key to sustaining the current comparative advantage, the present paper made an attempt towards analyzing the technology strategies of firms operating in India's ICT sector. Since the conventional measures of innovation, developed mostly in the context of goods producing sectors, have their limits in capturing innovation in a service sector like ICT, we developed an Index of Claimed Technological Competence using firm-level information about areas of specialization of firms. The theoretical base of the index was drawn from the literature on technological opportunity.

The estimates of firm-level ICTC shows that there has been a significant decline in the number of firms with relatively low ICTC, while

TABLE 3.5 Mean Revenue of Firms According to ICTC and Adopted Strategy

	Activity Choice of Firms															
	Low		*Medium*		*High*		*Low and Medium*		*Medium and High*		*Low and High*		*Low and Medium and High*		*Total*	
Year → *Index Class ↓*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*	*1998*	*2001*
0–10	30.08	59.83	55.9	192.1	112.6	36.58	21.7	485.34			95.8	7.918			74.23	172.04
10–20			10.9	42.5	165.8	256.62	27.7	65.11	85.0	281.29	25.03	93.78	47.17	258.2	70.65	237.81
20–30									79.6	384.0	84.5	23.8	113.98	136.9	111.5	211.91
30–40									107.28	73.14			648.11	257.41	543.18	238.33
40–50									5.5	11.54			207.12	592.21	201.67	587.1
50–60													505.82	271.42	490.12	272.67
60–70													113.23	1,345.9	1,113.24	1,345.9
70–80													1,467.56	3,737.9	1,467.56	3,737.9
Above 80													2,209.66	12,387.3	2,209.66	12,387.3
Total	30.08	59.83	52.3	186.6	124.0	117.65	133.1	213.12	83.67	286.02	56.68	38.28	384.18	580.28	272.13	474.24

Source: Authors' calculations.

the number of firms with higher ICTC showed an increase. Thus, during a short span of three years, one could observe a clear indication of the upward mobility of ICT firms in terms of their technological competence. In terms of technological strategy, it was found that the most preferred strategy has been to diversify into a wide range of activities. However, the strategy of diversification did not necessarily facilitate the upward mobility of firms on the ICTC index. It was found that diversification strategy could help firms to go up the ICTC index only if they have a threshold level of size as well as accumulated experience. Thus, diversification into a number of areas may not be a sufficient condition for firms to improve their technological competence.

The empirical evidence presented in the study therefore points towards the fact that the Indian ICT sector is technologically vibrant and that it is capable of addressing development needs. But to harness this capability to address India's development problems, there appears to be the need for a shift in strategy with greater domestic market orientation. The perils of hitherto followed export-oriented ICT growth strategy of India are evident from the findings of a study by IMF (2001). The study finds that IT using countries tend to benefit somewhat more than the IT producing countries. But India is yet to have any policy towards becoming a major ICT consumer by accelerating the diffusion of ICT to different sectors of the economy in general and the industrial sector in particular. As of today, the diffusion of ICT into India's industrial sector remains rather limited. It has been shown that only 1.77 per cent of the factories in the industrial sector make use of robots, only 3.7 per cent of the factories have Internet and only 1.5 per cent of the factories are with networks (Joseph 2002). If the Indian industry is to survive in the current era of globalization and fruits of the new technology are to reach the rural poor, we need to have a diffusion policy, instead of an export-oriented IT policy. Greater diffusion of ICTs and the resulting demand could act as a catalyst in the process of technological capability building and provide a springboard for the domestic ICT sector to sustain its current comparative advantage.

Appendix

TABLE 3.1A Activities of Software Firms: 1998–99

Technology	*Number*	*Percentage*
Business Process Consultancy/Reengineering (M)	161	35.38
CAD/CAM/CAE (H)	59	12.97
CD-ROM Publishing/Media (L)	43	9.45
Chip Design/Microprocessor/ASIC (H)	28	6.15
Computer Games/Graphics (M)	17	3.74
Data Processing/Data Conversions/Medical Transcriptions (L)	71	15.60
E-Commerce/EDI (M)	231	50.77
ERP/MRP Solutions (H)	195	42.86
Euro Currency Solutions (L)	127	27.91
Facility Management (H)	64	14.07
GIS/Imaging (M)	53	11.65
IT Education & Training (M)	101	22.20
Localization of Software (M)	56	12.31
Product Distribution/Support/Implementation (L)	120	26.37
RDBMS/Data warehousing/Data Mining (M)	211	46.37
Software Maintenance and Migration (L)	224	49.23
Software Product Development (H)	279	61.32
System Integration/Networking (M)	182	40.00
Telecom Solutions/Communication Software (M)	126	27.69
Web Content Development/Back Office Operations (M)	101	22.20
Web Technologies/Internet/Intranet (H)	306	67.25
Year2000 Solutions (L)	155	34.07
Total No. of Firms	452	

Note: The percentages do not add up to 100 as the firms were found to be engaged in more than one activity. L, M and H stand for low, medium and high skill/technology intensity, respectively.

TABLE 3.2A Activities of Software Firms: 2000–01

Technology	*Number*	*Percentage*
Antivirus/Security Solutions (H)	82	13
Application (L)	161	25.5
Business Processing Consultancy/Reengineering (M)	261	41.3
CAD/CAM/CAE (H)	71	11.2
Call Centres (L)	114	18
CD-Rom Publishing/Multimedia (L)	86	13.6
Chip Design/Microprocessor/ASIC (H)	49	7.8
Computer Games/Computer Graphics/Animation (L)	85	13.4
Data Processing/Data Conversion (M)	158	25
E-commerce/EDI/CRM Solutions (M)	423	66.9

(*Table 3.2A contd*)

(*Table 3.2A contd*)

Technology	*Number*	*Percentage*
ERP/MRP Solutions (H)	223	35.3
GIS/Imaging (M)	91	14.4
ISPs/Payment Gateways (M)	72	11.4
IT Education & Training (M)	152	24.1
Localization of Software (M)	134	21.2
Medical Transcription (L)	27	4.3
Product Distribution/Support/Implementation (L)	188	29.7
RDBMS/Data Warehousing/Data Mining (M)	345	54.6
Software Maintenance and Migration (L)	345	54.6
Software Product Development (H)	420	66.5
System Integration/Networking (M)	312	49.4
Telecom Solutions/Communications software (M)	191	30.2
WAP/M-Commerce (M)	211	33.4
Web Content Development (M)	229	36.2
Web Technology/Internet/Intranet (H)	474	75.0
Total No. of Firms	630	

Note: Percentages will not add up to 100 because firms were found to engage in more than one activity.

Notes

1. This has attracted the attention of researchers and there are a large number of studies focusing on the different aspects of ICT growth. An illustrative list includes Heeks (1996), Kumar (2001), Joseph and Harilal (2001), Arora et al. (2001) and Nath and Hazra (2002).
2. Out of the top 20 software and service firms in India in 1998–99 only six were subsidiaries of foreign companies (Arora and Athreye 2002).
3. For detailed accounts of the policy measures and institutional interventions by the state to promote ICT export see Joseph (2002), Parthasarathi and Joseph (2002).
4. It may be surprising to note that today countries like Taiwan and South Korea, where firms began as original equipment manufacturers (OEMs), occupy dominant positions among countries in terms of the number of patents registered (Wu Rong-I et al. 2002).
5. See Patel and Pavitt (1995) for a discussion on the issues involved in the measurement of innovative activity.
6. Patel and Pavitt (1995) have been explicit in stating challenges involved in measuring innovations in software.
7. In this paper, the terms innovation capability, technological capability and technological competence have been used interchangeably.
8. This is not to undermine the insights offered by the literature on learning by doing and learning by using.
9. This has been viewed against the widely prevalent practice of costing adopted in the offshore projects, which are the dominant form of ICT exports at present.

A common practice of pricing in the offshore projects is the 'cost plus pricing', wherein the client provides to the exporting firm a margin over the cost involved in 'time and materials'. Hence, for the foreign firm, it is important that local firm does not overstate the 'time and material cost'. To take care of the possibility of overcharging, foreign firms find it advantageous to have an equity stake (often less than 20 per cent) so that issues of overcharging and shirking do not arise. Therefore, many of those cases involving neither royalty nor lump sum were involved in significant transfer of technology.

10. Most of the studies have been carried out in the context of developed countries. Studies on developing countries have not given much attention to technological opportunity.

References

Amsden, A. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. NewYork: Oxford University Press.

Arora, A. and J. Asundi. 1999. 'Quality Certification and Economics of Contract Software Development: A Study of Indian Software Industry', NBER Working Paper No. 7260. Cambridge, MA: National Bureau of Economic Research.

Arora, A., V.S. Arunachalam, J. Asundi and F. Ronald. 2001. 'The Indian Software Services Industry', *Research Policy*, 30(3): 1267–87.

Arora, A. and S. Athreye 2002. 'The Software Industry and India's Economic Development', *Information Economics and Policy*, 14: 254–73.

Barras, R. 1986. 'Towards a Theory of Innovation in Services', *Research Policy*, 15(2): 161–173.

Basant, R. 1997. 'Technology Strategies of Large Enterprises in Indian Industry: Some Explorations', *World Development*, 25(10): 1683–1700.

Basant, R. and B. Fikkert. 1996. 'The Effects of R&D, Foreign Technology Purchase, Domestic and International Spillovers on Productivity of Indian Firms', *The Review of Economics and Statistics*, 78(2): 187–99.

Bell, M.D. Scott-Vemmis and W. Satyarakwit. 1982. 'Limited Earning in Infant Industry: A Case Study', in F. Stewart and J. James (eds), *The Economics of New Technology in Developing Countries*. London: Frances Pinter 138–55.

Cohen, W. 1995. 'Empirical Studies of Innovative Activity', in Stoneman P. (ed.), *Handbook of the Economics of Technological Change*. Cambridge, MA: Blackwell.

Cohen, W.M. and S. Klepper. 1992. 'The Tradeoff between Firm Size and Diversity in the Pursuit of Technological Progress', *Small Business Economics*, 4: 1–14.

Cooper, Charles. 1980. 'Policy Interventions for Technological Innovations in Developing Countries', *Staff Working Paper* No. 441. Washington, DC: The World Bank.

Dahlman, C.J. 1984. 'Foreign Technology and Indigenous Technological Capability in Brazil', in Martin Fransman and K. King (eds), *Technological Capability in the Third World*. London: Macmillan.

Dahlman C.J. and L. Westphal. 1987. 'Managing Technological Development: Lessons from the Newly Industrializing Countries', *World Development*, 15(6): 759–75.

Dasgupta, P. and J. Stiglitz. 1980. 'Industrial Structure and the Nature of Innovative Activity', *Economic Journal*, 90: 266–93.
D'Costa, A. 2002. 'Export Growth and Path Dependence: The Locking in of Innovations in the Software Industry', *Science, Technology and Society*, 7(1): 51–89.
Deolalikar, A. and R.E. Evenson. 1989. 'Technology Production and Technology Purchase in Indian Industry', *Review of Economics and Statistics*, 71: 689–692.
———. 1990. 'Private Inventive Activity in Indian Manufacturing: Its Extent, and Determents', in R.E. Evenson and G. Ranis (eds), Science and Technology: Lessons for Development Policy. Boulder, CO and San Francisco, CA: Westview.
Desai, A.V. 1980. 'The Origin and Direction of Industrial R&D in India', *Research Policy*, 9: 74–96.
———. 1985. 'Indigenous and Foreign Determinants of Technical Change in Indian Industry', *Economic and Political Weekly*, 20(special number): 2081–94.
Enos, J.L. 1991. *The Creation of Technological Capability in Developing Countries*. London: Pinter.
Evenson, R.E. and K.J. Joseph. 1997. 'Technology Licensing in Indian Industry: An Econometric Analysis of Choice of Partners, Terms of Contract and Effect on Licensees' Performance', *Economic and Political Weekly*, 34(27): 1801–09
Evenson, R.E. and Y. Kislev. 1976. 'A Stochastic Model of Applied Research', *Journal of Political Economy,* 84: 657–74.
Fransman, M. 1986. *Technology and Economic Development*. Brighton, Sussex: Wheatsheaf Books.
Griliches, Z. 1995. 'R&D and Productivity: Econometric Results and Measurement Issues', in P. Stoneman (ed.), *Handbook of the Economics of Technological Change*. Cambridge, MA: Blackwell Publishers.
Heeks, R. 1996. *India's Software Industry: State Policy, Liberalization and Industrial Development*. New Delhi, Thousand Oaks, London: Sage Publications.
IMF. 2001. *World Economic Outlook: The Information Technology Revolution*. Washington, DC: IMF.
Joseph, K.J. and K.N. Harilal. 2001. 'Structure and Growth of India's IT Exports: Implications of an Export-Oriented Growth Strategy', *Economic and Political Weekly*, 36(34): 3263–70.
Joseph, K.J. 2002. 'Growth of ICT and ICT for Development: Realities of the Myths of the Indian Experience', Discussion Paper No. 2002/78. Helsinki: UNU/WIDER.
Katrak, H. 1985. 'Imported Technology, Enterprise Size and R&D in a Newly Industrializing Country: The Indian Experience', *Oxford Bulletin of Economics and Statistics*, 47(3): 213–30.
———. 1989. 'Imported Technologies and R&D in a Newly-Industrializing Country: The Experience of Indian Enterprises', *Journal of Development Economics*, 31(1): 123–39.
Kattuman, P. and K. Iyer. 2001. 'Human Capital in the Move up the Value Chain: The Case of Software and Services Industry', Department of Applied Economics, University of Cambridge (mineograph).
Katz, J.M. 1984. 'Domestic Technological Innovations and Dynamic Comparative Advantage', *Journal of Development Economics*, 16(1–2): 54–71.
———. (ed.). 1987. *Technology Generation in Latin American Manufacturing Industries*. London: Macmillan.

Kraemer, K.L. and J. Dedrick. 2001. 'Information Technology and Economic Development: Results and Policy Implications of Cross-Country Studies', in M. Pohjola (ed.), *Information Technology, Productivity and Economic Growth: International Evidence and Implications for Economic Development*. New York: Oxford University Press.

Kumar, N. 1987. 'Technology Import and Local Research and Development in Indian Manufacturing', *The Developing Economies*, 25: 220–33.

———. 2001. 'Indian Software Industry Development: International and National Perspective', *Economic and Political Weekly*, 36(44): 4278–90.

Kumar, N. and A. Agarwal. 2000. 'Liberalization, Outward Orientation and In-house R&D Activity of Multinational and Local Firms: A Quantitative Exploration for Indian Manufacturing', Discussion Paper No. 07/2000. New Delhi: Research and Information System for the Non-Aligned and Other Developing Countries.

Kumar, N. and N.S. Siddharthan. 1997. *Technology Market Structure and Internationalization: Issues and Policies for Developing Countries*. London and New York: Routledge.

Lall, S. 1983. 'Determinants of R&D in a LDC: The Indian Engineering Industry', *Economic Letters*, 13(3): 379–83.

———. 1987. *Learning to Industrialize: The Acquisition of Technological Capability in India.* London: Macmillan.

Levin, R.C. 1978. 'Technical Change, Barriers to Entry and Market Structure', *Economica,* 45: 347–61.

Levin, R.C. et al. 1987.

Mani, S. 1992. *Foreign Technology in Public Enterprises*. New Delhi: Oxford & IBH Publishing Co.

———. 2001. 'Role of Government in Promoting Innovation in the Enterprise Sector: An Analysis of the Indian Experience', Discussion Paper No. 2001/3 UNU/INTECH.

Nath, P. and A. Hazra. 2002. 'Configuration of Indian Software Industry', *Economic and Political Weekly*, 37(8): 737–42.

NASSCOM (National Association of Software and Service Companies). 1999, 2001. *Directory of Indian Software and Service Companies*, New Delhi: NASSCOM.

———. 2002. *The Software Industry in India: A Strategic Review*. New Delhi: NASSCOM.

Nelson, R.R. 1982. The Role of Knowledge in R&D Efficiency, *Quarterly Journal of Economics*, 97: 453–70.

Parthasarathi, A. and K.J. Joseph. 2002. 'Limits to Innovation with Strong Export Orientation: The Experience of India's Information Communication Technology Sector', *Science, Technology and Society*, 7(1): 13–49.

Patel, P. and K. Pavitt. 1995. Patterns of Technological Activity: Their Measurement and Interpretation', in P. Stoneman (eds), *Handbook of the Economics of Technological Change*. Oxford: Blackwell.

Pohjola, M. 2001. 'Information Technology and Economic Growth: A Cross country Analysis', in M. Pohjola (ed.), *Information Technology, Productivity and Economic Growth: International Evidence and Implications for Economic Development.* New York: Oxford University Press.

Raipurai, K. 2002. 'What Size the New Economy: A Conduit Approach', *Economic and Political Weekly*, 37(11): 16–22.

Richter, F.J. and P. Banerjee. 2002. *The Knowledge Economy in India*, New York: Palgrave.

Rodrik, D. 1995. 'Trade and Industrial Policy Reform', in J. Behrman and T.N. Srinivasan (eds), *Handbook of Development Economics*, vol. IIIB. New York: Elsevier.

Rosenberg, N. 1974. 'Science, Invention and Economic Growth', *Economic Journal*, 84: 90–108.

Scherer, F.M. 1965. 'Firm Size, Market Structure Opportunity and the Output of Patented Inventions', *American Economic Journal*, 55: 1097–1125.

Schware, R. 1987. 'Software Industry in the Third World: Policy Guidelines, Institutional Options and Constraints', *World Development*, 15(10/11): 1249–67.

Sen, P. 1995. 'Indian Software Exports: An Assessment', *Economic and Political Weekly*, 30(7 & 8): 2053–58.

Siddharthan, N.S. 1988. 'In-house R&D, Imported Technology and Firm Size: Lessons from Indian Experience', *The Developing Economies*, 26(3): 212–21.

———. 1992. 'Transaction Costs, Technology Transfer and In-house R&D: A Study of the Indian Private Corporate Sector', *Journal of Economic Behaviour and Organisation*, 18: 265–71.

Spence, A.M. 1984. 'Cost Reduction, Competition and Industrial Performance', *Econometrica*, 52: 101–21.

Stoneman, P. (ed.). 1995. *Handbook of the Economics of Technological Change*. Oxford: Blackwell.

———. 2002. *The Economics of Technological Diffusion*, New York: Blackwell.

Subrahmanian, K.K. 1988. 'Technological Transformation: An Assessment of India's Experience', in S.J. Patel (ed.), *Technological Transformation of the Third World*: vol. 1, *Asia*. Ahmedabad: Gujarat Vidyapith.

UNDP. 1999. *Human Development Report 1999*. New York: UNDP/Oxford University Press.

World Bank. 1999. *Knowledge for Development*. World Development Report 1998/99, Washington, DC: Oxford University Press for the World Bank.

Wu Rong-I, Xin-Wu Lin and Hsiu-Ying Lin. 2002. 'Moving from foreign Technology to Indigenous Innovation: The Case of Chinese Taipei' (paper presented in the OECD-IPS workshop on *Promoting Knowledge-based Economies in Asia Singapore*), 21 and 22 November.

4

Human Capital, Labour Scarcity and Development of the Software Services Sector

Suma S. Athreye

The software services sector in India has shown remarkable growth. Indian software growth has been marked by two salient features: it was mostly led by the growth of export revenues, and the period of the most remarkable growth was 1995–2001. This growth of revenues has also been accompanied by increasing productivity (as measured by revenue per employee and reported in Table 4.1). In this too, the period of the most rapid increase has been 1995–2001.

Human capital is widely believed to have been the main force in the growth of the industry in India as it has helped the industry to capitalize on the sudden surge in demand for software services that emerged in the world economy in the late 1980s. Undeniably, the initial export of software services from India owed a lot to the mismatch between the supply of engineers and the low demand for them in the Indian economy, at a time when there was a global scarcity of software programmers and many Indian firms were able to employ engineers, teach them software skills on the job, and realize profits due to the high opportunity costs for such labour in western economies.

TABLE 4.1 India's Personpower and Revenues per Person-Year

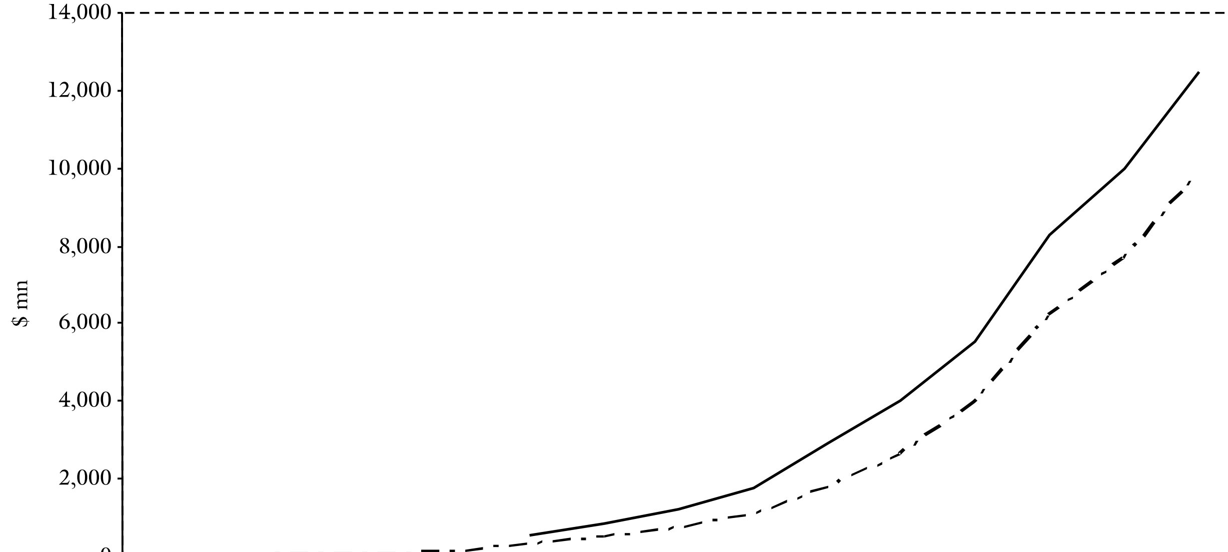
Year	*Personpower*	*Rev/Employee ($)*
1993–94	90,000	6,198.5
1994–95	118,000	6,998.0
1995–96	140,000	8,924.5
1996–97	160,000	11,036.0
1997–98	180,000	15,000.0
1998–99	250,000	15,600.0
1999–2000	—	—
2000–01	410,000	20,488.0

Source: NASSCOM, various volumes.

However, the abundance of engineering talent had mostly been exhausted by the mid-1990s, when Indian software firms began to suffer from a growing demand in the labour market for software programmers. The effects were felt in the high rates of labour attrition and rising wages for most categories of software programmers in India. Yet, this was also a period of robust export performance and rising productivity (Figure 4.1). The interesting question that then arises is whether it was human capital or labour scarcity during the boom period that was a key factor in the growth of exports from the software industry.

This paper argues that though human capital did play an important role in the early development of the industry, the sustained growth of the 1995–2001 period owed itself to the development of firms' capabilities in software process management. We follow the argument that the use of human capital by software firms in this early period was quite wasteful and involved negative externalities for other industries, particularly manufacturing (Arora and Athreye 2002). However, as the wage (scarcity) premium enjoyed by software programmers vis-à-vis the rest of the industry grew in the 1990s, this changed. In the face of escalating wage bills and continued attrition to other firms, software firms have had to rethink their labour use strategies and also their employment terms to compete with their global rivals. Some firms also became successful because they concentrated on organizational procedures and processes appropriate to maintain quality in software outsourcing, and by training cheaper

FIGURE 4.1 **The Growth of Software Revenues in India (1984–2002)**



	1984	1985	1986	1987	1989	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
exports	22	26	38	54	105	330	485	734	1,085	1,759	2,600	3,962	6,217	7,647	9,875
total						558	835	1,224	1,755	2,936	4,011	5,539	8,298	9,958	12,455

Source: Data for 1984–89 as quoted in Lakha (1994); data for 1993–2002 based on NASSCOM reports.

non-engineers to work on software programming. In this process, generic organizational capabilities have been developed in managing large-scale labour resources, in their training and deployment, and in being able to maintain the processes required to deliver an outsourced service of quality and timeliness. These are widely believed to be the key capabilities underlying the offshoring or complete outsourcing model of service exports—an area in which Indian firms have a 'created' comparative advantage.

Recognizing the relative roles played by human capital and labour scarcity is important for two reasons. First, labour scarcity coupled with growing markets has had an important influence in the build-up of firms' capabilities, which in turn contributed to rising productivity and growing comparative advantage in software services: a fact not well appreciated in current analyses of the industry. An implication of this is that the industry as a whole has moved to a slightly more labour-intensive trajectory of growth. Second, a distinction between the roles of human capital and labour scarcity is also relevant for policy purposes. Public attention has been focused on the depletion of human capital, and policy interventions have been geared towards increasing the supply of engineers. We argue this is not an appropriate policy response. High software salaries have meant that the rewards to software training are now well recognized and firms and individuals are willing to pay for this training—so the need for a government subsidy on this is not clear. However, the growth of software has also emphasized the value of literacy and basic education upon which further training can take place. It is here that a government subsidy is urgently needed and for which the present time is ripe. Literacy and basic education are also known to have other important effects on the reduction of poverty, the betterment of public health and overall economic growth.

The rest of the paper is organized in the following way: The first section reviews the role of human capital in the initial period of growth of the Indian software industry, while the second describes the period between 1995 and 2000, which saw a growing tightness of the labour market, the problems created because of it and the responses of firms. The following section discusses the role of generic capabilities and the impact of software on other service sectors, while the fourth section looks at the response of private training to the skilled labour scarcity, and the fifth assesses if public policy should intervene. The last section summarizes the arguments and provides a conclusion.

Human Capital and the Initial Growth of Indian Software Exports[1]

The dominant model of the early period of software growth was the onsite services model, where the software-exporting firm provided the personnel to execute the project, while the client firm provided the specifications, and in many cases, the capital equipment needed to execute the project. Several factors contributed to popularizing this business model among the early software exporters: the credibility gap due to the poor reputation of Indian exports, the relatively high cost of hardware, and the need for monitoring and communication with the client.[2] However, the main source of profitability and competitive advantage in this model, as argued by Heeks (1996), was the relative high cost of software programmers in the rest of the world. Firms that emerged as leading onsite vendors of software services, such as TCS and Patni, had a long history of collaborations with hardware manufacturers and often hired engineers so as to be better able to communicate with them. When these firms started working with small sub-contracted software projects for their foreign clients, many of them were executed by the engineers employed in these domestic companies.

It is widely believed that the initial and most important cause of the growth of the Indian software industry has been the large supply of engineers, relative to the limited demands for engineers from other sectors of the economy. Indeed, there is much evidence in Arora et al. (2001) which suggests that a very large proportion of employees of Indian software firms are graduates of engineering colleges. Surveys of India's premier technological institutions—the Indian Institutes of Technology (IITs) show that a very large fraction of postgraduates from those institutions enter the information technology (IT) sector, in some cases as many as 90 per cent! Indian software firms interviewed by Arora et al. (2001) reported hiring only engineers. In interviews, many firms categorically state that they hire only engineers. Data from a sample of nearly 60 software firms in their survey showed that over 80 per cent of their employees have an engineering degree. Only 13 per cent were non-engineers trained in software development. A study by NASSCOM (1999) also reported that only 2 per cent of all software developers trained in private training institutes joined software development firms.

As Arora and Athreye (2002) point out, the assumption that only engineering graduates were well suited to perform software programming tasks has shaky foundations. First, the bulk of the engineers working in the industry are not, in fact, trained in software engineering, computer science or related disciplines. A very significant part of the work involves developing and refining business applications, databases and the like. Indeed, initially the majority of the work involved porting applications from one computing platform, typically a mainframe, to another, such as Unix. While this work required familiarity with software development tools, it did not demand an in-depth knowledge of computer architecture or operating systems.[3] Finally, much of the export work tended to consist of small projects, with fairly low levels of technical complexity.

Therefore, bright graduates from any field could, with proper training, do what was needed (Arora and Athreye 2002). It seems that the preference for engineers was in some cases a way of signalling quality to customers. With only limited market power, Indian software exporters tried to distinguish themselves from the competition by pointing to the quality of their processes and people, and when possible, their experience. If so, this early strategy of hiring engineers to do software services work represented an inefficient allocation of resources in a social sense. A more rational allocation would have firms substituting intelligent and hardworking non-engineers trained in the use of software development tools for engineers where possible. Engineers would be used where their substantive knowledge or design ability was of value.

It was also a strategy that involved considerable negative externalities for other industries. Indeed, the software industry has been growing in part by drawing away engineers from other industries. In their interviews, Arora et al. (2001) report coming across a number of instances of engineers with highly specialized training (such as very large-scale integration [VLSI] design or satellite systems) working on tasks such as database design or development of business application software. Quite a few senior-level engineers were drawn from a variety of public sector research and development institutions. In the short run, this was a negative pecuniary externality for other industries, particularly manufacturing.

Labour Scarcity, Attrition and the Growth of Software Exports in the 1990s

This preference of the software services industry for engineers was unremarkable, and of little consequence at the start of the industry, when its demand was small relative to the annual supply. It is estimated that India graduates over 160,000 engineers of all varieties every year (Arora et al. 2001). The sharp and sustained growth of the Indian industry however meant that by 1998–99, the number of employees had climbed to nearly 250,000 (NASSCOM 1999). This implied a growing scarcity of human capital (in the form of trained engineers), which is also consistent with other evidence.

In our interviews, some firms admitted to pooling labour with other firms in the event of need. So if firm A needed a programmer who knew Java and firm B had a good one, firm A would pay firm B to hire their programmer for the particular project they were doing. This was said to be more common for onsite jobs than offshore contracts. In 1999, many Indian policy makers called for declaring a state of 'educational emergency' to ensure that the supply of skilled software developers was increased. CEOs of smaller software development firms and the National Association of Software and Service Companies (NASSCOM)—the professional association representing the views of these firms—had begun to argue that the shortage of skilled labour was constraining their ability to grow (see also National Task Force 1999). When asked in 1998–99 to list the top three problems they faced, more than half of all firms (out of a sample of over 100 firms) irrespective of age, size or market orientations (either export or import) selected personpower shortage and employee attrition as the most serious problem affecting them (Arora et al. 2001). Despite paying substantially above Indian standards, virtually all firms found it difficult to attract and retain talented software developers.

An important factor in the sharp rise in software salaries and attrition rates was the international competition for Indian software programmers. While Indian software professionals earn an income that is 20 times the national average, their salary is only a fraction of that of their international counterparts. The existence of this disparity in terms of international wages makes software firms in India vulnerable to loss of middle-level employees to software firms in the West who are able to offer better salaries than what they can earn in India. However, the existence of the national premium in wages in favour of software has also meant that there is a continuous pressure on profitability within software firms, which is higher than that faced by their counterparts. This is clearly visible in Table 4.2, which reports salaries in 1995 and 1999 for some selected countries. Though software salaries in India continued to be lower than that in other countries in 1999, over the period between 1995 and 1999 software salaries in India grew at twice the rate they did in other countries.

TABLE 4.2 **Average Annual Software Labour Cost Comparison (US$ per annum)**

	1995				*1999*			
	USA	*UK*	*Ireland*	*India*	*USA*	*UK*	*Ireland*	*India*
Project Leader	54,000	39,000	43,000	23,000	65,600	47,400	52,300	33,700
Systems Designer	55,000	34,000	31,000	11,000	66,900	41,300	37,700	16,100
Development Programmer	41,000	29,000	21,000	8,000	49,800	35,300	25,600	11,700
Quality Assurance Specialist	50,000	33,000	29,000	14,000	60,800	40,100	35,300	20,500

Sources: www.man.ac.uk/idpm/isicost.htm for 1995 data and World Employment Report (2001) for 1999 data.

The vulnerability to employee attrition and rising wages created different kinds of problems for Indian software firms. Rising wages eat directly into a company's profitability and put pressure on the bottomline margins for firms. This pressure is somewhat exacerbated by the fact that most Indian software firms are service oriented, and their scalability and growth depend upon their ability to maximize the utilization of their trained personnel. Attrition creates a different kind of threat—the loss of employee-specific knowledge and the possibility that this knowledge has been lost to competitors. When attrition is at senior levels, it is also likely that a firm will lose some of its customer base to the competitor.[4] Interviews with US-based clients of Indian software firms (Arora et al. 2001) indicated that many of them saw employee attrition as an important problem as well, causing delays due to entire project teams leaving in the midst of an ongoing project, in response to a more lucrative offer. Such delays were particularly troubling for smaller and product-focused clients who need to shorten product development cycles.

However, both of these problems—attrition and wage increases—have prompted software firms to aggressively introduce human capital management strategies and organizational measures comparable to their international rivals, and in some areas, improve upon those practices. The main measures to combat attrition and its effects upon companies include:

- Organizational practices designed to retain the interest and loyalty of employees, such as employee stock options (ESOPs),[5] and attention towards charting a management career path for technical personnel in firms—perhaps the first signs of a technocracy;
- organizational innovations designed to diffuse and recombine employee-specific knowledge in a variety of different ways, most notably, through the reduction of hierarchical tiers and teamwork;
- the use of embodied forms of software knowledge such as tools, or where possible, through the use of licences and intellectual property rights (IPR) protection; and
- continuous search and recruitment policies to fill gaps in project teams.

The adoption of ESOPs and the charting of career paths in management for technically qualified professionals have also had at least one unintended outcome. Technically qualified persons now view entrepreneurship itself quite differently. It is a logical extension of the managerial tasks that they would in any case hope to do with growth in their careers, with an added element of risk that nevertheless promises large rewards. All the leading software firms are alive to these concerns. Ex-employees of HCL and Wipro, in particular, have been active entrepreneurs.

The impact of the upward pressure on salaries was to prompt Indian software firms to look for more rational labour, using strategy to keep costs down in a market where other domestic firms were mainly competing on costs. These new labour-using strategies adopted through the mid- and late 1990s had the following main components:

- The first was the use of proprietary software tools for automating some parts of the writing of software code.
- The second was to substitute non-engineers for engineers wherever possible, thus reversing the wasteful use of engineering talent in the very early period.
- A third prong was to invest in specialized training after mapping the lacunae in the capabilities of project teams. Industry analysts claim

> that Indian software companies are able to prepare a graduate with only three years of experience to work at levels comparable to what a graduate with 10 years of developer experience can do in the West.[6]

An implication of strategies like the increased use of software tools and training was a mild increase in the size of setting-up costs and capital intensity in the sector. Table 4.3 reports some measures of size, employment and size of authorized capital for the median firm in 1995, 1997 and 1999. These data have been computed from the NASSCOM directory for the respective years. The table shows a mild increase in capital intensity (whether measured as the ratio of authorized capital to output or authorized capital to labour employed), and also an increasing scale of operations (measured by turnover or employment) for the median firm. The proportion of software professionals employed also fell marginally between 1997 and 1999.

TABLE 4.3 **Changes in Size, Employment and Revenues of the Median Firm**

	1994–95	*1996–97*	*1999–2000*
Size of Authorized Capital (Rupees mn)	7.8	12.5	40.0
Sales Revenue (Rupees mn)	28.0	38.0	50.0
Export Revenue (Rupees mn)	20.0	25.0	27.0
Total Employed (in numbers)	85.0	115.0	100.0
Percentage of Software Professionals in Total Employed	78.0	78.0	67.0
Revenue per Employee	0.33	0.33	0.50

Source: NASSCOM directories 1996, 1998, 2001.

The offshore model that gained popularity in the mid- and late 1990s was uniquely suited to the new labour-using strategies outlined earlier. The popularity of the offshore model rests in it being a cheaper way for a western firm to meet its software needs than either a fully-owned subsidiary or onsite servicing. NASSCOM sources claim that costs in the offshore model were roughly 1/3 those of the onsite model due largely to the higher expense of living costs in the US. Arora and Asundi (1999) also note that vendors preferred the offshore model, as it was more profitable than onsite work. This suggests that there was considerable reduction in the cost of software development in the Indian variant of the offshore model and that perhaps average wage costs were somehow kept much lower in the offshore case.

Two kinds of factors could produce this effect of a lower average wage in offshore work. First, if there was increasing substitution of cheaper (non-engineering) labour for the more expensive engineering labour. This in turn was possible because the larger scale of operation of development centres meant they permitted a finer splitting up of software tasks. Second, if the spread of salaries for engineering and non-engineering labour was lower in the domestic market than in the international market.

It is important to realize that such a rationalization of labour use was a strategy permitted by the growing scale of software operations, as export demand remained buoyant through the 1990s. Certainly no other industry in India had faced such a long demand boom (for over a decade). Second, innovative policy initiatives to improve telecom infrastructure, such as privatization of telecommunications and the building of optic fibre links were also important, though their influence began to be felt only towards the end of this period. Policies to improve internet access (such as the Science and Technology Parks of India [STPI] scheme) enabled service delivery over the web and allowed small firms to benefit from the export boom.

Indian software firms also invested in developing process management capabilities that allowed them to deliver an internationally competitive combination of low cost–high quality software services despite attrition and wage increases. A testimony to this is the fact that India has one of the largest numbers of software firms with quality certification in the world—next only to the US. More than half of the software companies in the world ranked at CMM level 5 are in India.[7] However, perhaps the best evidence of the value of this increased capability is in the growing size of software contracts being routinely bagged by the leading firms. This can be seen in Table 4.4 which lists some of the contracts bagged by Indian software firms between 2001 and 2003, culled from newspaper reports.

The Emergence of the Generic Offshoring Model

There is much evidence that parts of the services sector have been favourably affected by software growth. First, there is the rapid growth of the informal IT sector studied by Kumar (2000). This spans the

TABLE 4.4 Large Contracts Bagged by Indian Software Firms Reported in National Newspapers (2001–03)

Month/Year	*Indian Firm*	*Contracting Client Firm*	*Contract Type*	*Value (period)*
August 2003	L&T Infotech	Motorola	Unknown.	\$70–90 mn (3–5 years)
August 2003	Satyam	Certain Teed (USA)	Outsourcing contract to implement end-to-end supply chain solution. Fixed cost.	\$15 mn (9 months)
June 2003	HCL	Airbus	Embedded software.	–
April 2003	HCL	British Telecom Group (UK)	Outsourcing contract for business. telemarketing, billing and conferencing work.	\$160 mn (5 years)
April 2003	Progeon (Subsidiary of Infosys)	BT group (UK)	Second service provider for BPO services.	– (5 years)
March 2003	Patni Computer Systems	Guardian Life Insurance Co. (US)	70% offshore contract for gap analysis and implementation of IT systems in the marketplace.	\$35 mn (7 years)
March 2003	Ramco–Boeing	Aloha Airlines (US)	Technical services with main marketing by Boeing (50 % of revenues for each).	–
November 2002	TCS & Wipro	Lehmann Bros	IT outsourcing.	\$50–70 mn annually

(*Table 4.4 contd*)

(*Table 4.4 contd*)

Month/Year	*Indian Firm*	*Contracting Client Firm*	*Contract Type*	*Value (period)*
October 2002	Wipro	Ericsson	'Total' R&D outsourcing with Wipro taking over the Ericsson R&D centres in India.	—
July 2002	Wipro	Transco (UK) (formed as a result of merger between Lattice group and National grid)	Application, maintenance support and integration services around SAP tools.	\$20 mn
January 2002	TCS	GE medical systems	'Take or pay' model, whereby GE is committed to making a fixed payment irrespective of work done by TCS.	\$100–120 mn (2 years)
July 2001	Wipro	Lattice Group (US)	Outsourcing.	\$70 mn (3 years)

provision of IT maintenance services to firms, data entry firms and customization services for domestic users—services that were virtually non-existent about a decade ago. Second, there is the huge growth of the IT-enabled services (ITES) sector, whose growth owes much to the success of software service exports.

The large cost reductions from a move to the offshore services model was extremely important as it showed the possibility of large cost savings through the full outsourcing of services, generally to the rest of the world. From trading in skilled labour in the late 1980s, Indian firms built up a capability and reputation for being able to deliver a sub-contracted service at a low cost and with adequate quality of and timeliness of delivery. Once this capability was established and a 'Made in India' brand was established, it was leveraged to other service areas, such as electronic customer relationship management (e-CRM), medical transcription, content management, analysis of financial data and even call centres.

The basic business model that underlies the growth of these services is similar to that of software—outsourced demand by large firms of part of their operations that takes advantage of the availability of a large English-speaking population at relatively low wages. The similarity of the basic business model might also mean similar organizational strengths can be leveraged to implement the outsourcing in ITES. These may lie in the area of process management, large-scale human resource management and the similarity of the infrastructure required to run outsourcing contracts (for example, networked computers and telecommunication links). Perhaps the best evidence of this is the involvement of large Indian IT firms in the newly emerging business process outsourcing (BPO) market. Thus, Spectramind (ranked fourth in a recent NASSCOM survey of ITES providers) is backed by Wipro, while Daksh eServices has Citigroup (also behind Citicorp Overseas Software Limited) as one of its chief promoters. Infosys and Satyam have set up their own subsidiaries, Progeon and Nipuna respectively, to deliver BPO services. TCS has entered into an agreement with US-based Household International to provide it with BPO services.

Estimates by NASSCOM (2002), reported in Table 4.5, show a rapid growth of the IT-enabled services in India. The two most promising segments of growth have been customer interaction services, including call centres and content development and animation. Smaller cities like Gurgaon, Mumbai, Hyderabad, Bangalore, Chennai, Pune,

TABLE 4.5 **ITES–BPO Revenues by Service Lines**

Type	*2001–02* *Employment*	*(US$ mn)* *Revenues*	*2002–03* *Employment*	*(US$ mn)* *Revenues*	*2003-04* *Employment*	*(US$ mn)* *Revenues*
Customer Care	30,000	400	65,000	810	95,000	1,200
Finance	15,000	300	24,000	510	40,000	820
HR	1,500	30	2100	45	3,500	70
Payment Services	7,000	110	11,000	210	21,000	430
Administration	14,000	185	25,000	310	40,000	540
Content Development	39,000	450	44,000	465	46,000	520
Total	106,500	1,475	171,100	2,350	245,500	3,580

Note: Employment figures are in numbers, while figures for 2003–04 are estimated figures.
Source: Estimates reported in www.nasscom.org/images/itesbpo-p66.gif.

Ahmedabad and Thiruvananthapuram are also fast emerging as major hubs of IT-enabled services.

This growth will put further pressure on the ability of software development firms to meet their staffing needs, although some portion of this demand would draw on a different pool, whose primary skills are related to the use of software rather than software development. Medical transcriptions and other forms of data entry, for instance, simply rely on high school or college graduates who know typing and possess language skills (for which they are trained). For instance, to transcribe the audiotaped diagnoses of physicians located in the US, Indian firms rely on software developers trained to understand English spoken with an American accent and who have the ability to type in English.

In turn, the ITES sector also shows a similar dynamic of growth to software. Salaries have increased phenomenally and there is high attrition as several multinationals rush to set up back-offices in India. The current recession has whetted the appetite for companies to outsource many important business functions as a way of cutting costs. It remains to be seen if the ITES sector will exhibit a similar switching to a growth regime driven by strong firm capabilities (as happened in software), once the abundant stock of human capital is exhausted and fresh graduates become much more expensive to hire.

Private Sector Response to Labour Scarcity: Investments in Training

The increasingly tight market for engineers and managers not only affected the organization of economic activity and the balance between capital and labour (or more precisely, between capital and human capital), resulting in organizational innovations, but also demonstrated the clearly increasing payoffs to human capital in individuals. In turn these also induced greater investment in human capital. The Indian middle class has always relied upon education, particularly professional education such as engineering or medicine as a means of economic advance. With a slowly growing economy and a sluggish manufacturing sector the returns to such investments have not been very high. The rapid growth of the software sector has, however, marked a watershed. One of the most rapidly growing sectors within the software industry is for private training.

Private training institutions train individuals specifically for work in software development (NASSCOM 1999). For instance, the National Institute of Information Technology (NIIT), one of the largest such training institutions, had around 10,000 students in 1999 in its GNIIT (Graduate NIIT) programme, a three-year programme for software developers, including a year of internship (professional practice) with a software development firm. Aptech, which claims to be the world's largest software training organization in terms of number of students (it has more than 1,200 franchisees and a presence in 40 countries, including the US, Europe and Australia), has an arm, Asset International, that specializes in training software developers. Asset International currently trains both software developers with work experience and fresh graduates in certification courses, such as Microsoft Certified Systems Engineers (MCSE) and Microsoft Certified Systems Developer (MCSD), Certified Novell Professional (CNP) and Oracle and IBM net commerce software developers. NASSCOM sources estimated that there were 3,800 such training firms in 1998, in what was then a $300 mn market. More recent estimates by Desai (2003) suggest that the supply of training was far more responsive and elastic. As individuals were prepared to pay for special training, existing educational institutions and new training institutions rose to the challenge. It is also noteworthy that this is a private sector response to a market opportunity, namely, the demand for training in specialized skills. In the US and elsewhere, for-profit firms compete with a variety of public institutions, such as state and community colleges.

Should Public Policy Respond to the Labour Scarcity?

The abundant human capital in the early phase of software growth certainly owed something to the policies followed by Nehru, who saw technical institutions as part of his vision of creating 'temples of modern India'. Yet, most industry insiders believe that the best thing to happen to software was liberalization and the non-interference of the state. With the success of the software industry, it has become almost impossible for the government to stay out. Not only is it eager to participate in the success, it has been called upon by industry to actively intervene in some areas, such as in the provision of better rules for venture capital and foreign investment, and in the provision of a better infrastructure in telecom and power.

An important call for government intervention also came in the wake of the shortage of engineers. As pointed out earlier, the sharp and sustained growth of the Indian industry meant that by 1998–99, the software industry was running out of engineers to hire. The public policy response to this situation was to create opportunities for increased investments in engineering colleges, increase emphasis on information technology in engineering curricula, and the creation of institutes of information technology (IIITs) along the lines of the better-known IITs. Though superficially reasonable, this is, however, not the answer (Arora and Athreye 2002). These investments are unlikely to have a significant effect on supply in the short run. Moreover, expanding such capacity faces the problem that the growth of the software industry has tended to siphon off engineering masters and Ph.D. students. This depletion of basic science and R&D resources does not augur well for the country's long-term technological capability.

The precarious state of public finances has also limited the ability of the central and state governments to expand tertiary education. The bulk of the Indian engineering capacity is located in just a few states—Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. Further, in these states the bulk of the capacity is accounted for by 'self-financed' colleges, where students receive much smaller subsidies, if at all, compared with the state-financed colleges. An interesting and hitherto unexplored issue is the reason behind the concentration of organizational innovation in self-financing colleges of these states, instead of diffusing to other parts of the country. We can only speculate that this has to do partly with cultural and political factors, and partly with the lower returns to investments in human capital in other parts of the country. It is perhaps not a coincidence that the south and west are also economically more advanced.

Although investments in engineering education are necessary, a bigger part of the solution lies in a more efficient use of existing human capital resources. As we showed in the first two sections, this is already happening. The growth of software salaries has prompted a more efficient use of engineering talent and the build-up of firm-level organizational capabilities. Though labour scarcity threatened the profitability of firms in the short-run, its long-term effect has been to improve industrial productivity by encouraging the adoption of efficient practices and stimulating investment in process management capabilities.

The success of software has demonstrated amply the rewards to literacy and training. The mushrooming growth of the ITES sector has reinforced this. A far more fruitful intervention by the government would be for public policy to cash in on this mood and increase spending on basic education, upon which further private training can build. The area of basic education at the school level still needs subsidizing by the government. To put this in perspective, consider the following: the annual cost of studying for an engineering degree at the Indian Institute of Technology, Delhi (one of India's premier state-funded engineering colleges) is lower than studying in Class II of any one of Delhi's better primary schools! Yet, could any student study in an IIT without studying at a good school first?

Second, the quality of basic education is highly uneven, especially between English-medium and the so-called vernacular schools that are more common in small towns and rural areas, and where many lower income groups send their children. Some of these schools also receive a large public subsidy. The protest in December 2000 by students of NDMC (New Delhi Muncipal Corporation) schools, demanding the right to be taught English at their schools to enhance their earning prospects, is a case in point. More can and should be done to bring parity in basic education across English- and vernacular-medium schools across the length and breadth of the country.

Investments in basic education have other pay-offs as well. They will help in the public use of computerization—such as in e-governance initiatives and in the maintenance of better financial and revenue records. Investment in literacy, concurrently with a rise in spending on such programmes can be a huge source of domestic demand for software services. Investments in basic education are also known to be beneficial for the reduction of poverty and the improvement of public health. With these investments in place, the software boom may yet form the basis of a more egalitarian growth in incomes for the economy as a whole.

Conclusions

This chapter concentrates on the role of software salaries in the growth of the Indian software sector. Most analyses of the software industry have concentrated on the wage advantage enjoyed by Indian software firms relative to software firms in other countries and the relative abundance of human capital. However, I have shown that the wage (scarcity) premium enjoyed by software employees vis-à-vis the rest of industry grew in the mid-1990s, prompting software firms to rethink their labour use strategies and also their employment terms to compete with their global rivals. The impact of labour scarcity, coupled with a buoyant demand in the mid-1990s, was to push the industry onto a somewhat more capital-intensive trajectory of growth. Some software firms also invested in developing process management capabilities and in managing large-scale labour resources, which are now being leveraged in other outsourcing activities. Thus, while abundant human capital was very important to kick-start the industry in the 1980s, the relative scarcity of programmers may have stimulated the development of firms' capabilities that have sustained the growth of exports and revenues since the mid-1990s. More importantly, the scarcity premiums to skilled labour have amply and clearly demonstrated the rewards to education and training to the economy's population, and also attracted much private investment in training provisions. Public policy would do well to use this opportunity to make investments in basic education, which ultimately feed these training programmes.

Notes

1. This part draws heavily upon Arora and Athreye (2002).
2. These are discussed in greater detail in Athreye (2005).
3. There is one significant exception—telecommunications-related software, where telecommunications engineers are required. Similarly, companies such as Texas Instruments, Oracle and Microsoft are locating development and R&D centres to tap into the engineering talent.
4. An early example of this was the setting up of Infosys by a group of employees that left Patni Computer Systems.
5. Kumar (2000) estimated that as many as 41 Indian software firms had adopted ESOPs in addition to pay in 1998–99.
6. Author's interviews with firms and industry analysts.
7. CMM stands for Capability Maturity Model—a certification procedure designed by the Software Engineering Institute at Carnegie Mellon University, to assess the quality of software processes in a firm.

References

Arora, A. and J. Asundi. 1999. 'Quality Certification and the Economics of Contract Software Development: A Study of the Indian Software Industry', NBER Working Paper No. W7260. Massachusetts: National Bureau of Economic Research.

Arora, A. and S. Athreye. 2002. 'The Software Industry and India's Economic Development', *Information Economics and Policy*, 14(2): 253–73.

Arora, A., V.S. Arunachalam, J. Asundi and R. Fernandes. 2001. 'The Indian Software Services Industry', *Research Policy*, 30(8): 1267–87.

Athreye, S. 2005. 'The Indian Software Industry and Its Evolving Service Capability', *Industrial and Corporate Change*, 14(3).

Desai, A. 2003. 'The Dynamics of the Indian Information Technology Industry', DRC Working Paper No. 20, Centre for New and Emerging Markets, London Business School, London.

Heeks, R. 1996. *India's Software Industry: State Policy, Liberalization and Industrial Development*. London: Sage Publications.

Kumar, N. 2000. 'Developing Countries in the International Division of Labour in Software and Service Industry: Lessons from Indian Experience', Version 2.1 (mimeo) New Delhi. Research and Information System for Developing Countries.

Lakha, S. 1994. The New International Division of Labour and the Indian Software Industry', *Modern Asian Studies*, 28(2): 381–408.

NASSCOM (National Association of Software and Services Companies). 1999. The Software Industry in India: A Strategic Review. New Delhi: NASSCOM

———. Various volumes. Indian IT Software and Services Directory. New Delhi: NASSCOM.

National Task Force. 1999. *Basic Background Report* (BR-3) for the National Task Force on Information Technology (IT) and Software Development, submitted to the Prime Minister of India, 18 March.

World Employment Report. 2001. *Life at Work in the Information Economy*. Geneva: International Labour Office.

Websites

www.man.ac.uk
www.nasscom.org

5

Has the New Economy Created Wealth? A Study of Infotech Companies

J. Dennis Rajakumar

Introduction

Sources of wealth creation and accumulation have been changing over time. Centuries ago, agriculture was the prime mover of economic activities and hence was the primary source of wealth. With changes brought about by the Industrial Revolution, manufacturing replaced agriculture in the course of time. The larger needs of industrial capital gave rise to joint stock companies with the capital market as a medium of dispersing ownership among individuals. Over the years, the market has played a fundamental role in not only providing capital but also in enhancing wealth. With rapid advances in sciences, knowledge has become the 'new basis for wealth', and the advent of knowledge-based firms moved the trajectory of wealth creation to a new stage

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(Thurow 1999). Yet, the capital market continues to remain important in wealth creation.

In India, manufacturing was seen as a vehicle of growth and received greater thrust in development planning. Keeping in line with changes taking place around the world, in India too the focus shifted to knowledge-based industries, which are a feature of the 'new economy'. Policy emphasis on the new economy was evolving even before the 1990s (Heeks 1996), and there was a sharp and continued focus on it in the 1990s as well because of its export potential. Many companies belonging to the new economy entered the capital market in order to meet their increasing fund requirements.

There are differing views on the allocative efficiency of the capital market in India. It has been observed that the market was weakly efficient in the 1990s (Nagaraj 1996; Rajakumar 2001; Singh 1998). There has, however, been overwhelming activity in the market with respect to stocks of companies belonging to the new economy. This strengthens the view that the source of wealth creation has moved to a new stage with the capital market acting as the medium. Whether or not this has been achieved can be better understood using capital market valuations, which this paper seeks to address. The new economy is a broad canvas, and hence the discussion is confined to a very important constituent of it, the infotech sector.

The paper is organized in two sections. Since the capital market plays a fundamental role in the analysis, the first deals with certain important market indicators relating to infotech companies. These indicators are compared with that of some other selected industry groups. In the next section, I discuss techniques such as economic value added and market value added, which are used to measure wealth. I then present estimates of wealth generated by infotech companies and discuss probable contributory factors of such wealth.

Financial Market Indicators

By infotech companies, I shall refer to those firms offering computer-related products or services and these include computer accessories, hardware, software and training. To understand how the capital market values these companies, I have examined trends in the number of listed companies and composite price to earnings (P/E) ratios. I have also related share prices of individual companies to their respective earnings. To provide a perspective on market valuation of the infotech segment, indicators have been compared with industries that received priority in development planning. These include cement, heavy engineering, power, textiles, and automobiles. In addition, I have included some modern industries such as personal care and pharmaceuticals.

Trends in the Listed Companies

As far as the infotech sector is concerned, entry is relatively easy for two reasons: first, it is not highly capital intensive; and, second, there is a readiness on the part of many venture funding agencies to provide the required seed capital. While entry is easy, getting it listed in a stock exchange requires compliance with various prescribed listing norms. As these norms set the standard for better working of companies, the number of listed companies can be used as an indicator of its relative attractiveness in the capital market (Table 5.1).

TABLE 5.1 Number of Listed Companies: Selected Industries (1996–2002) (as on the last week of March)

Industry Groups	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Infotech							
Computer Accessories	2	2	2	5	9	8	3
Computer Hardware	12	11	12	13	16	13	8
Computer Software	9	14	16	32	104	141	113
Computer Training	NA	3	4	8	9	6	5
Total	23	30	34	58	138	168	129
Others							
Auto—2 and 3 Wheelers	10	8	9	10	12	12	9
Auto—LCVs/HCVs	6	6	6	5	5	5	5
Cement—Major	17	23	23	23	22	21	23
Cigarettes	4	4	4	4	5	5	4
Heavy Engineering	21	25	21	22	25	25	14
Personal Care	14	13	13	15	19	17	12
Pharmaceuticals	64	81	76	83	170	164	85
Power Gen. and Distn	7	9	9	10	10	9	7
Refineries	NA	9	9	9	9	9	9
Textiles—Composite Mills	22	19	15	14	19	16	9
Textiles—Spinning and Cotton Blend	24	39	32	35	33	32	29
Telecom Equipment	14	13	14	14	19	20	14

Source: *Dalal Street Investment Journal*, various issues.

As seen in Table 5.1, there has not been much of a rise in the number of listed companies across the board except for infotech and pharmaceuticals. In particular, the number of listed infotech companies registered a sharp rise from 23 in 1996 to 58 in 1999, and further to 168 in 2001. Computer software firms dominated the infotech segment with a share of more than 80 per cent. The number of pharmaceutical companies was 64 in 1996 which went up to 83 in 1999 and then doubled to 170 in the next year. The trend in listed companies of all other industries showed very little change. Thus, infotech companies, especially software companies, have been a major attraction in the capital market since the mid-1990s.

Industry Composite P/E Ratios

Price–Earnings ratio (P/E ratio) gives the multiples of price paid for a share with respect to its earnings, denoted by earnings per share (EPS). Given the EPS, the multiple reflects the number of years it takes to recoup the value of investment. Larger P/E ratio means a longer period required to do this, unless the companies exhibit tremendous growth opportunities. Table 5.2 gives the industry composite of P/E ratio of infotech companies along with that of other selected industries.

The P/E ratio of many industries showed an upward trend until 2000, after which it declined. In the initial years, only personal care had high P/E ratios, followed by cigarettes. They were, however, outperformed by the infotech sector in the subsequent years, with its composite P/E ratios rising phenomenally from 24.9 in 1998 to 81.9 in 1999 and further to 223.3 in 2000. The same has come down to 40.4 in 2001 and further down to 23.7 in 2002. The P/E ratios of 2001–02 are, however, comparable with other industries. More importantly, the ratio of computer software continued to be high and second only to the personal care industry in 2002.

Share Prices and Earnings

It was noticed that the infotech sector had a record of the largest number of listed companies in 2001 and the highest P/E ratio in 2000. The P/E ratio has been computed taking into account the closing price of the accounting year, which conceals intra-year price movements. During 2000–01, there was a phenomenal rise and fall in the share prices

TABLE 5.2 Industry Composite Price–Earnings (P/E) Ratios: Selected Industries (1996–2002) (as on the Last Week of March)

Industry Groups	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
Infotech							
Computer Accessories	9.2	2.0	1.9	14.9	46.1	19.4	9.1
Computer Hardware	13.6	4.8	8.5	3.6	22.2	3.2	9.2
Computer Software	16.4	10.1	24.9	81.9	223.3	40.4	23.7
Computer Training	NA	13.6	22.3	5.3	111.8	11.4	7.4
Others							
Auto—2 and 3 Wheelers	21.0	18.1	19.2	20.0	13.1	7.6	20.4
Auto—LCVs/HCVs	30.0	16.0	9.7	14.3	11.8	7.0	4.9
Cement—Major	19.1	7.2	11.6	13.5	16.0	6.6	17.9
Cigarettes	30.3	31.7	52.2	41.3	27.7	27.4	16.4
Heavy Engineering	11.4	32.3	22.0	11.0	10.9	9.9	12.6
Personal Care	48.6	51.0	52.7	52.5	49.1	18.9	29.1
Pharmaceuticals	20.6	13.6	17.2	28.7	30.7	19.5	19.0
Power	12.5	8.3	11.1	5.9	7.8	6.9	7.8
Refineries	NA	16.3	18.7	6.6	6.5	5.6	8.0
Textiles—Composite Mills	12.5	8.3	11.7	7.8	7.4	2.3	6.6
Textiles—Spinning and Cotton Blend	7.5	7.2	4.1	3.5	4.1	2.3	2.6
Telecom Equipment	21.4	4.1	5.1	14.3	103.8	9.3	4.7

Source: *Dalal Street Investment Journal*, various issues.

of infotech companies. This was, therefore, considered as the reference year. In a two-way distribution table, we have the distribution of firms for different intervals of high price against certain range of EPS.[1] Of the total 168 companies listed in 2000–01, only 114 (about two-thirds) were considered due to limited availability of relevant data (Table 5.3).

As seen from Table 5.3, the share price of more than two-thirds of the firms were valued at higher than Rs 100. Of these, 20 had a value of more than Rs 1,000. Share prices of six companies had exceeded Rs 5,000, out of which two had extended beyond Rs 10,000. The share price in 2001 was related to the EPS in 1999–2000. As high as 80 per cent of the firms reported EPS of less than Rs 10, with 13 firms reporting net loss (negative EPS). Stocks of these companies were, however, traded for prices exceeding Rs 25. Nearly half of them were traded between Rs 200 and Rs 1,000. Little more than one-third (41 companies) reported EPS of less than Rs 2.5. Stocks of two such companies were traded in the range of Rs 500–1,000 and Rs 2,000–5,000. The correlation co-efficient between EPS and closing prices during 2000–01 was 0.52.[2] This suggests a weak association

TABLE 5.3 Distribution of Firms—High Share Prices of 2000–01 by Earnings per Share (EPS)

High Share Price during 2000–01	*EPS of 1999–2000 (Range in Rs)*							
(Range in Rs)	*Negative*	*0–2.49*	*2.50–4.99*	*5–9.99*	*10–24.99*	*25–49.99*	*50+*	*Total*
11–25	0	7	0	0	0	0	0	7 (6.1)
26–50	2	11	0	2	0	0	0	15 (13.2)
51–100	4	10	2	1	0	0	0	17 (14.9)
101–200	1	7	7	1	1	1	0	18 (15.8)
201–500	4	6	5	5	1	0	0	21 (18.4)
501–1,000	2	1	3	4	4	2	0	16 (14.0)
1,001–2,000	0	0	0	2	3	0	0	5 (4.4)
2,001–5,000	0	1	0	3	2	2	1	9 (7.9)
5,001–10,000	0	0	1	0	1	1	1	4 (3.5)
10,001+	0	0	0	0	0	2	0	2 (1.8)
Total	13 (11.4)	43 (37.7)	18 (15.8)	18 (15.8)	12 (10.5)	8 (7.0)	2 (1.8)	114 (100)

Note: Figures in brackets are percentages to total.
Source: *Dalal Street Investment Journal*, various issues.

between a company's share price and its earnings. Higher prices paid for shares of infotech companies are thus not firmly based, that is, the market valuation is not based on existing fundamentals, such as current earnings. The high share prices have to, therefore, be explained by their growth potential and opportunities.

The analysis so far suggests that the infotech sector commanded a higher premium relative to other industries, which can be attributed to market perception of its growth potential. How real was their growth potential? This can be understood in terms of wealth generated by these companies, which adds to shareholders' value.

Wealth Created by Infotech Firms

In this part, I estimate the wealth created by infotech companies and trace its possible determinants. To begin with, I briefly discuss techniques used for measuring wealth and problems encountered while operationalizing these techniques. The Appendix provides an account of how the variables used for estimation have been constructed.

Measurement Techniques and Data

In the framework proposed here (see Appendix), capital market mechanisms play a fundamental role in wealth creation. The market value of firms depends upon two factors: existing assets and growth opportunities (Damodaran 2001). Conventionally, profitability is measured in terms of returns on capital employed, taking into account current earnings and book value of only existing assets. Since market evaluation depends upon growth opportunities, we need to compute return not only in relation to current earnings, but also to prospective earnings. The market price of shares embodies expectation of future earnings and so becomes crucial in our framework. Techniques such as Economic Value Added (EVA) and Market Value Added (MVA) consider market prices and are thus generally accepted for measuring wealth.[3]

More precisely, a company creates surplus (wealth) if its return is greater than the cost of capital measured in terms of market value. This is measured by EVA, which is given as:

$$\text{EVA} = \text{Net Operating Profits} - (\text{Weighted Average Cost of Capital} * \text{Capital Employed})$$

If EVA is positive, the company is said to have created wealth, or else it has destroyed shareholder value. Since profits earned are the net cost of the capital used to generate cash flows, they are termed 'real' profits or 'economic' profits. EVA thus measures productivity of all factors. To quote Drucker in this context:

> Until a business returns a profit that is greater than its cost of capital, it operates at a loss. Never mind that it pays taxes as if it had a genuine profit. The enterprise still returns less to the economy than it devours in resources. It does not cover its full costs unless the reported profit exceeds the cost of capital. Until then, it does not create wealth; it destroys it.... By measuring the value added over all costs, including the cost of capital, EVA measures, in effect the productivity of all factors of production (Drucker 1995: 59).

The other measure of wealth is MVA, which gives the extent to which market value of a firm exceeds its book value. It is given by

$$\text{MVA} = \text{Market Value of Firm} - \text{Book Value of Firm}$$

Like EVA, firms are said to have generated wealth if MVA is positive. Here, the book value of firms is identified with replacement cost, such that MVA becomes a variant of Tobin's q, which is the ratio of market value of firms to replacement cost (Tobin and Brainard 1977). According to Tobin's q, a firm should invest if its market value is greater than its replacement cost.[4] That is, the gain for the investing firm is q–1. In a similar vein, MVA measures gain in the form of wealth.

On comparing the variables used in both these techniques, a conceptual difference between these two techniques can be discerned. While variables used for estimating EVA are concerned with current years only, those of MVA are outstanding figures at the end of the year. Thus, it can be argued that EVA is a flow concept, whereas MVA is a stock concept, so that the estimates of EVA are likely to be lower than those of MVA. Moreover, MVA is sensitive to market dynamics—a bull run would increase it, whereas a bearish mood would reduce it. Thus, MVA can be expected to fluctuate widely, depending upon the condition of the market, more than EVA.

It may be mentioned that only in recent years have these wealth measuring techniques been adopted by companies in India for performance evaluation of various processes/departments, fixing of employees' compensation packages, and so on. Many companies provide MVA and EVA data in their annual reports as pointers of wealth created by their management. However, not many studies have been undertaken attempting to employ these techniques in a macro perspective.

Given the capital market-centric economic policy of the 1990s, the focus has drifted to value creation away from cost control, which hitherto underlined policy formulation. As aptly remarked by Drucker (1995: 58), 'Enterprises are paid to create wealth, not control costs'. Thus, for sustaining capital markets, value creation is important, and hence these techniques assume significance.

At the same time, there are data constraints while operationalizing these techniques. The problem is intense in the case of software companies, as we shall see later.

Data Source and Problems Data for analysis was collected from the electronic database of the Centre for Monitoring Indian Economy (CMIE), called PROWESS.[5] PROWESS is a near-reproduction of information given in respective annual reports of those companies included in the database. We faced the following problems while using the information given in PROWESS.

First, companies selected for analysis are registered under the Indian Companies Act of 1956, which are subsequently listed in stock exchanges. The Act requires each of these companies to prepare their final accounts in a prescribed format. For instance, balance sheets have to be prepared consistent with the format specified in Schedule VI, Part A of the Act. This format was designed a long time back, largely keeping in view the nature of manufacturing activities. It is different from the one prescribed for commercial banks in Form A of the third schedule of the Banking Regulation Act, 1949, the reason being that banking services are different from those of manufacturing companies. The activities and kinds of assets of infotech firms are, however, quite different from those of manufacturing companies. Nevertheless, they need to report their final position in the format prepared largely for the latter. Accordingly, infotech companies have to modify and classify information to satisfy the statutory requirements of the Companies Act.

The second problem relates to the concept of capital. For manufacturing firms, it refers to tangible fixed assets used in the production process, and so this form of asset constitutes a major chunk of total assets of manufacturing companies. On the contrary, infotech companies rely on the productive power of human capital, that is, intellect. While the reward for services of human capital gets accounted for in the revenue recognition, human capital does not get reported in the final accounts. As long as growth of infotech companies is 'powered by intellect', non-reporting of human capital would conceal its true value. Very few companies provide the valuation of their human capital and that too outside the balance sheet. This compounds the problems of valuing infotech companies using their balance sheet information.

The third issue relates to classification of firms by PROWESS. A company is classified under a product group which contributes more than half of its gross sales. It was, however, noticed that while the life cycle of a majority of firms, such as Infosys, belonged to the infotech category right from their inception, some existing companies like Wipro diversified and became infotech companies in course of time. PROWESS does not report this shift. Moreover, once a company is categorized under a group, it is not possible to get the break-up of revenues from its various other activities. The entire current and past information, say, of Wipro, has to be treated as if it relates to the infotech sector. Similarly, we cannot get information about a company which originally belonged to the infotech sector, but has moved to other product groups over the years.

These problems give rise to complications while using PROWESS information. Since there is no systematic reporting of information pertaining only to the infotech sector, this is the only option. There is also no way of determining the census frame, and so we could not blow up the sample estimates to arrive at population estimates. Moreover, there is a large number of firms not registered under the Company Act and not listed in the stock exchanges. The estimates presented in the following sub-section can, therefore, be taken as representing the lower bound.

Trends in Wealth Creation

Tables 5.4 and 5.5 give the estimates of EVA and MVA, respectively, for the period 1995–96 to 2001–02.[6] My scheme of presentation of estimates is as follows: first, estimates are reported for all sample companies; second, due to the possibility of EVA and MVA being negative, estimates are presented only for those companies with positive values; and third, the relative share of the top five companies is worked out in order to understand the concentration of wealth.

Trends in EVA and MVA As seen in Table 5.4, EVA had not only remained positive, but had continuously increased over the years. The marginal decline in 2001–02 can be attributed to the reduced number of sample companies. The EVA of all companies was 0.01 per cent of GDP in 1996–97, which then increased to 0.17 per cent in 2000–01. When companies with positive EVA alone were considered, total wealth increased by a small margin. It indicates that there are wealth-destroying infotech companies in the sample. At the same time, the share of top five companies in the total EVA was 39 per cent in 1995–96, which sharply rose to 82 per cent in 2001–02. This shows that the increase in overall EVA has been accounted for by the spectacular wealth creation of the top five companies.

Like EVA, the MVA also remained positive throughout the period (Table 5.5). It was in the order of 0.13 in 1995–96, which subsequently rose to 4.21 per cent in 2001–02. The increase was steady except for 1999–2000, when it rose sharply to 18 per cent. It was earlier noted that MVA is conceptually a stock and EVA is flow and hence MVA is expected to be greater than EVA. This is borne out by the evidence of MVA (as percentage of GDP) being higher than EVA.

Thus, there are wealth creating and destroying companies as indicated by the difference between all sample companies and companies with only positive MVA. Here again, the top five companies account for more than three-fourths of the MVA, which is substantially higher than their share in EVA.

The analysis reveals that the infotech sector has created substantial wealth. However, the top five companies accounted for the bulk of such wealth. The question is whether or not these companies distribute the wealth which they accumulate. To gauge this, I shall examine shareholding patterns.

Shareholding Patterns of the Top Five Companies The same firms did not occupy top five positions throughout the period. A few firms went out of this list and others upgraded to it in course of time. All firms which appeared at least once in the list of the top five companies were considered for the study. Data on shareholding patterns was available for 30 September 2002.

TABLE 5.4 Trends in Economic Value Added of Infotech Companies (1995–96 to 2001–02)

	All Companies			*Companies with Positive EVA*			
Year	*No. of Companies (1)*	*Total EVA (Rs bn) (2)*	*As % of GDP (3)*	*No. of Companies (4)*	*Total EVA (Rs bn) (5)*	*As % of GDP (6)*	*Share of Top 5 Companies as % of (5) (7)*
1995–96	75	2.30	0.02	62	2.58	0.02	38.8
1996–97	94	0.75	0.01	49	2.00	0.02	54.0
1997–98	108	3.20	0.02	60	4.20	0.03	51.2
1998–99	112	5.58	0.03	76	6.75	0.04	52.6
1999–2000	135	12.90	0.07	101	13.84	0.08	56.1
2000–01	142	32.96	0.17	107	34.44	0.18	60.9
2001–02	92	26.95	0.13	50	30.85	0.15	81.9

Source: PROWESS database, CMIE. For national income, see EPWRF (2002).

TABLE 5.5 Trends in Market Value Added of Infotech Companies (1995–96 to 2001–02)

	All Companies			*Companies with Positive EVA*			
Year	*No. of Companies (1)*	*Total MVA (Rs bn) (2)*	*As % of GDP (3)*	*No. of Companies (4)*	*Total MVA (Rs bn) (5)*	*As % of GDP (6)*	*Share of Top 5 Companies as % of (5) (7)*
1995–96	75	13.57	0.13	62	21.88	0.20	73.2
1996–97	94	14.88	0.12	49	25.52	0.21	77.7
1997–98	108	106.96	0.77	60	113.93	0.82	79.9
1998–99	112	573.25	3.55	76	577.73	3.57	69.8
1999–2000	135	325.92	18.24	101	326.17	18.26	76.6
2000–01	142	822.02	4.34	107	832.74	4.39	89.8
2001–02	92	853.50	4.13	50	871.70	4.21	89.8

Source: PROWESS database, CMIE. For national income, see EPWRF (2002).

TABLE 5.6 Shareholding Pattern as on 30 September 2002: Selected Categories

Company Name	*Foreign*	*Corporation*	*Directors*	*Other*
Digital Globalsoft Ltd	65.92	2.54	NA	14.93
GTL Ltd	14.45	12.71	25.52	41.59
HCL Infosystems Ltd	0.62	4.72	63.42	22.14
HCL Technologies Ltd	6.38	4.15	77.1	6.48
Information Technologies (India) Ltd*	2.82	25.5	44.23	22.5
Infosys Technologies Ltd	38.73	1.08	28.55	21.93
NIIT Ltd	35.46	7.96	30.71	19.33
Pentamedia Graphics Ltd*	6.2	15.16	2.5	73.85
Silverline Technologies Ltd*	35.32	10.97	NA	51.73
Satyam Computer Services Ltd	43.92	2.44	21.61	19.77
Tata Infotech Ltd.	0.62	2.39	74.77	20.97
Wipro Ltd.	5.08	1.77	84.04	7.69

Notes: *Relates to 30 June 2002; NA denotes not available.
Source: PROWESS database, CMIE.

As seen in Table 5.6, the shareholding pattern was highly skewed, with promoters/directors and foreign investors having a major stake in most of the top five companies. Only in three companies out of 12 was the 'Others' (largely public) holding higher than 40 per cent. The companies which consistently appeared in the list, namely, Digital Globalsoft, HCL Infosystems, HCL Technologies, Infosys Technologies, NIIT, Satyam Computer Services and Wipro, had overwhelming holdings by either promoters/directors or foreign investors. Thus, there is a tendency of wealth created by infotech companies to get concentrated in very few hands.

Wealth Creation and Capital Allocation I had earlier observed that the P/E ratio of the infotech sector was higher than many other industries in the late 1990s. Subsequent to changes in policies in 1992, the prevailing market price became the primary factor for fixing the price at which new and further capital could be issued. If the market price is more than face value, companies can issue capital at a premium.

An analysis of various sources of funds reveals that infotech companies have increasingly resorted to capital market funding since 1997–98. In particular, the proportion of share premium, which was meagre in 1997–98, sharply rose to 32.4 per cent in the subsequent year and constituted more than half of the total fund raised in 2000–01 (Table 5.7). In 2001–02, this again came down. The substantial proportion of premium is yet another reflection of the market's perception about the growth potential of infotech companies.

TABLE 5.7 Sources of Funds of Infotech Companies (as percentage of total)

Sources of Funds	*1997–98*	*1998–99*	*1999–2000*	*2000–01*	*2001–02*
A. Internal	59.2	50.4	43.2	37.6	60.8
Reserves	37.4	35.3	32.5	29.4	46.0
B. External	40.8	49.6	56.8	62.4	39.2
Capital Market	10.2	39.1	53.2	50.1	25.2
Fresh Capital	5.0	4.8	11.4	1.5	2.2
Share Premium	3.5	32.4	39.2	52.9	23.5
Total (A + B)	100.0	100.0	100.0	100.0	100.0
No. of Sample Companies	107.0	113.0	135.0	142.0	92.0

Source: PROWESS database, CMIE.

How does wealth creation compare with capital allocated to this sector? To examine this, I consider fresh capital plus share premium as the quantum of new capital allocated to these companies.[7] The EVA and MVA of a given financial year is a result of capital at the end of the previous year and that added during the year. As noted earlier, the fundamental difference between EVA and MVA is that while the former follows the flow concept, the latter follows the stock concept. Thus, EVA is more appropriate to understand if wealth is created for every rupee of capital allotted to these companies (Table 5.8).

TABLE 5.8 Trends in EVA and MVA per Unit of Additional Capital Allocated (in rupees)

Indicators	*1997–98*	*1998–99*	*1999–2000*	*2000–01*	*2001–02*	*Mean*
For all Sample Companies						
1. EVA (Rs)	299	68	51	57	203	136
2. MVA (Rs)	10,006	6,933	12,992	1,424	6,412	7,554
Sample Excluding Top 5 Companies						
1. EVA (Rs)	174	40	23	23	34	59
2. MVA (Rs)	1,614	5,319	3,209	170	1,460	2,354

Source: PROWESS database, CMIE.

As seen in Table 5.8, for every rupee allocated to infotech companies, there has been substantial amount of wealth created. If EVA alone is considered, on an average Rs 136 was created for every rupee and it came down to Rs 59 if the top five companies were excluded. When MVA is considered, the wealth created per unit of capital becomes substantial. Undoubtedly, these results suggest that the infotech sector has created wealth for every additional unit of capital allotted to it.

Factors Contributing to Wealth Creation

The magnitude of wealth created by infotech companies is so large that it calls for examining the contributory factors. The sector has a competitive advantage globally because of a fairly elastic supply of skilled human resources in India and its high export potential. Therefore, I have examined if these factors lead to wealth creation along with profit margins. Movements of these variables are expected in the same direction as noticed with respect to EVA and MVA.

To benchmark the performance of these factors, I have worked out similar ratios for public limited companies from RBI's study of company finances (RBI 2001, 2002, 2003). It may be noted that RBI's study comprised companies belonging to over 20 industry groups, predominantly from the manufacturing sector.

Human Capital It is generally argued that growth of the infotech sector is powered by human capital. Following a conventional analysis, this could be gauged by calculating labour productivity. Kumar (2001) has measured the productivity of human resources in the software industry as revenue per unit of wage bill. I have used a similar ratio and wage share in gross value added in order to understand if the performance of human capital is a contributory factor for wealth creation (Table 5.9).

It can be noticed from Table 5.9 that the percentage of wage to sales showed an upward trend and it more than doubled between 1997–98 and 2001–02 from 12.4 per cent to 26.5 per cent. Wage not only constituted a major portion of gross value added but its magnitude increased over the years. It accounted for 36 per cent in 1997–98, and then sharply rose to 47 per cent in 2001–02. These trends signify the role of high performance of human capital in the wealth generation process. The infotech sector's performance has been substantially greater than that of its manufacturing counterparts, as shown by the RBI study.

TABLE 5.9 **Trends in Human Capital Productivity**

Sector	*1997–98*	*1998–99*	*1999–2000*	*2000–01*	*2001–02*
Infotech Sector:					
Wage to Sales (%)	12.4	14.1	16.1	19.1	26.5
Wage to Gross Value Added (%)	35.8	36.7	37.3	38.3	46.5
RBI Study:					
Wage to Sales (%)	6.5	6.7	6.5	6.5	6.2
Wage to Gross Value Added (%)	26.9	28.4	28.1	28.5	28.1

Source: Infotech sector—PROWESS database, CMIE. For the RBI study, see RBI 2001, 2002, 2003.

Export Propensity The infotech sector has received overwhelming financial and infrastructure backing because of its export potential. The share of software exports in India's total export of goods and services increased from 4.41 per cent in 1998–99 to 7.89 per cent in 2000–01 (Kumar 2001). It has further been pointed out that growth of the infotech sector has been propelled by concerns of export (Desai 2002). The export propensity of the sample companies has been calculated using the following measures:

Export Intensity = Total Export to Sales
Net Export Ratio = Total Export – Total Import to Total Export

In 1997–98, export of infotech companies constituted more than one-third of the total sales and it more than doubled in 2001–02, which indicates that a large part of the revenue had originated from their exports (Table 5.10). Moreover, they are net exporters with the net export to sales rising phenomenally. The export intensity of manufacturing companies, as revealed by the RBI study, was relatively lower, although it showed a rise from 10.5 per cent in 1997–98 to 16.2 per cent in 2000–01. More importantly, the sample in the RBI study imported more than what they exported. The greater export orientation of infotech companies is no doubt a major contributory factor for wealth creation.

Profit Margin There is a positive relationship between profit margin and wealth. First, better profit margin influences dividend payout, and second, sustained margin is an indicator of growth. They have significant bearing on the market perception of the growth potential, which gets reflected in wealth. Profit margin is defined here as net profit (profit after tax) to sales, and net profit to gross value added.

TABLE 5.10 **Trends in Export Propensity**

Sector	*1997–98*	*1998–99*	*1999–2000*	*2000–01*	*2001–02*
Infotech Sector:					
Export to Sales	31.1	39.5	46.4	57.9	64.4
(Export–Import)/Export	15.0	31.9	34.6	43.6	45.3
(Export–Import)/Sales	4.7	12.6	16.1	25.2	29.2
RBI Study:					
Export to Sales	10.5	13.8	14.2	16.2	13.3
(Export–Import)/Export	–41.8	–24.3	–18.1	–4.2	–35.2
(Export–Import)/Sales	–4.4	–3.3	–2.6	–0.7	–4.7

Source: Infotech sector—PROWESS, CMIE. For the RBI study, see RBI (2001, 2002, 2003).

From Table 5.11, we see that the profit margin of infotech companies had risen phenomenally from 9.5 per cent in 1997–98 to 23 per cent in 2000–01. This, however, declined to 19.3 per cent in 2001–02. The net profit constitutes nearly one-third of the gross value added. The year 2000–01 witnessed the highest profit margin; which coincides with the high amount of wealth created. It thus supports a near-direct relationship between profit margin and wealth, particularly as measured by the EVA. The profit margin of the infotech sector has been well above the RBI's sample of public limited companies.

TABLE 5.11 **Trends in Profit Margin**

Sector	*1997–98*	*1998–99*	*1999–2000*	*2000–01*	*2001–02*
Infotech Sector:					
Net Profit to Sales (%)	9.5	12.4	17.5	23.0	19.3
Net Profit to Gross Value Added (%)	27.2	31.2	38.0	43.4	33.9
RBI Study:					
Net Profit to Sales (%)	4.6	3.3	3.4	3.4	2.6
Net Profit to Gross Value Added (%)	18.9	14.2	14.9	14.8	11.7

Source: Infotech Sector—PROWESS database, CMIE. For the RBI study, see RBI (2001, 2002, 2003).

Concluding Remarks

This paper attempted to study the dividends obtained from the new economy by focusing on wealth created by infotech companies. This study assumes relevance in the context of a surge in capital market activities in the 1990s, wherein companies belonging to the new economy enjoyed a tremendous goodwill. While there has been an argument that the capital market is not efficient in its allocative mechanism, it is important to examine whether such views hold good for new economy companies too. Central to such a view is the value creation by the capital market that could be captured through wealth created by companies. In this study, infotech companies of the new economy were considered and the extent of wealth created by them studied. This paper concludes with the following observations:

1. Infotech companies have definitely created wealth, howsoever measured. This has increased both in terms of absolute amount and as a proportion of the national income, implying that the rate of growth of wealth generated by this sector outweighs the rate of growth of national income.
2. The relative share of the top five companies in the total wealth created was not only large but increased within the period studied. These companies of the top slot had about 39 per cent of EVA in 1995–96, which more than doubled to 82 per cent in 2001–02. A similar trend with higher magnitude was also observed when wealth was measured in terms of MVA.
3. Most of the top five companies had a skewed shareholding pattern, with either directors/promoters or foreign investors having a major stake, and public holding being very low. This indicates that the benefits of growth in the infotech sector tend to be poorly distributed.
4. The infotech sector has, on an average, created wealth for every additional unit of capital allotted to it. This is so despite the fact that there are a few companies which suffered losses. This evidence somewhat undermines the argument of inefficient allocation of funds by the capital market, at least with respect to infotech companies. It may, however, be pointed out that wealth created tends to get concentrated in a few hands.
5. Impetus to wealth creation of the infotech sector has come largely from its improved performance of human capital, export

orientation and high profit margin. These indicators have better performance in case of infotech companies as compared to public limited companies of the RBI study.

6. The larger share of labour in value addition, greater export propensity and higher profit margins indeed give effect to policies that encourage the expansion of the infotech sector and view it as a driver of growth.

Appendix

Construction of Variables

Net Operating Profits (NOP): This refers to the operating cash flow net of tax. It is given as:

$$\text{NOP} = \text{Operating Profit} + \text{Interest Expense} - \text{Tax Provision}$$

Weighted Average Cost of Capital (WACC):[8] This is given by

$$\text{WACC} = \omega_E K_E + (1 - \omega_E)\, K_D$$

where ω_E = Weights of Equity Capital = Equity/(Equity + Total Debt)
K_E = Cost of Equity Capital
K_D = Cost of Debt

Cost of Equity (K_E) (Ross et al. 2000): This has been computed following the constant growth dividend discount model.[9] It is given by

$$K_E = D_t/P_E + g$$

where $D_t = D_{t-1} * (1 + g)$
D = Dividend paid
g = Dividend growth rate[10]
P_E = Market value of equity

Market Value of Equity = Closing Price[11] * Total Number of Shares = Market Capitalization

Cost of Debt (K_D): Since there is no active secondary debt market in India, the market value for debt could not be calculated. Moreover, return on debt is fixed and obligatory. Interest paid on debt is allowed to be deducted while computing tax liability. There is thus some implicit tax advantage, which needs to be netted out from the cost (Rajakumar 2001). Taking these factors into account, the cost of debt has been worked out as:

$$K_D = I\,(1 - \tau)/D$$

where I = Interest expense
D = Total debt outstanding
τ = Corporate tax rate

Capital Employed (CE): It is defined as shareholder fund *plus* borrowed capital.[12]

$$CE = \text{Net worth} + \text{Borrowings}$$

where Net worth = Share capital + Reserves and surplus

Market Value of Firm (MV): This refers to the market valuation of firms. Firms have three major forms of capital which are valued in the market, namely, equity, preference and debt. Of these, only equity valuation is relevant in the Indian context, given the virtual non-existence of a secondary market for debt when preference capital is not resorted to. I had netted out inventory from this. Hence market value is defined as:

MV = Market Value of Equity + Book Value of Debt – Inventory[13]

Book Value of Firm: This refers to the replacement cost of capital, that is, gross fixed assets. Gross fixed assets are generally expressed at historic cost. The sample firms were of different vintage, as can be noticed from Table 5.1A.

TABLE 5.1A **Distribution of Sample by Year of Incorporation**

Year of Incorporation	*No. of Firms*
Before 1980	5
1980–84	16
1985–89	30
1990–94	75
1995–2000	31
Total	157

To measure actual value of gross fixed assets, the latter have to be adjusted. This calls for capital stock estimation at firm level. Having estimated for a base year, one can then arrive at capital stock existing at various points of time using the perpetual inventory method. Such an exercise requires a revaluation factor for a base year. To calculate this, I used the methodology as given by Srivastava (1996). The replacement factor (R_f) is given as:

$$R_f = \{[(1 + g)^{t+1} - 1]\,(1 + \pi)^t\,[(1 + g)(1 + \pi) - 1]\}/\{g([(1 + g)(1 + \pi)]^{t+1} - 1)\}$$

where g = growth rate of capital formation
π = the growth rate of price of capital.

As base year, 1999–2000 was taken, when all sample firms had reported gross fixed assets. I had taken gross fixed capital formation of the registered manufacturing sector as a measure of capital formation and their implicit deflator as the price of capital (1993–94 = 100). As followed elsewhere (Rajakumar 2001), I have considered 20 years as the average age.

Notes

1. The high prices prevailing during the 52 weeks of the accounting year (April to March) were considered.
2. When EPS was correlated with low prices, high prices and the average of low and high prices, the correlation coefficient did not improve.
3. The concepts of EVA and MVA were popularized by the New York-based consulting firm, Stern, Stewart and Co. In fact, the company enjoys trademark rights over the term Economic Value Added (EVA). See Stern et al. (1997).
4. Application of Tobin's q is generally found in empirical studies on investment theories. For studies in the Indian context, see Rajakumar (2001).
5. For a review of its strengths and weaknesses, see Shanta and Rajakumar (1999).
6. The survey conducted by Business Today–Stern Stewart (2002) attempted to identify wealth creators of India Inc., including companies belonging to the public sector. Interestingly, the survey found that the largest wealth creators belonged to the infotech sector in India, whose performance was better than its US counterpart. The survey identified MVA with wealth.
7. This is justified because the source of funds account, from which this information was collected, follows the flow concept.
8. One important source of capital is preference shares. It was noticed that only eight firms in the sample had preferred capital with a total of 32 observations, which were not significant. So this was added to equity capital.
9. An alternative way of working out the cost of capital is by following capital asset pricing model (CAPM), also known as security market line (SML) approach. It is given by

$$K_E = R_f + \beta_E * (R_M - R_f)$$

where R_f = Risk-free rate
R_M = Market return
β_E = beta

In view of difficulties in obtaining relevant beta for each and every sample firm and market risk premium ($R_M - R_f$), such an exercise could not be carried out.

10. Assuming that dividend grows steadily, we have taken the average as *g*, obtained for the period for which data were available for a firm.
11. Closing price refers to the last trading day of the financial year. The alternative could be the average of high and low prices of the whole financial year.
12. Some analysts feel that 'investments' made outside the company should be excluded from capital employed.
13. Identical with book value, as defined in Athey and Reeser (2000) and Rajakumar (2001).

References

Athey, M.J. and W.D. Reeser. 2000. 'Asymmetric Information, Industrial Policy and Corporate Investment in India', *Oxford Bulletin of Economics and Statistics*, 62(2): 267–92.

Business Today–Stern Stewart. 2002. 'India's Largest Wealth Creators', *Business Today*, 17 February.

Damodaran, A. 2001. *The Dark Side of Valuation Valuing Old Tech, New Tech, and New Economy Companies*. London: Prentice Hall.

Desai, V.A, 2002. 'The Dynamics of the Indian Information Technology Industry' (paper written for Centre for New and Emerging Markets), London Business School.

Drucker, P. 1995. 'The Information Executives Truly Need', *Harvard Business Review*, January–February: 54–63.

EPWRF (Economic and Political Weekly Research Foundation). 2002. *National Accounts Statistics of India New Linked Series with 1993/94 as the Base Year*. Mumbai: EPWRF.

Heeks, R. 1996. *India's Software Industry State Policy, Liberalisation and Industrial Development*. New Delhi: Sage.

Kumar, N. 2001. 'Indian Software Industry Development International and National Perspective', *Economic and Political Weekly*, 36(45): 4278–90.

Nagaraj, R. 1996. 'India's Capital Market Growth, Trends, Explanations and Evidence?' *Economic and Political Weekly*, 31(35–37): 2553–63.

Rajakumar, J.D. 2001. 'Financing Patterns and Investment: A Study of the Private Corporate Sector in India', Unpublished Ph.D. thesis submitted to Jawarhalal Nehru University, New Delhi, Thiruvananthapuram: Centre for Development Studies.

RBI (Reserve Bank of India). 2001. 'Finances of Public Limited Companies, 1999–2000', *RBI Bulletin*, June: 631–71.

RBI (Reserve Bank of India). 2002. 'Finances of Public Limited Companies, 2000–01', *RBI Bulletin*, September: 583–624.

———. 2003. 'Finances of Public Limited Companies, 2001–02', *RBI Bulletin*, October: 635–75.

Ross, A. Stephen, R.W. Westerfield and B.D. Jordan. 2000. *Fundamentals of Corporate Finance*, sixth edition. Boston, MA: McGraw-Hill.

Shanta, N. and J.D. Rajakumar. 1999. 'Corporate Statistics: The Missing Numbers', *Journal of Indian School of Political Economy*, 11(4): 655–68.

Singh, A. 1998. 'Liberalization, the Stock Market, and the Market for Corporate Control: A Bridge too Far for the Indian Economy', in I.S. Ahluwalia and I.M.D. Little (eds), *India's Economic Reforms and Development Essays for Manmohan Singh*. New Delhi: Oxford University Press, 169–96.

Srivastava, V. 1996. *Liberalisation, Productivity and Competition: A Panel Study of Indian Manufacturing*. New Delhi: Oxford University Press.

Stern, J., B. Stewart and D. Chew. 1997. 'The EVA® Financial Management System', in D. Chew (ed.), *Studies in International Corporate Finance and Governance Systems: A Comparison of the U.S., Japan and Europe*. Oxford: Oxford University Press, 354–68.

Tobin, J. and W.C. Brainard. 1977. 'Asset Markets and the Cost of Capital', in R. Nelson and B. Balassa (eds), *Economic Progress: Private Values and Public Policy: Essays in Honor of W. Fellner*. Amsterdam: North-Holland, 235–62.

Thurow, C.L. 1999. *Creating Wealth: The New Rules for Individuals, Companies and Countries in a Knowledge-based Economy*. London: Nicholas Brealey Publishing.

6

The Political Economy of the Computer Software Industry in Bangalore, India

Balaji Parthasarathy

Following Granovetter (1985), the idea of the social embeddedness of economic activity has prominently influenced the literature on economic development in newly industrializing countries (NICs) and that on regional development. In the economic development literature, sociologists highlight the importance of ties between the state and local capital to bring about economic transformation. They emphasize the role of the state in promoting technological learning in local firms to explain the manufacturing exports-led development successes of the East Asian 'tigers', which have gone well beyond relying on low wages. Evans (1995), in particular, talks of the importance of 'embedded autonomy': a state that is sufficiently autonomous from various social groups and internally coherent to independently formulate a development project, while also cultivating formal and informal ties with civil society groups that help it to achieve those project goals. To Evans, states have varying degrees of embedded autonomy. Those completely lacking it are 'predatory states', in polar contrast to 'developmental states', of which Taiwan and South Korea (henceforth Korea) are cited as exemplars. Evans also identifies the roles that effective development states have to take on. He argues that a state confining itself to the roles of a 'custodian' (regulation and policing) and a 'demiurge' (where it takes on a direct role in production, presuming that private capital is incapable of doing so) will be developmentally less effective than states that take on the roles of 'midwifery' and 'husbandry'. These latter roles refer to assisting the emergence of entrepreneurs by, for instance, granting them incentives and subsidies, and directing them into new areas of production, including cajoling them into meeting challenges in the global market.

In the regional development literature, geographers studying industrial agglomerations, such as Brusco (1982), Piore and Sabel (1984) or Storper (1997), have focused attention on the organization of production to explain how highly localized and embedded industrial systems facilitate innovation and economically desirable developmental outcomes. The argument is that a decentralized production network of specialized, vertically disintegrated firms, when embedded in a range of local institutions, including other firms, universities, industry associations and trade unions, helps an agglomeration deal collectively with the challenges posed by rapidly changing demand and technology. Thus, for example, the dense network of semiconductor and computer manufacturing firms, along with supporting public institutions, in Hsinchu Science Park has been crucial in making Taiwan a dominant global producer in both industries (Matthews and Cho 2000).

If the character of the Taiwanese state has enabled it to initiate many of the supporting institutions that give firms in Hsinchu their strengths (Hsu 2000), this paper argues that the literature on economic sociology and economic geography have not been bridged adequately to tell us how the embeddedness of the state affects embeddedness in the region. Specifically, we do not know the kind of agglomerations that one can expect to find in the vast majority of states in the NICs that are, to use Evans' phrase, 'intermediate states', that is, those that do not possess the balance of embeddedness and autonomy to facilitate the developmental outcomes witnessed in East Asia.

Evans' argument that intermediate states have not undergone economic transformation to develop globally competitive industries because they have less embedded autonomy, is inadequate. Specifying development outcomes along a single dimension obscures the fact that the trajectories of economic transformation and the organization of production, followed even by exemplars such as Taiwan and Korea have been dissimilar (Hsu and Saxenian 2001). As Wright (1996) points out, embedded autonomy is a two-dimensional concept and the specific balance between embeddedness and autonomy is contingent upon a social and political context. Any change in the context need not affect the two variables identically, giving rise to the possibility of multiple, historically specific, trajectories.

What is the relationship between different trajectories and the organization of production in a region? Unfortunately, the literature is not very helpful. It does say that a reliance on low wages and borrowed technology as a source of regional advantage will eventually be eroded, and that an innovative region requires a decentralized production network embedded in diverse local institutions. As a number of intermediate states struggle to encourage economic transformation by building ties with private capital and pursuing 'business-friendly' policies, what will be the characteristics of the agglomerations they develop? It is unrealistic to expect the blossoming of many a Hsinchu as in Taiwan, since it is an exception rather than the rule among NICs. In other words, the intermediate possibilities remain unspecified since the impact of the changing character of the state on the spatial character of industry is not well understood, despite its wide relevance.

The Case of the Indian Software Industry in Bangalore

Without exhaustively specifying the spatial outcomes of multiple development trajectories, this paper will provide insights into this relationship by analysing the impact of the changing character of the Indian state on the emergence of an agglomeration of the computer software industry in Bangalore, Karnataka.[1] Despite its relatively high levels of illiteracy and poverty,[2] by 2000, India (along with Israel) was the largest software exporter among non-OECD countries, with exports increasing from virtually nothing in 1985 to $4 bn in 2000 (Table 6.1). The next two sections explain how the emergence of the Indian software industry is an outcome not only of an explosion in global demand for highly skilled, low-wage software professionals, following the PC and the internet revolutions of the 1980s and the 1990s, but also because of changes in the character of the Indian state.

TABLE 6.1 **India's Software Revenues and Exports (1985–86 to 2000–01)**

Year	*Revenues (US$ mn)*	*Exports as % of Revenues*	*Exports % Share of STPIs*	*Exports as % of all Exports*
1985–86	81	29.63		
1986–87	108	36.11		
1987–88	130	40.00		
1988–89	160	41.88		
1989–90	197	50.76		
1990–91	243	52.68		
1991–92	304	53.95		
1992–93	388	57.99	8.0	
1993–94	560	58.93	12.0	
1994–95	787	62.13	16.0	1.9
1995–96	1,253	60.18	29.0	2.4
1996–97	1,841	59.75	46.0	3.3
1997–98	3,011	58.42	54.0	5.0
1998–99	4,069	63.90	58.0	7.8
1999–2000	5,611	70.61	68.0	10.8
2000–01	8,386	74.14		14.0

Source: NASSCOM 1992, 1993; STPI data from www.stpi.soft.net/areport12.html.

As Evans argues, since the 1980s, the Indian state has increasingly attempted to encourage economic growth by embedding itself in private capital, and this is especially evident in the policies that have facilitated the growth of the software industry. The paper is divided into six sections: the second section describes the policies in three phases and their impact on the organization of production in the industry; while the third discusses how the policy changes led to Bangalore's emergence as India's leading centre of software production, earning the city epithets like 'Silicon Plateau' (Fineman 1991) or 'India's Silicon Valley' (IDG 2001) in the international press. The basis for comparison with Silicon Valley, arguably *the* centre of innovation in the information technology (IT) industry, is not just the quantitative expansion in software exports, but also the qualitative changes the industry has undergone in Bangalore, transforming the region from a low-wage backwater to an important production centre that develops products for the global software industry. The fourth section, however, points to the limits of the comparison by arguing that Bangalore's further transformation to a region that defines new products and technologies is constrained by the export success and limited domestic software consumption. In other words, while Bangalore can be termed Silicon Valley's India, it cannot be called India's Silicon Valley.

The fifth section links the constraints on Bangalore's transformation to social constraints on the state. Even as the growing embeddedness of the state has triggered a software export boom, its failure to ensure socio-economic transformation has eroded its autonomy to limit the effects of policy initiatives taken to encourage the further growth of IT production and consumption, and the broader socio-economic transformation that could potentially result. The paper concludes by discussing how the transformation of, and constraints on, Bangalore's software industry point to the opportunities and challenges facing firms and regions from intermediate states as they attempt to transform their position in the international division of labour. In addition to primary data, the essay draws extensively on interviews conducted in India, with policy makers and industry representatives, between 1996 and 2000.

The Global Context for Indian Software Production

An independent global software industry developed following IBM's decision in 1969 to sell software separately instead of bundling it with hardware (Steinmueller 1996). The decision was crucial as it gave customers the option of buying their software and hardware from different vendors, since IBM at that time commanded two-thirds of the world's computer market. Soon after, Intel's invention of the microprocessor in 1972 facilitated the development of powerful mini and microcomputers that successfully challenged the dominance of the larger and more expensive mainframe computers. With the availability of increasingly more powerful and inexpensive hardware, there was a proliferation of computer usage in various economic sectors, creating a huge demand for software.

However, while automated, capital-intensive operations permit the mass production of high-quality hardware, software production in comparison has remained a craft-like, labour-intensive affair, plagued by uneven productivity and quality, relying more on trial and error to achieve its goals (Gibbs 1994). The result is that software development is notoriously prone to 'bugs', delays and cost overruns. In other words, software productivity and quality have lagged behind those of hardware, creating a 'software bottleneck'.

To overcome the bottleneck, the discipline of software engineering has evolved along the lines of industrial engineering. Managing the software development process, or structured programming, by breaking it down into segments to permit co-ordination and control over a team of programmers working on a large project, has a long history. The six-stage 'waterfall' model, that is, requirement analysis, specification, design, coding, testing and implementation, with each stage completed before flowing into the next, is a classic conceptualization of the development process (Keuffel 1991). Recent software management practices have focused on adopting industry-wide certification norms so that organizations adhere to codified quality procedures in the development process (Kitchenham and Pfleeger 1996). The norms include the ISO-9001/9000-3 standards prescribed by the International Standards Organization, and the Software Engineering Institute's five-level Capability Maturity Model (SEI-CMM).

Although the widespread adoption of software engineering practices has helped improve overall productivity and quality, the bottleneck persists due to wide variations in programmer productivity and quality (Gibbs 1994). The extent to which process standards, such as those laid down by the ISO and SEI, will guarantee a quality product, remains contentious (Schneidewind and Fenton 1996). The waterfall model of development is criticized for enforcing a rigid top-down methodology on the grounds that no generic process model will work for all projects (Davis 1993), much less one that is linear and sequential. In practice, software development tends to be iterative; there is learning by doing, with no sharp demarcation between conceptualizing and implementing (Keuffel 1991). Thus, Kraft's (1977) prediction that structured programming will lead to a division of labour between mental and manual labour has not quite happened. Though the last three stages of the waterfall model have been amenable to automation with computer-aided software engineering tools, such automation demands tediously clear and detailed specifications. Consequently, much coding, testing and implementing is still done manually and the division of labour in software production is better seen as a division between more and less skilled labour, but skilled nevertheless. In short, quality and productivity improvements delivered by software engineering have thus far been limited, supporting Brooks' (1995) point that there is no 'silver bullet' for the bottleneck. Thus, overcoming the bottleneck has required the deployment of more software professionals.

Apart from the demand generated by the growing use of software, there is also plenty of older software demanding maintenance. For instance, firms using computers extensively since the days when mainframes were dominant, typically spend over 70 per cent of their systems budgets on maintenance activities because they

> ... operate what can only be regarded as software museums: collection of systems that incorporate or exemplify all the significant developments in computing …including some of the blind alleys. The result is the systems equivalent to a medieval city, a hotchpotch of dissimilar buildings and winding lanes where only the locals can find their way around (Mayall 1991: 40).

The hotchpotch structure makes maintenance and re-engineering labour intensive.[3] Discarding older systems is often not easy, as they embody years of valuable business information and experience. One aspect of the hotchpotch structure is format problems, such as those involving dates, of which the Year 2000 (Y2K) problem received the widest publicity.[4]

The many such time-specific, labour-intensive demands coming together in the 1990s, and the general expansion in the use of software, created a huge demand for skilled labour, especially in advanced industrial countries that use IT extensively. In the US, for instance, though the question of whether there is a shortage of skilled labour is controversial, there is agreement that there is a shortage of people with specific skills (Koch 1998). For instance, finding people familiar with old codes written for mainframe systems is difficult. The shortage of people with specific skills, and the pressure to limit the costs of labour-intensive projects, forced firms in the US to look elsewhere for the appropriate skill–cost combination.

Among the countries able to offer this combination, a 1992 World Bank sponsored survey found that US and European vendors ranked India as the top choice for onsite and offshore software development, ahead of Israel, Ireland, Mexico, Singapore, China, Hungary and the Philippines (InfoTech Consulting 1992: DA16). How this perception of Indian firms developed requires an understanding of the policy environment, which has gone through at least three distinct phases, with a fourth under way.

The Changing Character of the Indian State: Growing Embeddedness

The availability of the necessary skill–cost advantage will not automatically guarantee the profitable exploitation of a global opportunity without a supportive socio-economic environment for firms. Thus, for instance, the globalization of the semiconductor industry since the 1960s bypassed India (Henderson 1989). Indeed, when India established the Department of Electronics (DoE) (the Ministry of Information Technology [MIT] since November 2000) in 1971 to formulate its electronics policy, India's electronics production was larger than Korea's (Sridharan 1996). But, a decade later, Korean production and exports dwarfed India's, as the DoE's domination by a scientific community committed to self-sufficiency and self-reliance, within a broader, state-dominated, autarchic, import substitution-led industrialization (ISI) strategy pursued since the 1950s, proved inimical to innovation and entrepreneurship. The highlight of Indian computer policy in the 1970s was forcing IBM to shut its operations in 1978 (Grieco 1984). Neither was there an Indian software industry to speak of, despite (unsuccessful) development efforts by the state to build a commercially viable computer, nor did efforts to promote exports, by permitting the import of hardware in exchange for a guarantee to export a certain amount of software, prove effective (Subramanian 1992). In Evans' framework, the Indian state enjoyed an autonomy that allowed it to take on the roles of a custodian and demiurge.

In the early 1980s, India's relatively poor economic record led to cautious efforts to liberalize the policy regime to encourage private investment and trade (Sridharan 1996). After Rajiv Gandhi became Prime Minister in 1984, liberalization received strong political backing, which a group of technologically and commercially pragmatic bureaucrats, now heading the DoE, and keen that the globalization of the software industry not bypass India, immediately seized. As a result, the period until 1990, phase two of the software policy regime, witnessed many initiatives, and described here are two key ones. The Computer

Policy of November 1984, besides easing the local manufacture and availability of computers, recognized software as an 'industry', making it eligible for investment allowance and other incentives. It also lowered duties on software imports and made software exports a priority.

The Computer Software Export, Development and Training Policy of December 1986 explicitly aimed at increasing India's share of world software production. The means to do this was the 'flood in, flood out' feature: firms in India were provided liberal access to global technologies to encourage '... thousands of small software companies in the country and thereby increasing export as well as local development' (*Dataquest* 1987: 87). Industry was to be independent with the government stepping in to provide only promotional and infrastructure support. Overall, this policy was an explicit rejection of Indian ISI and the ideology of self-reliance in the software sector.

Despite these policy initiatives, exporting in this phase typically involved little more than body-shopping, or the practice of providing inexpensive onsite (that is, at customer locations overseas) labour on an hourly basis, for low value-added programming services such as coding and testing. Body-shopping had its advantages and limitations. On one hand, it meant 'input-less exports', requiring only a contact overseas, a little finance, and the names of local programmers who could be hired and sent to the site (Heeks 1996). The drawback, however, was an under-utilization of the skills of well-trained engineers, many of whom tended to quit to seek more challenging and better paid jobs once sent overseas. The high turnover only reinforced the tendency of Indian firms to compete on low costs rather than being able to fall back on a repository of technical and managerial expertise acquired from previous projects.

Although body-shopping seems like a quick-buck strategy, there were not too many other options for firms from a country that had hitherto not merited any consideration as a source of IT products. Banerjee and Duflo's (2000) study of 230 projects across 125 firms in India shows that reputation matters in software contracting, even after controlling for project, firm and client characteristics. There is also agreement within the industry that in order to gain the confidence of global customers, there was no alternative to onsite services in the 1980s. Further, while Indian engineers had the necessary technical skills, they had trained in a closed economy. Onsite services provided exposure to market trends, management processes and socially specific communication protocols, besides emerging technologies.

The official encouragement given to body-shopping mostly reflected a limited understanding of the industry among policy makers: software was widely perceived as being 'high-tech', without adequate distinction made between the different stages of production or the corresponding value added. The limitation, on one hand, allowed the pragmatically inclined to overcome the ambivalence about promoting 'intellectual coolie-ism' among the scientifically inclined, by arguing that for India to realize its ambitions of becoming to software what Taiwan and Korea were to hardware, it would have to begin by providing low value-added services before moving up the value chain.[5] On the other hand, according to a former economic advisor at the DoE (Sen 1994) amidst the euphoria following the growth in software exports in the 1980s, ignorance and arrogance combined to encourage the opinion that the software industry did not need much by way of policy support. He scathingly writes, 'until 1991–92, there was virtually no policy support at all for the software sector. Even the term "benign neglect" would be too positive a phrase to use in this connection' (Sen 1994: 55). In other words, Sen argues that the policy shifts of the 1980s only led to the state reducing its custodial role rather than actively taking on the midwifery and husbanding roles.

A fundamental change in the approach to policy making came about in the nineties, paving the way for a better understanding of the industry and providing greater policy support for local software development. Whereas until the 1980s, policy making was concentrated within a closed bureaucratic apparatus, since then the state has increasingly attempted to embed itself in private capital, to make policies by drawing on industry feedback, and this was especially evident in the software industry (Evans 1995). Based on input from the IT firms, which in 1988 came together to form the National Association of Software and Service Companies (NASSCOM) to promote their interests, subsequent policy measures tried to promote the industry more proactively. The clearest instance of this was the establishment in 1990 of software technology parks (STPs).

As export zones dedicated to the software industry, STPs offered data communication facilities using which firms could offer offshore services, that is, service provision from India, instead of having to work at customer sites overseas.[6] Although in principle, STPs were similar to the export processing zones (EPZs) or the 100 per cent export-oriented unit programme under the Ministry of Commerce, the DoE bypassed the ministry's programmes arguing that they imposed unrealistic export obligations on firms. Instead, the DoE wanted to limit itself to placing realistic shadow prices on the two scarce resources, foreign exchange and skilled labour.[7] Thus, the annual export obligation of 150 per cent of the wage bill was set with an eye on competition from other low-wage countries, such as China. Likewise, the decision to provide high-speed data communications facilities required intrusion onto the turf of the Department of Telecommunications (DoT), then a monopoly service provider, in response to industry frustration with the DoT's slow and expensive service.

In 1991, the year after the STPs were established, a balance-of-payments crisis induced a major shift in economic policies, including the devaluation of the rupee, trade liberalization and duty rationalization, openness to foreign investment, and a new industrial policy that removed entry barriers for new firms, a process that is still under way.[8] Even as these economy-wide changes have benefited the software industry, many sector-specific policy changes also emerged from constant state–industry interaction, with NASSCOM represented on various committees at the DoE, the DoT, the Ministries of Commerce, Finance, Human Resources Development and Labour. Examples include income tax exemption on profits from service exports in 1992; elimination of import duties on software by 1997; and permission to grant ADR (American Depository Receipts)/GDR (Global Depository Receipts) linked employee stock options in 1998.

Indian Software Exports: From Body-shopping to Offshore Turnkey Contracts

The shift to offshore services in a more liberal economic environment marked the beginning of a new relationship between the Indian software industry and the global market. According to Sen's (1994) analysis of quarterly export growth, between 1987 and 1992–93, a linear equation provides the best fit for the growth. From 1992–93 (until 1994, the last year for which Sen had data), however, an exponential equation provides a better fit. Although Sen had insufficient data to determine if it was a long-term trend, he projected that if exports maintained the exponential trajectory, they would reach $630 mn by 1997. Since actual exports in 1996–97 were $1.1 bn (Table 6.1), there was clearly a change in the growth characteristics of Indian software exports.

While the conscious policies since 1984 were crucial in facilitating the change, reinforcing their efficacy were certain serendipitous benefits conferred by policies from earlier years. Despite widespread illiteracy, Indian education policies managed to create a large pool of skilled labour that, in a relatively slow-growing economy, suffered from under-employment if not unemployment, thus offering a ready resource. The colonial legacy also meant that this labour was mostly educated in English. India's most pointed advantage came, however, not merely from the availability of low-cost, English-speaking labour, but from the skills embodied in it. Following IBM's departure and the unsuccessful local efforts to build a commercially viable computer, users had to rely on imports. Since high duties were a disincentive to imports, mainframes never had a significant presence in India, and the few that were imported were of various vintages and sources (Harding 1989). As Indian programmers worked on a variety of platforms in the 1970s, this proved helpful in acquiring contracts to maintain various older systems in the 1980s.

With the growth in computer manufacture and usage in the 1980s, Unix became the operating system of choice. As the government undertook limited computerization of some of its activities, it played a role by encouraging the use of Unix, especially in public sector bank automation. This emerging market encouraged many innovations in the design of Unix-based hardware as firms obtained a Unix source code and modified it to run on machines they designed (Heeks 1996). It is impossible to over-emphasize the importance of familiarity with Unix. Developed initially at Bell Labs in 1969 as a multi-user operating system to provide a comfortable programming environment, its use spread rapidly as AT&T's liberal licensing to universities led to the collaborative development of a truly open system, various versions of which were widely adopted by the world's leading computer vendors. Reviewing it on its twenty-fifth anniversary, Salus (1994: 82) writes,

> Putative standards and consortia have done nothing to calm the splintered 25 year old. Solaris, HP-UX, AIX, Ultrix, and myriad derivatives sit at the ... table today. Since the late 1970s, Unix has influenced every operating

> system that is sold today. Unix has had a profound impact on DOS, Mac OS, and Windows NT. Windowing, multitasking, and networking would not be what they are today without Unix.

As circumstances forced Indian programmers and engineers to adopt Unix,

> ... India entered the 1990s in a position of special advantage. Indian programmers are not only well educated and English-speaking, but out of necessity they're keenly focussed on client/server or multiuser solutions for PCs running DOS (with Netware) or Unix—just the kinds of solutions that US and European companies are rushing to embrace (Udell 1993: 56).

A geographical accident benefiting Indian firms is the 12.5 hour difference with the US, their main market, allowing them to undertake offshore maintenance and re-engineering after regular users there leave for the day. This means lower costs and profitability as professionals in India are paid wages in Indian currency, whereas once abroad, they are also paid an overseas allowance (Heeks 1996). Offshore development also offers the advantage of having most employees under one roof, instead of them being scattered across customer sites, allowing the firm to build a repository of knowledge to compete for subsequent projects and to move employees from one project to another in a crunch.

It was against the backdrop of such conscious efforts and unforeseen benefits that the STPs helped transform the industry in the 1990s. Software factories emerged in India, with the infrastructure, technology, training programmes, quality processes, productivity tools and methodologies of the customer workplace. Thus, by 27 June 2002, 316 Indian software companies had acquired quality certifications and India had 85 companies assessed at SEI-CMM level 5, compared to 42 elsewhere in the world.[9] Despite the uneven impact of such certification, Arora and Asundi (1999) identify two reasons that Indian firms seek quality certification. First, it is a marketing device, to signal to potential customers that the firm follows a well-defined and documented development process. Second, a well-defined process improves the ability of firms to estimate and manage the time and resources required for a project, helping them bid for larger projects, thereby expanding business.

Although Arora and Asundi conclude that the relationship between certification and better rates is not very robust, they add that for firms with an ongoing commitment to quality, getting bigger projects is a route to obtaining contracts that are more profitable. Interviews indicated that firms with a well-established record were able to bid for projects directly with clients rather than work as sub-contractors for other vendors. This opened the doors to turnkey contracts, giving Indian firms responsibility for more segments of the software development process. Obtaining turnkey contracts forces firms to develop substantial management skills, as they have to co-ordinate a much wider range of tasks than just programming and take responsibility for the overall project schedule, quality and productivity, in contrast to body-shopping, which is little more than résumé selling.

Not only did some Indian firms get better work at better rates, they also began to move away from competing on hour-based productivity to intellectual property rights-based productivity, by converting knowledge gained from development projects in specific application areas, such as banking, retailing or telecommunications, to a customizable generic product for clients with similar needs. Apart from the shift to offshore services by large Indian firms, the liberal economic climate of the 1990s also led to an influx of multinational corporations (MNCs), including IBM's return, to establish offshore development centres (ODCs). The ODCs capitalized on the communications infrastructure in STPs and on Indian skills, especially since the early entrants in the 1980s, such as Texas Instruments and Verifone, demonstrated that India could be more than a low-wage hunting ground. Indeed, some ODCs even outdid their parent organizations. For instance, in 1994, Motorola's Bangalore centre was only one of two software centres worldwide (the other being Loral's space shuttle software project in the US) to attain CMM level 5 (Sims 1994).

Within India, software factories and development centres began sprouting in regions with skilled labour and communications facilities, both of which were available in Bangalore. In the 1980s, prominent domestic firms, such as Infosys, India's second largest software exporter by 1999–2000 and the first Indian firm to be listed on the NASDAQ, were established in the city and the early trickle of MNCs to India was also concentrated in Bangalore. They were attracted by the availability of skilled labour in the region, initially in public sector manufacturing industries and laboratories in sectors such as aerospace, defence electronics and telecommunications,[10] subsequently replenished by the large numbers of graduates from the engineering colleges of Karnataka and adjoining provinces (Table 6.2).

TABLE 6.2 Number of Approved Engineering Colleges and Intake (as on 21 January 1999)

State	*Colleges*	*Intake*
All India	663	156,493
Karnataka	70	24,752
Tamil Nadu	129	32,160
Maharashtra	118	28,985
Andhra Pradesh	88	20,285
4 Contiguous Provinces	405	106,182
as % of All India	61.09%	67.85%

Source: AICTE 1999: Annexure 4.1.

As establishing the first STP in Bangalore provided the necessary infrastructure to reinforce the formidable skill advantages the region already possessed, Bangalore became central to the expansion plans of domestic firms, and the first choice within India for the large number of companies from Silicon Valley wanting to establish ODCs in the country (Rao 1995; Table 6.3). Though the concentration of domestic companies and MNCs and the transformation of the software

TABLE 6.3 Spatial Distribution of the Indian Software Industry (2000–01)

Region	*Export %*	*Headquarters**
Bangalore	26.64	160
New Delhi/Gurgaon/NOIDA	15.34	106
Chennai	10.42	72
Hyderabad	7.02	61
Mumbai/Navi Mumbai	5.68	148
Pune	3.39	48
Kolkata	0.88	32
Ahmedabad/Gandhinagar	0.36	10
Thiruvananthapuram	0.03	14
Chandigarh/Mohali	0.01	7
Bhubaneshwar	neg.	8
Others	29.96	34

Note: *Includes the headquarters of NASSCOM's 700 largest members. This is admittedly a crude measure of the spatial organization of the software industry, since many firms have development centres in many cities (as with Infosys).

Source: www.bangaloreit.com/html.itsckar/itindustries other cities.htm; NASSCOM 2001.

industry following the shift to offshore services, means that Bangalore can be called Silicon Valley's India, the argument here is that the perception of the region as India's Silicon Valley is, at the very least, premature.

Comparing the Organization of Production in Bangalore and in Silicon Valley

The transformation that Indian industry has undergone in the 1990s with the shift to offshore service provision has been a limited one. This is largely because a small number of firms dominate Indian software exports: according to NASSCOM (1993, 2001), the 15 largest exporters accounted for 63.6 per cent of exports in 1992–93, whereas in 1999–2000 they accounted for 49.44 per cent. Since NASSCOM estimates that there were nearly 250 exporters in 1992–93 and 1,250 in 1999–2000, the export share of the 15 largest exporters declined by less than 15 per cent, whereas the number of exporters increased by 400 per cent. Thus, while a few large exporters have moved to providing domain-specific software by drawing on the experience of previous projects, the organizational shift to offshore services, though profitable, has by and large not been accompanied by any significant change in the nature of work that a majority of firms undertake. In other words, while Indian firms entrenched themselves in the international division of labour providing labour-intensive services in the 1980s by body-shopping, they have largely stuck to providing such services despite the changing organization of production. Thus, while Indian firms have gone beyond body-shopping, there are few signs of high value-added, innovative products or technologies, as in the Valley. MNCs are in a slightly different position, as this section discusses later.

At this point, a brief detour to understand the forces driving innovation and entrepreneurship in the Valley will help put things in perspective. Research shows that crucial to the Valley being the centre of innovation in the IT industry are specialist firms that constantly interact and work with one another, and with local institutions such as venture capitalists and educational institutions, especially Stanford University, creating what Saxenian (1994) refers to as a 'technical community'. The resulting sharing and circulation of ideas help firms develop new technologies and products that are compatible with the evolving technical and commercial needs of the market. They are also simultaneously shaping the market itself by establishing product standards to which firms elsewhere have to conform.

In Bangalore, however, there is little interaction among firms, thereby limiting innovation. The reason for this is the lack of a domestic market for IT products in various economic domains. By the late 1990s, Indian spending on IT as a share of its GDP was only 0.53 per cent, which is very low (Table 6.4). As a result, the share of exports as a percentage of software revenues generated by firms in India, is rising (Table 6.1). Essentially, the software industry in India has been unable to develop what Schware (1992) calls a 'walking on two legs' strategy to compete globally. The strategy entails developing a domestic market for various software niches to give firms an opportunity to develop their expertise locally before serving global markets.

TABLE 6.4 Information Technology Spending and Infrastructure (1999)

Country	*IT as % of GDP*	*PCs per 1,000 pop.*
USA	4.14	517.07
OECD	3.09	285.55
Asia-Pacific*	1.81	30.72
Malaysia	1.70	68.71
Taiwan	1.34	197.04
China	1.13	12.24
Philippines	0.78	16.92
Thailand	0.63	22.71
India	0.53	3.31
Indonesia	0.35	9.08

Note: *Asia-Pacific refers to Australia, China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan and Thailand.
Source: IT/GDP from International Data Corporation (www.idc.com.sg/products/About/IT-spending.asp); PCs per 1,000 population from International Telecommunication Union (www.itu.int/ITU-D/ict/statistics/at_glance/Internet99.pdf).

The importance of a local market for software arises from the characteristics of software. Development and marketing costs determine the cost of software, as production costs are negligible.[11] The commercial advantage comes primarily from the ability to innovatively meet user needs in various economic domains. To understand evolving user needs, however, access to markets is essential. It is here that the Indian industry is at a disadvantage. Although the availability of skilled labour at relatively low wages confers a huge advantage when it comes to development costs, the distance from final markets has meant that Indian firms are not able to react quickly with innovative products to meet the emerging needs of users. Despite the instantaneous access which modern data communication infrastructure provides to distant markets, the majority of Indian firms are stuck at the low end of the business because the knowledge required to develop innovative products is often tacit and difficult to convey over long distances.

Evidence from the US packaged software industry shows how the local market matters. Over time, the industry has drifted gradually from regions where the computer manufacturing industry is dominant to regions with a concentration of leading firms in various user industries (Egan 1997). Thus, for instance, producers of software for the oil industry are concentrated around Houston, the leading centre for the US energy industry. Indeed, the importance of proximity to users has even prompted many leading Indian firms to establish development centres in their main markets. For instance, in the 1990s, Infosys, in addition to expanding in Bangalore to accommodate growth, established development centres in other Indian cities, including Bhubaneshwar, Chennai, Pune and Mangalore, as well as in North America, the UK and Japan. The global development centres

> … expand the capabilities of Infosys' global delivery model to leverage talent and infrastructure in different parts of the world. These centers enhance client comfort and expand … engagement capabilities, to provide a wider range of services such as business consulting and technology architecture that involve high levels of client interaction over shorter engagement spans. They also complement larger campuses in India to accelerate engagement schedules and distribute engagement execution across multiple locations and time zones.[12]

Whereas Infosys' expansion within India reflects the continued growth opportunities offered by the offshore development model, opening development centres in its main markets suggests that Infosys is confronting certain limits to the model. For a firm trying to shift to more value-added work by providing domain-specific solutions, greater proximity to users is clearly becoming essential. Sending employees to understand the client's requirements and specifications before developing and coding the solution in India, it seems, does not always work. That the Infosys experience is not unique is evident from Table 6.5, which shows a sharp increase in offshore export activity in the early 1990s, following the commissioning of the STPs. However, between 1993–94 and 2000–01, onsite activity declined by only 5.9 per cent, despite the rapid expansion of data communications infrastructure and the number of STPs doubling from six to a dozen.

TABLE 6.5 **Sources of India's Software Export Revenues (1993–2001)**

Year	*Onsite Services*	*Offshore Services*	*Products & Packages*
1990	90.00	5.00	5.00
1993–94	62.01	30.05	7.94
1994–95	60.90	29.59	9.51
1995–96	60.32	31.63	8.05
1996–97	58.69	30.21	11.10
1997–98	59.00	32.20	8.80
1998–99	58.18	33.91	7.91
1999–2000	57.26	34.69	8.05
2000–01	56.09	38.62	5.29

Note: Figures are percentages of export revenues.
Source: NASSCOM 2001.

Ironically, Infosys has also talked of establishing development centres in China and the Philippines arguing that they offer high-skill, low-cost labour (Jayaswal and Vivek 2001; Nair 1998), precisely the advantages that India is supposed to possess over others. Underlying Infosys' argument is the issue of rising costs that firms face in Bangalore. Interviews indicated that a tightening labour market during the 1990s led to wage increases ranging from 25 to 40 per cent annually, and high employee turnover. There are at least two forces driving this process: First, having gained a favourable reputation since the 1980s, the Indian software professional no longer depends only on Indian firms for employment. In other words, with globalization, the Indian labour market for software professionals and the global labour market are no longer distinct universes. In the 1990s, the worldwide demand for skills drew Indian professionals in increasing numbers to lucrative opportunities overseas. Just one indicator of the phenomenon is that Indians have become the largest recipients of H1B visas to the US. This visa programme, established by the Immigration Act of 1990 to enable the employment up to six years of workers in 'specialty occupations', and used extensively by the US advanced technology sector, is now widely identified as an 'Indian programme' (Alarcon 1998).

Second, the difficulty that most Indian firms have in acquiring domain specialization means an inability to provide limited value beyond writing codes. Where there is specialization in output, growth can come from encoding some kind of intellectual content. Where the programmer is not responsible for any intellectual content, and improvement in programmer productivity is patchy, growth will depend almost exclusively on adding more hands. When employees are not required to have any special application knowledge beyond programming, they can easily and freely move between firms that make no such demands. Such firms become vulnerable to poaching, reinforcing high turnover, especially when there is a global gap between demand and supply.

With most firms in Bangalore addressing overseas markets, their ties are to customers and other firms in the main market. Confidentiality clauses in export contracts typically limit the ability of Indian firms to sub-contract work locally. As for MNC ODCs, although many develop new products and technologies for their parent bodies, they are often reluctant to share proprietary technologies and have almost no local ties. Indeed, ODCs that come under a STP jurisdiction are legally different entities from the subsidiaries that market the products of the parent firm. Interviews indicated that they also usually report directly to the R&D group in the home of the parent company, whereas the marketing subsidiaries report to the Asia-Pacific headquarters. Thus, since the presence of most firms in Bangalore is mainly because of the local availability of skills and the infrastructure to support export activity, there is limited interaction between them. Other local institutions that can potentially play a role in facilitating the generation, dissemination and sharing of ideas in the region have not done so. Academic institutions and public sector industries in technology-intensive sectors operate in relative isolation, helping only to supply skilled labour (Parthasarathy 2000).

Thus, any comparison between Bangalore and Silicon Valley is premature at best. In other words, while changes in public policy and firm strategy have supported the quantitative expansion of the Indian software industry and Bangalore's transformation from a low-wage backwater to Silicon Valley's Asia, the more limited qualitative transformation of the industry has inhibited the transformation of Bangalore to a Silicon Valley-like region that defines new products and technologies.

The Changing Character of the Indian State: Policy Initiatives and Declining Autonomy

The export focus of the software industry in Bangalore broadly reflects the inability of the state to encourage the use of productivity-enhancing IT applications in various economic sectors. The inability of the state reflects, in turn, wider societal changes since the 1980s. Even as the Indian state sought to alter its position vis-à-vis private capital, the failures of the state to ensure adequate economic growth and social transformation, which has led to relatively high levels of poverty and illiteracy, resulted in a gradual erosion of its autonomy, severely limiting the extent to which policy changes can be brought about. Without going into the details of the politics of the changing social character of the Indian state, this section will provide a couple of indicators of declining autonomy.[13]

Although the term of the Indian Parliament is for five years, India has had five general elections since 1989, as every election has produced highly fragile coalition governments (Table 6.6). In contrast, before 1989, the Congress party ruled almost continuously since Independence with comfortable majorities. The fragile coalitions themselves are the result of more parties entering the Parliament, many of which are often regional or single-issue parties, representing the narrow interests of one or another hitherto ignored group, typically poor, rural and lower caste, trying to get its voice heard nationally. Although such parties often have barely a handful of representatives in the Parliament, they are able to bring down a government if the overall effort to change economic policies affects their interests. Thus, while the economic environment in India has undergone significant changes since the mid-1980s, there are equally significant constraints on the state in bringing about the widely talked about 'second generation' reforms, many of which will affect IT production and usage.

On one hand, there is widespread recognition of the possibilities of e-governance and other means of using this general-purpose technology to improve socio-economic conditions. Thus, the late 1990s witnessed many initiatives to launch a new phase of the policy regime, to take advantage of the internet revolution and to overcome the limitations facing the software industry. In 1998, the prime minister established a National Task Force on IT and Software Development,

TABLE 6.6 The Fragmentation of the Indian Polity (1967–99)

		Seats	*Contesting Parties (a)*		*Parties*	*National Parties*		*Largest Party*	
Lok Sabha	*Year*	*Contested*	*National*	*Other (b)*	*Elected*	*Seats*	*% Votes*	*Seats*	*% Votes*
4th	1967	520	7	18	19	440	76.13	283	40.78
5th	1971	518	8	45	24	451	77.84	352	43.68
6th	1977	542	5	29	18	481	84.67	295	41.32
7th	1980	529	6	30	17	485	85.07	353	42.69
8th	1984	514	7	26	17	451	79.80	404	49.10
9th	1989	529	8	105	24	471	79.34	197	39.53
10th	1991	534	9	136	24	478	80.74	244	36.55
11th	1996	543	8	201	28	403	69.08	161(c)	28.80
12th	1998	543	7	169	39	387	67.98	182(c)	25.82
13th	1999	543	7	162	38	369	67.10	182(c)	28.30

Note: (a) The candidates of a political party registered with the Election Commission of India get preference in the allotment of free symbol vis-à-vis independent candidates. Further, registered political parties can get recognition. A political party is treated as a recognized party in a province, if it has been engaged in political activity for a continuous period of five years, and has at the last general election in that province to the Lok Sabha, or to the province's Legislative Assembly, returned at least one member to the Lok Sabha for every 25 members of that House, or any fraction of that number from that province, or at least one member to the Legislative Assembly of that province for every 30 members of that Assembly or any fraction of that number. Alternately, the total number of valid votes polled by all the contesting candidates set up by such party at the last general election in the province to the Lok Sabha, or to the province's Legislative Assembly, should not be less than 6% of the total number of valid votes polled by all the contesting candidates at such general election in the province. A party that is recognized in at least four provinces is recognized as a national party. (b) Includes parties recognized as provincial parties and all other registered parties. (c) The parties winning the largest number of seats did not win the highest percentage of votes in these cases.

Source: Election Commission of India (www.eci.gov.in/DataBase/DataBase_fs.htm).

with representatives from the government and the industry, to make recommendations to transform India into an 'IT superpower'.[14] Setting an export target of $50 bn by 2008 for software and IT-related services, the Task Force made 108 recommendations broadly relating to improving bandwidth availability and telecommunications infrastructure, fiscal incentives and expanding IT usage to ensure 'IT for all by 2008'. In 2000, the government passed the Information Technology Act[15] to legally recognize electronic commerce and to facilitate electronic filing of documents with public agencies. In addition to national policies, in recent years at least 18 provincial governments have announced their own IT policies, broadly to attract IT investments and to encourage IT proliferation by focusing on e-governance, IT education, etc.[16]

Despite the intentions, achieving the export goal for 2008 presents formidable challenges. In 2000, an Action Taken Report of the Ministry of Information Technology (MIT) indicated that, of the 108 recommendations made by the Task Force, 64 were implemented, implementation was under way for 37, no action was taken on four, while the government had rejected three.[17] However, as Verma (2000a, 2000b, 2000c) points out, although the implementation of many of the Task Force recommendations have boosted the Indian IT industry, the dream of 'IT for all' remains very distant. This is because many of the recommendations implemented have been relatively easy, often within the purview of the MIT. Hampering widespread usage of IT are infrastructure deficiencies due to bandwidth constraints and unreliable power in much of the country, and low purchasing power, reflected in the low PC penetration (Table 6.4). Further, there is the issue of low literacy and limited local language software availability.[18]

Dealing with these issues not only demands co-operation from other ministries, but also substantial investments, resources which the state lacks, and at a macro-economic level, the rising fiscal deficit of the national and provincial governments is but one indicator of the lack of resources (Table 6.7). The inability to contain the deficit reflects the political difficulties of reducing current consumption, such as subsidies,[19] and broadening the tax base. For instance, many provinces give farmers free electricity and taxing agricultural incomes is taboo. The deleterious effects of large fiscal and revenue deficits, such as the crowding out of private investment, limit the effectiveness of openness and encouragement to foreign/private investment (Acharya 2002).

TABLE 6.7 Consolidated Deficits of the Central and Provincial Governments

Year	*Fiscal Deficit*	*Revenue Deficit*
1980–81	7.5	0.4
1981–82	6.3	–0.6
1982–83	5.9	0.2
1983–84	7.3	1.1
1984–85	9.0	2.1
1985–86	8.0	1.9
1986–87	9.9	2.4
1987–88	9.2	2.9
1988–89	8.5	2.9
1989–90	8.9	3.3
1990–91	9.4	4.2
1991–92	7.0	3.4
1992–93	7.0	3.2
1993–94	8.3	4.3
1994–95	7.1	3.7
1995–96	6.5	3.2
1996–97	6.4	3.6
1997–98	7.3	4.1
1998–99	9.0	6.3
1999–2000	9.5	6.3
2000–01	9.7	6.3

Note: Figures are percentages of GDP at prevalent market prices.
Source: Acharya 2002: Table 13.

These also limit the ability of the state to spend in areas such as education. Although Nagaraj (1997) notes that spending on social sectors (education, health, housing and social services) held steady in the 1990s, it is clear that much higher levels of spending are required to ensure the socio-economic mobility that will bring India on par with other NICs. Whether and how reallocation of spending will take place in an era of unstable governments is unclear. There is reason to be sceptical about increased social spending as newly elected leaders practise their own version of distributive justice to secure privileges for their supporters. This is not limited to seeking the benefits of affirmative action or subsidies.

> There is a certain nonchalance in the rampant corruption among politicians in the newly emergent groups. Lower caste leaders, when they come to power, are sometimes quite unapologetic about being corrupt. They say that upper castes in control of the state have been corrupt for decades, and

> now it is their turn. Corruption is thus seen as a collective entitlement in an amoral game of group equity (Bardhan 1998: 133).

Since the state has become an arena of savage competition for resources, the implications for its developmental role are unclear:

> … the unfolding of populist democracy to reach the lower rungs of the social hierarchy have been associated with a loosening of earlier administrative protocols and a steady erosion of institutional insulation of the decision-making process in public administration and management …. What all this does to the institutional independence of economic decision-taking bodies or the credibility of commitment to long-run developmental policies is anybody's guess (Bardhan 1998: 133).

The underlying political instability affecting macro-economic management also affects the ability to bring about micro-economic reforms that will allow the industry to perform better, as the debate over labour market reforms exemplifies. The Industrial Disputes Act, 1947 makes government approval mandatory before retrenchments from any establishment employing more than 100 workers.[20] But permission is rarely granted, that is, those firms that will most likely be able to afford automation using IT cannot easily reap the benefits of such automation as it involves politically unpalatable work reorganization and possible job losses. Although the government announced in February 2001 its intention to raise the retrenchment threshold to 1,000, opposition within the ruling National Democratic Alliance coalition and from trade unions prevented progress on the issue (Joshi 2002).

Conclusion

The Indian experience shows that even in the current era of economic globalization, there is a critical role for states in NICs to help regions and firms seize the opportunities created by the emergence of new industrial sectors. Policy shifts are not merely a question of getting the state out of the way, but they must also be promotional in nature. Thus, changes in state policies in the 1980s, which rejected a highly regulated, autarchic development approach, were essential for the rise of a software industry in India. However, it was the initiative to provide the necessary infrastructure at the STPs which fundamentally altered how firms in India were able to seize the advantages offered by the growing global software industry. The initiative was also essential to capitalize on policies of earlier decades, such as the creation of a low-wage but highly skilled labour pool, besides reinforcing accidental advantages, such as the time difference with the US or the English language abilities of Indian engineers.

It also shows, however, that policies to develop a globally competitive software industry cannot be limited to promoting exports, as was the case with manufacturing industries of the East Asian tigers. This is because code by itself is of little value unless it serves an economic purpose, and embodying that purpose is an understanding of the specificities of activities in various economic domains. Efforts limited to promoting exports will not make it easy for firms to move beyond the low end of the business. Instead, the knowledge gained from local markets can provide the basis to move into more innovative and lucrative segments of the global IT industry.

For this, however, while embeddedness in private capital and business-friendly policies are necessary, it is the broader character of historically specific state–society relations that will determine whether the state can encourage the domestic economic restructuring that comes with using IT, thereby determining the trajectories of software-producing regions in the international division of labour. Thus, although the Indian state embedded itself in private capital, its development failures led to declining autonomy that in turn has challenged its ability to implement development policies. Broadly, it shows that although it is easier to abandon the role of custodian and demiurge, it is harder to take on the midwifery and husbanding roles. More specifically, the challenge was this: after reaping the benefits from sector-specific policies implemented by a reformed DoE, it has proven harder to bring about transformation in other government ministries and the sectors they control, indicating limited bureaucratic coherence. Bringing about the coherence is critical to exploit the productivity potential offered by an emergent sector that is widely seen to be at the heart of a third industrial revolution. Although the Indian development trajectory is just one among many possibilities, it shows a significant challenge that other NICs can potentially face as they attempt to take advantage of new industrial sectors and take on the roles of midwifery and husbanding.

The growth of the software industry in Bangalore points to the kind of agglomeration one can expect in an intermediate state faced with challenges. On one hand, the accumulated labour pool in public sector industries and laboratories were an immediate source of regional advantage as the regulatory environment changed in the mid-1980s, an advantage reinforced by the establishment of the first STP in Bangalore in the early 1990s. This attracted both domestic firms and MNCs. However, while the labour pool and the infrastructure provide the draw, the institutional means to sustain these advantages, especially as the wage rates for labour are tied to global and local demand, has proven difficult to create. This reflects the lack of ties among local firms catering to export markets. Although MNC ODCs do a lot of R&D for their parent bodies, they are islands unto themselves. The net result is to dampen the likelihood of creating a technical community committed to innovation, especially in the absence of incentives, such as the demands made by proximate customers, to interact and share ideas locally. In other words, innovation is socially embedded and creating regional institutions is the sufficient condition to support the process. This remains a daunting challenge for intermediate states even as it offers a promising research avenue for the future.

Notes

1. The state, in this paper, will refer to the national state. Although, as described later, with increasing initiatives to decentralize power and resources, the character of provincial states also merit analysis, examining the national state will suffice for the analytical agenda here.
2. In 2000, illiteracy among those older than 15 years was 42.8 per cent (www.uis.unesco.org/en/stats/stats0.htm), while India's gross national income, based on parity of purchasing power, was ranked 153 among 207 countries (www.worldbank.org/data/databytopic/GNPPC.pdf). In 1997, 44.2 per cent of India's population lived on less than $1 a day, and 86.2 per cent on less than $2 a day (www.worldbank.org/data/wdi2001/pdfs/tab2_6.pdf).
3. Re-engineering is a means of reducing and simplifying maintenance by essentially replacing the older software with equivalent new software, that is, changing its form without altering its function (Sneed 1995). The result is easier and more efficient data access by shortening access paths, providing better query facilities and distributing data among several servers. Other benefits include better security, elimination of bugs lurking in the older software, and laying the ground for functional enhancement. Typically, re-engineering involves migration from a mainframe to a newer operating environment, such as Unix, and is likely to entail

a language change. For example, C is upgraded to C++ or unstructured Cobol is upgraded to Object Cobol.

4. Jones (1998) points to other format problems with older software that were manifested in the 1990s. One date problem had to do with global positioning system (GPS) satellites. The network of 24 satellites kept track of dates from the midnight of 5 January 1980 for 1024 weeks. On the midnight of 21 August 1999, the week counter was reset to zero. This did not affect the satellites as much as applications, such as global fund transfers, which rely on GPS time signals. The shift to the Euro, replacing 12 European currencies, from 1 January 1999, posed a different kind of format problem.
5. Interview with N. Seshagiri, former Additional Secretary DoE, on 24 June 1996, and with N. Vittal, former Secretary DoE, on 25 June.
6. For details of all the benefits offered by STPs, see www.stpi.soft.net
7. Interview with Pronab Sen, former Economic Advisor, DoE, on 19 June 1996.
8. For details of these policy changes, see Acharya (2002) and the essays in Oman (1996).
9. www.nasscom.org/artdisplay.asp?cat_id-205.
10. The public sector enterprises include Bharat Earth Movers Limited, Bharat Electronics Limited and Hindustan Aeronautics Limited under the Ministry of Defence, Bharat Heavy Electricals Limited and Hindustan Machine Tools under the Ministry of Heavy Industry and Public Enterprises, and the Indian Telephone Industries under the DoT. Nine of 49 of the Defence Research and Development Organisation's (DRDO) laboratories are in Bangalore. These include the Aeronautical Development Agency, the Centre for Air Borne Systems, the Centre for Artificial Intelligence and Robotics, the Centre for Aeronautical Systems Studies and Analysis, the Defence Avionics Research Establishment, Defence Bio-Engineering and Electro Medical Laboratory, the Gas Turbine Research Establishment, the Electronics and Radar Development Establishment, and the Microwave Tube R&D Centre. A laboratory of the Centre for Development of Advanced Computing and a location of the National Centre for Software Technology, both under the Department of Information Technology, and a laboratory of the Centre for Development of Telematics of the DoT is in the city. Bangalore is home to the Council of Scientific and Industrial Research's (CSIR) National Aerospace Laboratories, and the Centre for Mathematical Modelling and Computer Simulation. Finally, the Indian Space Research Organisation (ISRO) of the Department of Space is also located in Bangalore.
11. There are no 'production' costs for one-off projects, whereas for mass market software products, the low duplication costs mean that the marginal cost of production is near zero.
12. www.infosys.com/about/history.asp. The essay describes Infosys not only because it is a large SEI-CMM level 5 exporter, but also because it was started in 1981 by professionally trained entrepreneurs with very little capital and is now widely admired for its accomplishments. The accomplishments include being the first company to be conferred the 'National Award for Excellence in Corporate Governance' by the Government of India, being rated the 'Best Employer of India' in a study by *Business Today*-Hewitt Associates in 2001 www.infosys.com/about/Narayana_Murthy.asp, and ranking first in 2002 in *Business World*'s survey of 'India's Most Respected Company'. Recently, CNN–Time named

N.R. Narayana Murthy, Infosys' Chairman of the Board and its main founder, as one of the 25 most influential global executives. The listing of these accomplishments here is to merely make the point that if a firm as accomplished and successful as Infosys faces constraints in Bangalore, dealing with them becomes as challenging, if not more, for other smaller firms.

13. This section draws from Bardhan (1998) and Nayar (1998), unless otherwise mentioned.
14. For details of the Task Force constitution and its recommendations, see http://it-taskforce.nic.in/index.html.
15. Details of the Act can be found at http://indiacode.nic.in/fullact1.asp?tfnm=200021.
16. The policies of most provinces can be found at www.nasscom.org/artdisplay.asp?cat_id-39.
17. The full report is available at www.mit.gov.in/atrnt.asp.
18. Studies conducted by the consulting firm McKinsey for NASSCOM also reflect these problems. In a 1999 study, it projected that India could export $30 bn of IT services by 2008, and estimated the domestic IT market at $20 bn. In a 2002 study, however, McKinsey changed its projections for the 2008 domestic market to $15 bn, even as its 1999 export projections remained unchanged (*Deccan Herald* 2002).
19. Subsidies take many forms, as Bardhan (1998) describes. They include explicit cash subsidies (for example, on food or for exports); interest or credit subsidies for below-market-rate loans; tax subsidies on things such as deduction of mortgage interest payments; in-kind subsidies such as the provision of free medical services; procurement subsidies in the form of government purchase of food grains; regulatory subsidies in administered prices; and equity subsidies due to investment in public sector firms providing little dividends.
20. For an analysis of Indian labour markets, see Datta Chaudhuri (1996).

References

Acharya, S. 2002. 'Macroeconomic Management in the Nineties', *Economic and Political Weekly*, 37(16): 1515–38.

Alarcon, R. 1998. 'The Migrants of the Information Age: Foreign Born Engineers and Scientists and Regional Development in Silicon Valley', Ph.D. dissertation, University of California, Berkeley.

AICTE (All India Council for Technical Education). 1999. *Reshaping Postgraduate Education and Research in Engineering and Technology.* New Delhi: AICTE.

Arora, A. and J. Asundi. 1999. 'Quality Certification and the Economics of Contract Software Development: A Study of the Indian Software Industry', Working Paper 7260. Cambridge, MA: National Bureau of Economic Research.

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

Bardhan, P. 1998. *The Political Economy of Development in India*, expanded edn. New Delhi: Oxford University Press.

Brooks, F.P. 1995. *The Mythical Man-month: Essays on Software Engineering,* second edn. New York: Addison Wesley Longman.
Brusco, S. 1982. 'The Emilian Model: Productive Decentralisation and Social Integration', *Cambridge Journal of Economics*, 6(2): 167–84.
Dataquest. 1987. The New Software Policy: Dr. Seshagiri Clarifies. January, 82–95.
Datta Chaudhuri, M. 1996. *Labor Markets as Social Institutions in India.* IRIS-India Working Paper 10, Center for Institutional Reform and the Informal Sector, University of Maryland at College Park, College Park, MD.
Davis, A. 1993. 'Software Lemmingineering', *IEEE Software*, 10(5): 79–81, 84.
Deccan Herald. 2002. 'IT Sector May Achieve $50 bn Exports by 2008, Says Study', 11 June.
Egan, E.A. 1997. 'The Spatial Dynamics of the U.S. Computer Software Industry', Ph.D. dissertation, University of California, Berkeley.
Evans, P.B. 1995. *Embedded Autonomy: States and Industrial Transformation.* Princeton, NJ: Princeton University Press.
Fineman, M. 1991. 'India's New Middle Class Finds Home in Bangalore', *The Los Angeles Times,* 17 December.
Gibbs, W.W. 1994. 'Software's Chronic Crisis', *Scientific American*, 271(3): 86–95.
Granovetter, M. 1985. 'Economic Action and Social Structure: The Problem of Embeddedness', *American Journal of Sociology*, 91(3): 481–510.
Grieco, J.M. 1984. *Between Dependency and Autonomy: India's Experience with the International Computer Industry.* Berkeley and Los Angeles: University of California Press.
Harding, E.U. 1989. 'India: After IBM's Exit, an Industry Arose', *Software Magazine*, 9(14): 48–54.
Heeks, R. 1996. *India's Software Industry: State Policy, Liberalisation and Industrial Development.* New Delhi: Sage Publications.
Henderson, J. 1989. *The Globalisation of High Technology Production: Society, Space and Semiconductors in the Restructuring of the Modern World*. London: Routledge.
Hsu, Jinn-Yuh and A. Saxenian. 2001. 'The Dynamic Institutionalism of Taiwan's Late-industrial District in the Globalization Process' (paper for the 97th Annual Meeting of the Association of American Geographers), 27 February–3 March, New York.
Hsu, Jinn-Yuh. 2000. 'Towards a Late-industrial District: The Construction of Learning Networks in Hsinchu-Taipei Corridor, Taiwan' (paper for *Global Conference on Economic Geography*, 5–9 December), Department of Geography, The National University of Singapore, Singapore.
IDG. 2001. 'India's Silicon Valley Lures Foreign Companies', *The Industry Standard*, www.industrystandard.com/article/0,1902,27396,00.html.
InfoTech Consulting. 1992. 'India's Software and Services: Export Potential and Strategies', Report submitted in fulfillment of contract with the Government of India, Department of Electronics under World Bank Japan Grant #2612.
Jayaswal, Rajeev and Kavita Vivek. 2001. 'External Affairs Ministry may be the Bull in Infosys' China shop', *Financial Express*, 14 September.
Jones, C. 1998. 'Bad Days for Software', *IEEE Spectrum*, 35(9): 47–52.
Joshi, R. 2002. 'Tokenism by Another Name', *Business India*, 4–17 March.
Kraft, P. 1977. *Programmers and Managers: The Routinization of Computer Programming in the United States.* New York: Springer-Verlag.

Kitchenham, Barbara and Shari Lawrence Pfleeger. 1996. 'Software Quality: The Elusive Target', *IEEE Software*, 13(1): 12–21.

Koch, Kathy. 1998. 'High-tech Labor Shortage', *CQ Researcher*, 8(16): 361–84.

Keuffel, Warren. 1991. 'House of Structure', *UNIX Review*, 9(2): 28–36.

Mathews, J.A. and Dong-Sung Cho. 2000. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia.* Cambridge: Cambridge University Press.

Mayall, A. 1991. 'Spaghetti Systems, *Which Computer?* 14(1): 40.

Nagaraj, R. 1997. 'What has Happened Since 1991? Assessment of India's Economic Reforms', *Economic and Political Weekly*, 32(44 & 45): 2869–79.

Nair, V. 1998. 'Infosys Eyes Big, to Set Up Three Software Centres Abroad', *Economic Times,* 28 October.

NASSCOM (National Association of Software and Service Companies). 1992. *Indian Software Directory, 1992.* New Delhi: NASSCOM.

———.1993. *Indian Software Directory, 1993–94.* New Delhi: NASSCOM.

———. 2001. *Indian IT Software and Services Directory*, *2001.* New Delhi: NASSCOM.

Nayar, B.R. 1998. 'Political Structure and India's Economic Reforms of the 1990s', *Pacific Affairs*, 71(3): 335–58.

Oman, C. (ed.). 1996. *Policy Reform in India.* Paris: OECD.

Parthasarathy, B. 2000. Globalization and Agglomeration in Newly Industrializing Countries: The State and the Information Technology Industry in Bangalore, India. Ph.D. dissertation, University of California, Berkeley.

Piore, M.J. and C.F. Sabel. 1984. *The Second Industrial Divide: Possibilities for Prosperity.* New York: Basic Books.

Rao, R.L.R. 1995. 'Second Wave of Software Investments to Flow into Bangalore', *The Economic Times,* 10 May.

Salus, P.H. 1994. 'Unix at 25', *Byte*, 19(10): 75–82.

Saxenian, A. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, MA: Harvard University Press.

Schneidewind, N.F. and N. Fenton. 1996. 'Do Standards Matter?' *IEEE Software*, 13(1): 22–24.

Schware, R. 1992. 'Software Industry Entry Strategies for Developing Countries: A "Walking on Two Legs" Proposition', *World Development*, 20(2): 143–64.

Sen, P. 1994. 'Software Exports from India: A Systemic Analysis', *Electronics Information and Planning*, 22(2): 55–63.

Sims, D. 1994. 'Motorola Self-assesses at Level 5', *IEEE Software*, 11(2): 92.

Sneed, H.M. 1995. 'Planning the Reengineering of Legacy Systems', *IEEE Software*, 12(1): 24–34.

Sridharan, E. 1996. *The Political Economy of Industrial Promotion: Indian, Brazilian, and Korean Electronics in Comparative Perspective 1969–1994.* London: Praeger.

Steinmueller, W.E. 1996. 'The U.S. Software Industry: An Analysis and Interpretive History', in D.C. Mowery (ed.), *The International Computer Software Industry: A Comparative Study of Industry Evolution and Structure.* New York and Oxford: Oxford University Press.

Storper, M. 1997. *The Regional World: Territorial Development in a Global Economy*. London: Guildford Press.

Subramanian, C.R. 1992. *India and the Computer: A Study of Planned Development.* New Delhi: Oxford University Press.

Udell, J. 1993. 'India's Software Edge', *Byte*, 18(10): 55–60.

Verma, S. 2000a. 'IT Task Force: Two Years Down ....', *Dataquest*, 18(20): 117–24.

———. 2000b. 'The IT Task Force Scorecard II: Bridging the Digital Divide', *Dataquest*, 18(21): 70–8.

———. 2000c. 'IT Task Force Scorecard III: The IT Industry Impact', *Dataquest*, 18(22): 111–20.

Wright, E.O. 1996. 'Review of Embedded Autonomy', *Contemporary Sociology,* 25(2): 176–79.

Websites

www. bangaloreit.com
www. eci.gov.in
www. idc.com
www. infosys.com
www. itu.int
www. mit.gov.in
www. nasscom.org
www. nic.in
www. stpi.soft.net
www. uis.unesco.org
www. worldbank.org

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Telecommunications and Economic Growth: Implications for India*

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Introduction

Early work on economic growth and development has highlighted the necessity of adequate infrastructure as a basis for development. Commenting on the definition and scope of social overhead capital (SOC), Hirschmann (1958) writes, 'SOC is usually defined as those services without which primary, secondary and tertiary production activities cannot function'. He goes on to write that in its wider sense, SOC '… includes all public services from law and order through education and public health to transportation, communications, power and water supply ….' Despite the wide range of services that may be included under the rubric of infrastructure, these services share several common traits. First, while these services yield direct benefits, their indirect contribution as intermediate inputs that may enhance the productivity of all other inputs is often considered to be more important. Second, production of these services is usually subject to increasing returns to scale. Third, while there has been an increase in the participation of the private sector in providing infrastructure in general, infrastructure provision is still publicly funded and owned. The rationale for public provision of these services is well known and is usually justified on the basis of a combination of externalities, non-rival consumption and non-excludable characteristics of such services.

In recent years, the potential role that may be played by a particular infrastructure, that is, information and communication technologies (ICTs), in promoting economic development especially in low-income countries has attracted considerable attention. Several commentators have argued that the propagation of and accessibility to these new technologies should be viewed as an integral part of a country's development strategy (see, for example, Pohjola 2002). Despite these comments, there are detractors who point out that developing countries have far more pressing investment priorities and investing scarce resources on ICT simply does not meet the needs of the poor (Roche and Blaine 1996; Saith 2002).

Whether additional investments in these technologies are justified and whether they have the potential to increase incomes and alleviate poverty can only be determined by empirical investigation. If these new technologies are to command the continued interest of the developing world and justify additional investments, a convincing demonstration of the effects of these technologies on economic performance is required. Motivated by considerable interest in these technologies and the limited empirical evidence of their impact on economic outcomes, this paper examines the impact of the terrestrial telecommunications infrastructure, by far the most widely prevalent communication technology in developing countries, on aggregate economic output.

There are several ways in which the ICT infrastructure of a country can have an impact on economic growth. Apart from the direct contribution that the development of such infrastructure may have on aggregate output, investments in these technologies are expected to have pervasive effects throughout the economy. The role of these technologies in reducing transaction costs, improving the functioning of organizations, enhancing the spread and development of factor and product markets and other potential effects has been outlined by several authors (for example, Leff 1984; Norton 1992; Saunders et al. 1983). The comments made by these authors is also echoed in recent documents issued by the Government of India (GOI). Despite neglecting the telecommunications sector for decades, in the last 10–12 years, policy documents issued by the GOI emphasize the importance of a high-quality telecommunications network (GOI 1994, 1999).

A key characteristic of ICTs that distinguishes them from other types of infrastructure is the nature of the externalities associated with such technologies. Expansion of telecommunication or internet networks generates benefits for new users and for existing users. This network externality is peculiar to ICT and suggests that the effects of these technologies on economic growth may be subject to the attainment of a critical mass. That is, unless the available telecommunications infrastructure in a country reaches a certain level, growth effects may not be discernible. Thus, the empirical work in this paper is geared towards addressing two issues. First, if there is an impact of telecommunication infrastructure on economic growth, and second, if there is a growth effect, how it varies across countries/regions with different levels of infrastructure and income.[1]

To carry out our empirical investigation, we relied on a dataset that covers 113 countries over the period 1980–2000. Our empirical framework explicitly accounts for the endogeneity between telecommunication infrastructure and economic output. We follow the four-equation framework used by Röller and Waverman (2001), and in the first instance, we replicate the model estimated by these authors. However, our estimation methodology and empirical work goes beyond their specification. In particular, we examine the time series properties of our data and correct for the presence of unit-roots.

The paper is organized in the following manner. The succeeding part summarizes the literature on telecommunications infrastructure and growth, the second part outlines an econometric model, the third describes the data and presents correlations between GDP and the availability of information and communication technologies. The subsequent part presents our results, followed by the conclusion.

Telecommunications Infrastructure and Growth: A Review[2]

Jipp (1963) and Hardy (1980) have undertaken some of the earliest studies that focus on the telecom–growth link. For instance, Hardy (1980) uses data from 15 developed and 45 developing countries for the years 1960 through 1973 and regresses GDP per capita on lagged GDP per capita, lagged telephones per capita and the number of radios. Hardy's results support the idea that the greater availability of telephones has a positive effect on GDP. By demonstrating the strong correlation between telephone density and GDP, these early papers drew attention to the potential role of telecommunications in influencing growth. The policy implications drawn from such studies were fairly clear and they argued for additional investments in telecommunications infrastructure. However, policy prescriptions based on the results of these papers quickly attracted strong criticism.

The primary criticism levelled at these first-generation studies is that they do not adequately account for the possibility of reverse causality and simultaneous determination of output and public capital. While it is tempting to infer a causal relationship from public capital to output, it is equally likely that the direction of causality goes from output to public capital. In the context of time-series analysis, the estimated coefficient may reflect a spurious correlation between output and public capital stock that is driven by a common time-trend and not by any underlying relationship between the two variables. That is, the data may be non-stationary and inferences based on these data may be misleading. Another problem primarily afflicting panel data studies may be cast in the mould of omitted variables. The first-generation panel data studies usually ignored the possibility of unobserved state- or country-specific variables that may sometimes influence both output and the stock of public capital. Ignoring such fixed effects is quite likely to lead to an exaggeration of the effect of infrastructure on output.

The more recent literature in this area takes these problems into account. A sophisticated example of this is Norton's (1992) study. Using data from a sample of 47 countries for the post–World War II period until 1977, Norton investigates the effects of telephone infrastructure on growth rates and also tries to identify the channels through which the availability of this infrastructure leads to growth.

The empirical framework replicates Kormendi and Meguire's (1985) study, but includes additional variables to capture the nature and conditions of the telecommunications infrastructure. Norton includes a number of macro-economic variables and two measures to evaluate the infrastructure, the latter being telephone density in 1957 and the mean telephone density over the time period of the sample. The use of the two infrastructure variables is an attempt to address the endogenous nature of telephone density and growth. Norton argues that a measure of telephone density prevalent during the early years of the sample is less susceptible to endogeneity bias than a variable that captures the mean telephone density during the entire time period. Norton's results show that the two measures of telecom infrastructure are statistically significant and exert positive effects on mean growth rates. For instance, increasing the 1957 telephone density by one standard deviation (9.909) leads to an increase in mean GDP growth of around 0.73 per cent. The effect of the average density variable is greater, but potentially more susceptible to reverse causality. While Norton controls for the endogeneity of telecom infrastructure and growth, the large effects reported in the paper are reminiscent of the effects reported in the first-generation literature. Norton does not control for country fixed-effects and it is likely that this omission is responsible for the large estimated effects of telecom infrastructure.

Madden and Savage (2000) follow the framework used by Mankiw et al. (1992) to estimate the effect of telecommunications on the level and growth of GDP for a cross-section of 43 countries—including 16 developing countries—covering the time period 1975–90. The authors present estimates based on ordinary least squares (OLS) regression analysis and estimates of instrumental variables to control for the possible endogeneity between telecom capital and GDP. Their results are not sensitive to alterations in estimation methodology and they report a substantial impact of telecommunications capital on the level of GDP. Once again, their estimates may be upward biased as they do not control for country fixed-effects.

Röller and Waverman (2001) present estimates of the effect of telecommunications on output based on a cross-section of 21 OECD countries over a period of 20 years. They tackle the endogeneity problem by estimating a four-equation model that endogenizes telecommunications infrastructure and also control for country fixed-effects. Their results display that estimates allowing for fixed-effects lead to a reduction in the elasticity of telecom density from 0.15 to 0.045. Despite the drop in the magnitude of the tele-elasticity, the growth effect attributed to telecom infrastructure is still quite large. The elasticity implies that about one-third of the economic growth in OECD countries between 1971–90 may be attributed to growth in telecommunications infrastructure. An interesting element of their work is the investigation of whether there is a non-linear relationship between telecom density and economic output. Their investigation shows that telecommunications density begins to exert an influence on output only when it is universally available, that is, a teledensity threshold or a critical mass of about 40 per cent.

While the robustness and generality of the threshold effect may be questioned, it does suggest that enhancements in telecommunications infrastructure may generate higher growth effects in developed countries than in developing countries. In addition, given the low telecom density in developing countries (the 1995 average was around 4 per cent), it appears that marginal improvements in telecom infrastructure may not generate the desired growth effects.

The Econometric Model and Estimation Methodology

In order to identify the causal effect of telecommunications on economic growth, we follow the model used by Röller and Waverman (2001). We endogenize telecommunications by estimating a demand and supply model for telecommunication investments and simultaneously estimate a macro-production function. Our primary aim is to examine whether the idea of a critical mass is valid for a larger sample of nations and for a longer time-period. In our analysis, we place special emphasis on examining this relationship for developing countries.

The econometric model that we use consists of four equations. The first of these equations is that of aggregate production function:

$$GDP_{it} = f(K_{it}, HK_{it}, TELECOM_{it}, t) \quad (1)$$

where *GDP* is the real gross domestic product, *K* is a measure of the real capital stock net of telecommunications capital (details are provided in the data section), *HK* represents human capital, *TELECOM* represents the stock of telecommunications infrastructure, and *t* is a linear time trend. The empirical counterpart of this equation may be represented as:

$$\text{(1a)} \quad \log(GDP_{it}) = a_{0i} + a_1 \log(K_{it}) + a_2 \log(TLF_{it}) + a_3 \log(PEN_{it}) + a_4 t + u^1_{it}$$

In this equation, *TLF* represents the total labour force and is used as a proxy for human capital. *PEN* is the telephone penetration rate, which is defined as the number of mainlines per 100 inhabitants. This variable is a proxy for the stock of telecommunications infrastructure (*TELECOM*). The coefficient on telecommunications infrastructure, *TELECOM*, estimates the one-way causal relationship between the stock of telecommunications and economic output.

The second equation in the model is the demand for telecommunications infrastructure. Demand is treated as a function of per capita *GDP* (*GDP/POP* where *POP* is the total population) and the price of telephone services:

$$\text{(2)} \quad TELECOM_{it} = h(GDP_{it}/POP_{it}, TELP_{it})$$

Given that the objective is to measure the demand for telecommunications, in this equation, *TELECOM* is approximated by the sum of the penetration rate and the waiting list per 100 habitants (*WL*). The price of telephone services is approximated by the total service revenue per main line (*TELP*). The empirical counterpart of this equation is given by

$$\text{(2a)} \quad \log(PEN_{it} + WL_{it}) = b_0 + b_1 \log(GDP_{it}/POP_{it}) + b_2 \log(TELP_{it}) + u^2_{it}$$

The third equation captures the supply of telecommunications investment (*TTI*). This equation is treated as a function of the price of telephone service (*TELP*) and a vector of variables (*Z*):

$$\text{(3)} \quad TTI_{it} = g(TELP_{it}, Z_{it})$$

The empirical counterpart of this equation is

$$\text{(3a)} \quad \log(TTI_{it}) = c_0 + c_1 \log(GA_{it}) + c_2 GD_{it} + \log(TELP_{it}) + u^3_{it}$$

where, as in the demand equation, service revenue per main line is used as a proxy for price. The scale of the country and the economic well-being of the country is measured by the geographic area in thousands of square kilometers (GA) and the government surplus (deficit) in billions of 1985 USD (GD), respectively.

The final equation in the model measures the relationship between investment in telecommunications infrastructure and changes in the stock of telecommunications infrastructure:

$$\text{(4)} \quad TELECOM_{it} - TELECOM_{i,t-1} = (TTI_{it}, R_{it})$$

where R represents a vector of exogenous variables. To empirically estimate this equation, the change in the stock of telecommunications is approximated by the change in penetration as a function of investment in telecom infrastructure and the geographic area:

$$\text{(4a)} \quad \log(PEN_{it}/PEN_{i,t-1}) = d_0 + d_1 \log(TTI_{it}) + d_2 \log(GA_{it}) + u^4_{it}$$

Since equations (2), (3) and (4) involve the demand for and supply of telecommunications infrastructure, they endogenize telecommunications infrastructure. All four equations may be estimated as a system or by using a two-step estimation procedure.

Röller and Waverman (2001) estimate the empirical model outlined here using variables in levels and with and without country fixed-effects. An issue which they do not take into account is that variables such as GDP and capital may follow a random walk. If these variables do indeed follow a random walk, then regression analysis may lead to spurious results. Detrending the variables before running the regression may not help as the detrended series may still be non-stationary. It is likely that only first differencing will yield a stationary series.

In this paper, we attempt to solve this problem by estimating equations in first differences. In our empirical work, we assume that the error terms in the four equations follow an error component model:

$$\text{(5)} \quad u_{it} = \mu_i + \nu_{it}$$

where $\mu_i \sim$ IID $(0, \sigma^2\mu)$ and $\nu_{it} \sim$ IID $(0, \sigma^2_\nu)$ are independent of each other and represent unmeasured time-invariant country and country/year effects, respectively. Given this error structure, lagged values of the dependent variable (the generic dependent variable is represented by Y)[3] will be correlated with the error terms in equations 1–4. Even though the first difference transformation mitigates this correlation problem by eliminating the individual effect, μ_i, OLS estimation of the differenced model would also be inconsistent, because now ΔY_{it-1} and $\Delta\nu_{it}$ are correlated (given that Y_{it-1} and u_{it-1} are correlated). Anderson and Hsiao (1981) observed that as long as u_{it} is not serially correlated, ΔY_{it-2} (which depends on the second and further lags of u_{it}) is clearly correlated with ΔY_{it-1}, but not with $\Delta\nu_{it}$ (which only depends on ν_{it} and ν_{it-1}). Therefore, ΔY_{it-2} is a valid instrument for ΔY_{it-1} and may be used to estimate the model consistently.

Arellano and Bond (1991) observed that, in order to gain efficiency, when the number of periods is small and the number of groups in the panel is large, the number of valid instruments grows with the number of available periods. For example, for $t = 3$ the only valid instrument is Y_{it-1}, but for t = 4 both Y_{it-1} and Y_{it-2} are valid instruments. Consequently, for any given period T, the set of valid instruments becomes $(Y_{i1}, Y_{i1t-1}, \ldots Y_{iT-2})$. Considering that the exogenous variables (which we will call x_{it} for simplicity, but include the other explanatory variables in the model, such as capital and labour force) may be predetermined and correlated with μ_i, the valid set of instruments is $x_{i1}', x_{i2}', \ldots x_{i(s-1)}'$ given that $E(x_{it}\nu_{is}) \neq 0$ for $s < t$, and it is zero otherwise.

From the lagged Y and the explanatory variables, a matrix of instruments (W) can be obtained, so that $E(W_i'\Delta v_i)=0$. With these instruments in hand, we may obtain consistent and efficient estimates of the four-equation system using the two-step, Arellano and Bond (1991, 1998) generalized method of moment (GMM) estimator. This two-step procedure provides robust standard errors.[4]

Data and Summary Statistics

To carry out our empirical analysis we have assembled a dataset that includes data on 113 countries and covers the time period 1980–2000. Our aim was to construct a comprehensive dataset and accordingly, the inclusion of a country was determined by the availability of extended time series data on the variables that are required for our analysis. The list of countries in our dataset, their distribution according to income categories and according to region are given in the Appendix in Table 7.1A.

The assembled dataset is tailored to the needs of our empirical framework and contains information on economic variables, such as output, labour force, capital stock and budget deficit (surplus). The telecommunications-related variables are annual investment in telecommunications, telephone density, and revenue per telephone line. In addition to these variables, the data contains information on the availability of other information and communication technologies. Table 7.1 provides a list of the variables, their descriptive statistics and also indicates the source of the variables.

Most of the variables may be obtained from publicly accessible databases, such as *World Development Indicators* (*WDI*) and those of the International Telecommunications Union (ITU). However, some of them, particularly the telecommunications capital stock and total physical capital stock, require construction. This can be done using the data on annual investment in telecommunications available in the WDI. Telecommunications capital stock can be constructed using the perpetual inventory method (PIM) (Torero et al. 2002).

Figure 7.1 shows the availability of different ICTs for five income groups. The availability of each of the ICTs in the figure is the country average within each income group. Even after the explosive growth of modern ICTs in the 1990s, fixed telephony still occupies the highest share of ICT in low-income, lower-middle income and OECD countries. However, mobile telephony has emerged as the second most important communication technology. In some cases, for instance, in higher-middle income countries and high-income non-OECD countries, cellular telephony outnumbers fixed telephony. Except for access to fixed line telephony, the level of modern ICTs, for instance, internet hosts and personal computers in low-income countries, remains very low.

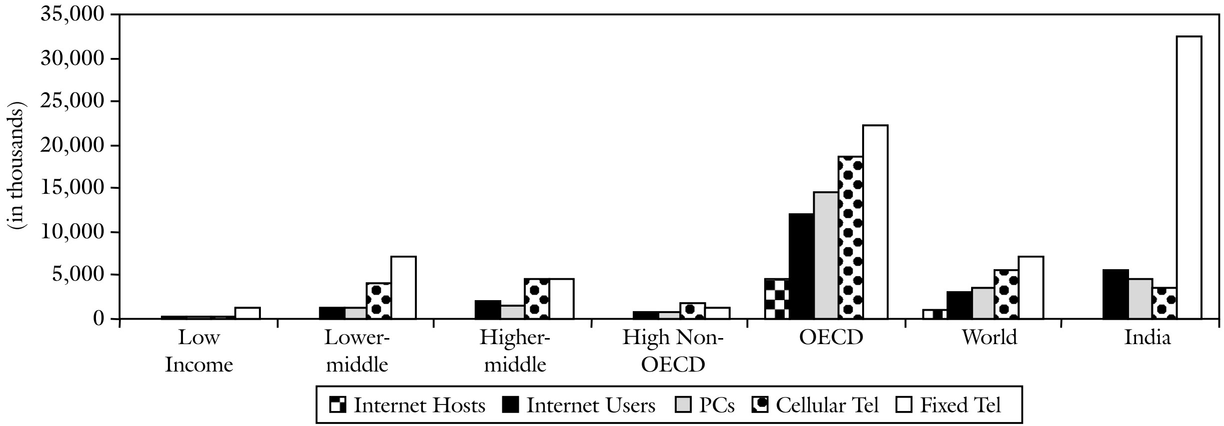
Though countries in all income groups experienced sizeable growth in ICTs in the 1990s, the total stock of ICTs in low-income countries remained extremely low compared to other income groups. For instance, compared to 4.7 million internet hosts per OECD country, the low-income country average is 2,432, which is 0.05 per cent of the OECD average. Though the stock in the case of fixed telephony is higher compared to other ICTs in low-income countries, it is 5.82 per cent of the OECD average. In fact, the relatively high average of

TABLE 7.1 **List of Variables and Summary Statistics (1995)**

	N	*Min.*	*Max.*	*Mean*	*SD*
GDP (US$ mn)*	1,829	199.61	7,723,512.50	229,782.90	798,217.13
Total Labour Force in millions*	1,829	0.02	979.67	33.75	113.90
Total Physical Capital Stock (US$ mn)**	1,829	761.49	21,100,000.00	659,167.41	2,300,430.01
Annual Investment in Telecom (US$ mn)*	1,772	0.01	37,080.61	1,240.20	3,888.95
Land Area in thousand sq. km*	1,819	0.32	9,326.41	838.60	1,891.43
Govt Budget Surplus (deficit) (US$ mn)*	1,404	–309,010.96	84,042.30	–10,406.74	34,965.53
Main Telephone Lines per 100 Inhabitants***	1,828	0.09	70.69	15.83	18.29
Cellular Mobile Subscribers per 100 Inhabitants***	1,791	0.00	47.47	1.17	4.02
Telephone Service Revenue per Mainline (US$ mn)***	1,369	58.21	1,314,365.28	3,499.36	51,340.28
Cellular Service Revenue per Mainline (US$ mn)***	393	0.00	17,532.79	1,141.04	1,387.06
Waiting List for Mainlines per 100 Inhabitants***	1,611	0.00	20.73	1.21	2.16
Internet Users per 1,000 Inhabitants***	563	0.00	294.25	12.99	31.68
Internet Hosts per 10,000 Inhabitants***	1,362	0.00	945.82	11.65	56.96
Personal Computers per 1,000 Inhabitants***	689	0.01	406.87	57.65	81.09

Source: **WDI* 2002; **Nehru and Dhareshwar 1993 and authors' estimation based on *WDI* data; ***ITU 2002.

FIGURE 7.1 **Availability of ICTs for Different Income Groups and India in 2000**



Source: Based on ITU (2002).

fixed telephony in low-income countries is due to the outliers within the group, such as India and Indonesia; the total number of fixed telephones (mainlines) in India and cellular phones in Indonesia in 2000 were more than 25 times and 12 times the low-income country average. In addition to the low availability of various ICTs, there is an imbalance between the availability of fixed telephones and modern ICTs, such as internet in low-income countries. While the ratio between fixed telephone and internet accounts is 1.85 to one in OECD countries on an average, it is five to one in low-income countries.

Table 7.2 shows the compounded annual growth rates (henceforth, CAGR) of GDP per capita and telephone mainlines per 100 inhabitants for the period of 1980–2000. During this period, the world as a whole (113 countries in the present case) experienced positive growth in per capita income and positive growth in mainlines. While per capita income grew at a rate of 1.13 per cent on an average, the telephone mainlines per 100 inhabitants grew at a rate of 6.24 per cent. The last column shows the correlation between the CAGR of GDP per capita and the CAGR of telephone mainlines per 100 inhabitants.

As displayed in the table, during the period 1980–2000, the per capita income of low-income countries has remained almost stagnant, while all other income groups have experienced substantial positive growth. In the case of growth in telephone mainlines per capita, all income groups have achieved positive growth, while low-income countries have grown at a rate higher than the high-income countries. Although low-income countries have attained higher growth in terms of absolute figures, telephone mainlines per capita were only 1.17 in 2000 compared to 58.24 in high-income countries. Turning to other income groups, middle-income countries have attained a higher growth rate in telephone lines compared to low-income and high-income countries, and higher growth in per capita GDP compared to low-income countries. Despite differences in growth rates among different income groups, except for the high-income non-OECD countries, there is a positive and statistically significant correlation between telecommunications and GDP growth for all income groups.

Table 7.3 provides further evidence on the positive relationship between the relative availability of ICTs and GDP per capita. The table combines both traditional ICTs, such as fixed telephones, and modern ICTs such as mobiles and internet and presents the relationship for all the countries in our dataset and by income groups. Except for

TABLE 7. 2 CAGR of GDP per Capita and Telephone Mainlines: Income Groups[5]

	GDP per Capita		*CAGR (%)*	*Mainlines per 100 Inhabitants*		*CAGR (%)*	*Correlation bet. Growth*
	1980	*2000*	*1980–2000*	*1980*	*2000*	*1980–2000*	*Rates*
India	230.96	461.28	3.35	0.31	3.2	11.76	0.18
Income Group:							
Low Income (36)	388	389	0.04	0.36	1.17	5.94	0.549**
Low-middle Income (27)	1,394	1,642	1.05	2.30	10.21	8.19	0.869**
High-middle Income (21)	3,964	5,526	1.85	4.86	22.72	7.78	0.817**
High Income Non-OECD (8)	13,466	17,147	1.81	16.67	47.84	5.24	0.146
High Income OECD (21)	19,155	29,624	2.11	32.06	58.24	3.12	0.518*
World, 113 countries	5,707	8,263	1.13	8.71	21.25	6.24	0.464**

Note: *Significant at 5% level; **significant at 1% level.
Source: Authors' calculation based on the data from *WDI* (2002) and ITU (2002).

TABLE 7.3 Correlations between GDP per Capita and Telephones, Internet Hosts and PCs (2000)

	Correlation Coefficients between GDP per Capita and					
	Telephone Mainlines per 1,000		*Cellphone*	*Internet Users*	*Internet Hosts*	
	1980	*2000*	*per 100*	*per 1,000*	*per 10,000*	*PCs per 1,000*
Income Group:						
Low Income (36)	0.34*	0.47**	0.52**	0.32	0.23	0.42*
Low-middle Income (27)	0.35	0.22	0.15	0.52**	0.44*	0.57**
High-middle Income (21)	0.70**	0.56**	0.62**	0.66**	0.19	0.72**
High Income Non-OECD (8)	–0.26	0.16	0.86**	0.89**	0.84**	0.87**
High Income OECD (21)	0.64**	0.66**	0.15	0.31	0.14	0.63**
World, 113 countries	0.87**	0.89**	0.88**	0.86**	0.64**	0.93**

Note: *Significant at 5% level; **significant at 1% level.
Source: Authors' calculations.

telephone mainlines, all the correlation coefficients are for the year 2000.

There is a positive relationship between telephone penetration rates and GDP per capita, and with the exception of high-income non-OECD countries,[6] the correlation coefficients between telephone mainlines and GDP per capita remained positive and significant for all income groups in the period under study. The correlation coefficient for all 113 countries is very high and increased slightly from 0.87 in 1980 to 0.89 in 2000.

An important development in ICTs in recent times is the tremendous surge in the penetration rate of cellular phones. Not surprisingly, there exists a positive correlation between cellular phone penetration rates and GDP per capita and the correlation between these is higher than that between fixed phone penetration rates and GDP per capita in the case of low-income countries. However, there is no observable pattern, that is, the correlation coefficient does not increase or decrease with GDP per capita. There is a strong positive correlation between the presence of modern ICTs—internet connectivity and personal computers, for instance—and GDP per capita. With the exception of the OECD countries, there is a trend between GDP and internet users and personal computers. As one moves from low-income to high-income countries, the correlation becomes stronger.

The numbers discussed here show that although cellphone penetration rates are catching up, fixed-line telephony is still the most widely available ICT in low-income countries. The tables also show that over time, there is a strong and stable correlation between availability of different ICTs and GDP per capita. Whether this bivariate relationship represents a causal link running from teledensity to economic growth is examined in the next section.[7]

Results

As discussed in the section on estimation methodology, data differencing and Arellano and Bond's instrumentalization technique have been the preferred estimation methodology. This is advantageous, as it may increase the efficiency of the parameters with respect to OLS or GMM in levels, but especially as it tackles the problem of unit roots.[8]

Table 7.4 presents estimates of the output equation 1a using different estimation methods. Equations 2a, 3a and 4a have been used to instrumentalize this equation. Models 1–3 present the results for different estimation methods using the variables in levels, while models 4 and 5 present the results following Arrellano and Bond's dynamic panel data estimation. A comparison of the estimates suggests that the presence of unit roots may lead to an overestimation of the impact of the penetration rate on aggregate output. For example, based on model 3, a 1 per cent increase in the penetration rate is associated with a 0.11 per cent increase in output. On the other hand, correcting for the unit root and using GMM with the data in first differences reduce the impact of the penetration rate on economic output. Models 4 and 5 show that a 1 per cent increase in the penetration increases economic output by 0.03 per cent, which is probably a more realistic coefficient.

TABLE 7.4 Output Equation

	Dependent Variable: $log(GDP)_{it}$				
	2-Stage LS (1)	*3-Stage LS (2)*	*GMM-IV (3)*	*A-Bond Dynamic Panel Data (4)*	*(5)*
$\log(GDP)_{(t-1)}$	–	–	–	0.793 (38.11)**	0.959 (27.87)**
$\log(GDP)_{(t-2)}$	–	–	–	–	–0.188 (7.20)**
$\log(PEN)_{it}$	0.113 (9.87)**	0.173 (18.78)**	0.113 (9.57)**	0.033 (3.33)**	0.033 (2.96)**
$\log(KNT)_{it}$	0.468 (29.41)**	0.37 (27.51)**	0.468 (28.52)**	0.028 (1.96)*	0.057 (3.68)**
$\log(TLF)_{it}$	0.061 (2.89)**	0.114 (6.43)**	0.061 (2.81)**	–0.004 (0.41)	–0.009 (0.73)
Trend	0.008 (9.58)**	0.009 (13.76)**	0.008 (9.29)**	–	–
Constant	5.188 (10.66)**	6.769 (16.55)**	4.135 (8.69)**	0.003 (6.36)**	0.003 (5.68)**
Observations	1655	1655	1655	1639	1596
No. of Countries	95	95	95	95	95
R2	0.9983	0.9982	0.9669		
Sargan Test	88.818**			816.70**	687.57**

Note: Absolute value of z statistics in parentheses.
*Significant at 5%; **significant at 1%.
All models include fixed-effects.
1/GMM estimates (all variables in first differences).

Our diagnostic tests displayed the presence of unit roots. The importance of addressing this issue is also highlighted by the comparisons presented in Table 7.4. Accordingly, for the rest of our study, we decided to work with differenced data and use the Arrellano and Bond dynamic GMM techniques for each of the four equations outlined in the estimation methodology section. The estimates for each of the four equations is presented successively in Tables 7.5 through 7.8. In each table we present a series of regression results. We first present estimates based on the entire set of countries. We then divide the countries into five income groups and present estimates of our four-equation model for each of the income groups. These disaggregated estimates allow us to identify the particular country groups that contribute to the overall effect. Before turning to the results, we would like to emphasize that the aim of our work is to estimate the impact of telecommunication infrastructure on economic development in the most credible manner. It is not our aim to estimate demand and supply relationships in the telecommunications industry, and the results of the demand, supply and production equations (equations 2a, 3a and 4a) should be viewed as intermediate steps in the estimation of the output equation (equation 1a).

The first column in Table 7.5 presents results for the entire set of countries. These estimates have already been presented in Table 7.4 and have been reported here to facilitate comparisons. A look across the tables shows that while telecommunications penetration has a significant impact on output growth for the entire set of countries, there are differences across country groups. The estimates show that the impact of telecommunications is statistically significant only for high- and low-middle income countries, while it is not significant for OECD and high-income non-OECD countries and for low-income countries. This result is consistent with the idea that high-income countries have already reached a critical mass of telecommunications infrastructure and therefore any marginal increase in the telecom infrastructure has limited impact on output. In direct contrast, high- and low-middle income countries are involved in a period of growth of telecommunications infrastructure and this has a positive effect on aggregate output. Finally, telecommunications infrastructure does not show any impact on aggregate output in low-income countries.[9]

This differentiated result across income groups could be reflecting the characteristic of network externalities. As mentioned in several studies (Leff 1984; Saunders et al. 1983), an implication of network

TABLE 7.5 Output Equation

	All Countries	*OECD*	*OECD and High non-OECD*	*High-middle Income*	*Low-middle Income*	*Low Income*
$\log(GDP)_{i(t-1)}$	0.959	1.34	1.24	1.054	1.046	0.952
	(27.87)**	(29.37)**	(29.11)**	(19.90)**	(19.06)**	18.41)**
$\log(GDP)_{i(t-2)}$	–0.188	–0.382	–0.39	–0.24	–0.339	–0.115
	(7.20)**	(7.96)**	(8.85)**	(4.69)**	(6.46)**	(2.29)*
$\log(PEN)_{it}$	0.033	0.012	0.015	0.064	0.032	0.017
	(2.96)**	(1.16)	(0.91)	(3.98)**	(2.36)**	(1.24)
$\log(KNT)_{it}$	0.057	–0.033	0.074	0.016	0.173	0.031
	(3.68)**	(1.53)	(2.62)**	(0.82)	(6.07)**	(1.41)
$\log(TLF)_{it}$	–0.009	–0.045	–0.008	0.211	0.211	–0.018
	(0.73)	(1.07)	(0.27)	(4.49)**	(4.46)**	(1.50)
$\log(CEL)_{it}$	–	–	–	–	–	–
Constant	0.003	0.002	0.002	–0.004	–0.005	0.003
	(5.68)**	(2.69)**	(2.45)*	(2.79)**	(3.35)**	(2.67)**
Observations	1,596	395	518	321	372	385
Number of Countries	95	19	26	20	21	28
Sargan Test	687.57**	326.81	400.31	363.27	365.54	371.98

Note: GMM estimates (all variables in first differences); dependent variable: $\log(GDP)_{it}$.
Absolute value of z statistics in parentheses.
*Significant at 5% **significant at 1%.
In all models, PEN is instrumentalized according to models of equations 2a, 3a and 4a.

externalities is that the impact of telecommunications infrastructure on growth might not be linear. The piece-wise linear regressions presented here show that in poor countries, where a critical mass of telecommunications infrastructure does not exist (the mean penetration rate for this group of countries is 0.58 per cent), marginal increases in the penetration rate will not spark off economic growth. On the other hand, in high- and low-middle income countries, where mean penetration rates range from 5 to 11 per cent, telecommunications infrastructure has a positive and statistically significant impact on aggregate output. In OECD and other high-income countries with average penetration rates of about 40 per cent (which may be considered universal coverage), there is little impact, suggesting that additional investments in telecommunications infrastructure may not be growth inducing. The limited impact on OECD countries is different from the results reported in Röller and Waverman (2001), who find a strong causal link between telecommunications infrastructure and economic output in OECD countries. It is possible that their results were driven by the presence of unit roots in some of the key variables, such as GDP, the investment in telecom infrastructure, and the non-residential capital stock net of telecommunications capital.

Estimates of the demand, supply and production equations are presented in Tables 7.6, 7.7 and 7.8 respectively. We provide brief comments on these results. The demand equation estimates display that effective demand is inversely related to telephone price for the full sample. There are differences in this across income groups, but for the three lowest income groups, the price effect is negative. The price elasticity is less than one, implying static demand for telecommunications. Demand for telecommunications infrastructure is positively correlated with income and income elasticity is considerably higher than price elasticity. This result is consistent with many other studies, such as those by Pasco-Font et al. (1999), Doherty (1984), Gatto et al. (1988), Duncan and Perry (1994) and Levy (1996).[10]

With respect to the supply equation, neither geographical area nor government surplus (or deficit) is significant in explaining telecommunications investment. Although government surplus has the expected positive sign, implying that telecommunications infrastructure investment is positively affected by a government surplus, it is not significant in any of the regressions. As expected, the waiting list for mainlines per capita is positively related to the supply of

TABLE 7.6 Demand Equation

	All Countries	*OECD*	*OECD and High non-OECD*	*High-middle Income*	*Low-middle Income*	*Low Income*
$\log(PEN+WL)_{i(t-1)}$	0.729	0.944	0.925	0.82	0.695	0.649
	(37.76)**	(160.60)**	(139.07)**	(31.18)**	(20.23)**	(20.12)**
$\log(GDP/POP)_{it}$	0.636	0.021	0.017	0.123	0.618	0.234
	(14.99)**	(10.78)**	(5.75)**	(3.33)**	(9.60)**	(3.20)**
$\log(TELP)_{it}$	–0.035	0.425	2.048	–0.035	–0.03	–0.08
	(3.07)**	(0.13)	(0.32)	(2.20)*	(1.31)	(3.28)**
Constant	0.001	0	0.001	0.007	0.013	0.02
	(0.51)	(0.01)	(3.18)**	(3.39)**	(5.44)**	(6.56)**
Observations	1,366	451	597	266	288	346
Number of Countries	95	19	26	20	21	28
Sargan Test	882.82**	862.11**	663.75**	435.86	519.01	507.75

Note: GMM estimates (all variables in first differences); dependent variable: $\log(PEN+WL)_{it}$.
Absolute value of z statistics in parentheses.
*Significant at 5%; **significant at 1%.

TABLE 7.7 Supply Equation

	All Countries	*OECD*	*OECD and High Non-OECD*	*High-middle Income*	*Low-middle Income*	*Low Income*
$\log(TTI)_{i(t-1)}$	0.261	0.635	0.626	0.152	0.344	0.394
	(6.82)**	(19.30)**	(17.86)**	(2.50)*	(6.30)**	(5.35)**
WL_{it}	0.105	0.024	–0.005	0.094	0.11	0.076
	(3.56)**	(2.20)*	(0.43)	(2.35)*	(3.55)**	(0.27)
$\log(GA)_{it}$	–238.924	–96.72	31.892	–	–	–
	(0.48)	(0.99)	(0.22)	–	–	–
GD_{it}	0.000	0.000	0.000	0.000	0.000	0.000
	(0.11)	(0.44)	(0.39)	(1.44)	(1.23)	(0.52)
$\log(TELP)_{it}$	0.116	0.477	0.075	0.654	–0.062	0.115
	(2.21)*	(7.58)**	(3.64)**	(3.77)**	(0.47)	(0.62)
Constant	0.047	0	0.018	0.053	0.062	0.023
	(9.90)**	(0.00)	(6.19)**	(5.65)**	(5.30)**	(1.99)*
Observations	889	290	365	200	189	135
Number of Countries	83	19	24	19	20	20
Sargan Test	495.63	383.14	421.97	205.16	272.86	154.96

Note: GMM estimates (all variables in first differences); dependent variable: $\log(TTI)_{it}$.
Absolute value of z statistics in parentheses.
*Significant at 5%; **significant at 1%.

TABLE 7.8 Production Equation

	All Countries	*OECD*	*OECD and High Non-OECD*	*High-middle Income*	*Low-middle Income*	*Low Income*
$\log(PEN)_{i(t-1)}$	0.941	0.944	0.883	0.916	0.971	0.885
	(119.56)**	(160.60)**	(61.59)**	(81.08)**	(87.08)**	(47.38)**
$\log(TTI)_{it}$	0.024	0.021	0.013	0.038	0.046	0.005
	(7.27)**	(10.78)**	(3.02)**	(9.95)**	(10.33)**	(1.10)
$\log(GA)_{it}$	–1.91	0.425	–	–294.542	0	0
	(0.13)	(0.13)	–	(0.56)	(.)	(.)
Constant	0.002	0	0.01	0.003	0.002	0.011
	(3.64)**	(0.01)	(8.39)**	(3.20)**	(2.14)*	(6.99)**
Observations	1,671	451	724	350	379	345
Number of Countries	95	19	49	20	21	28
Sargan Test	984.73**	862.11**	648.38**	483.67	485.22	482.14

Note: GMM estimates (all variables in first differences); dependent variable: $\log(PEN)_{it}$.
Absolute value of z statistics in parentheses.
*Significant at 5%; **significant at 1%.

telecommunications infrastructure, suggesting that countries with excess demand will tend to invest more in telecommunications infrastructure. Finally, price is positively correlated to investment in telecom infrastructure.

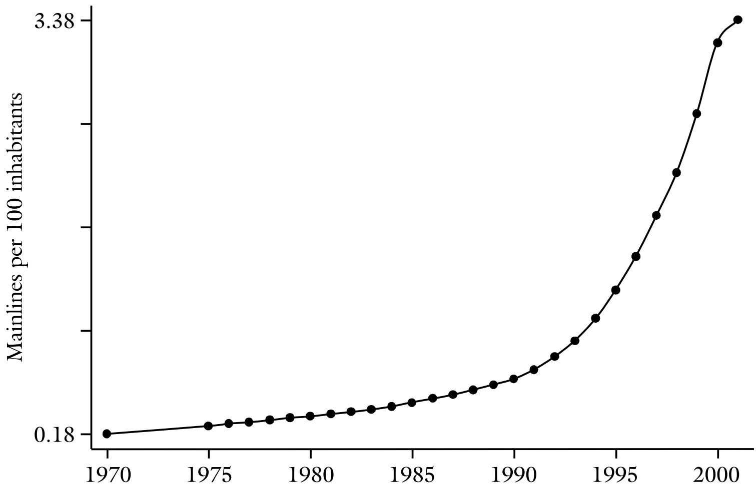
Table 7.8 presents estimates of the production function relating investment to the penetration rate. As expected, the relationship is positive and significant for the panel of all countries and across all income groups, with the exception of low-income countries. The elasticity is about 0.024, indicating that a 10 per cent increase in telecommunications investment would result in about a 0.2 per cent increase in the penetration rate. This is consistent with observations in the longitudinal series. Although the geographical area is not significant, this could be because the lagged penetration rate could already be incorporating this effect.

Discussion and Conclusion

In this paper we investigated the impact of an important information and communication technology in influencing the economic performance of a country. In particular, we put together a substantial database covering 113 countries over a 20-year period and examined the impact of telecommunications infrastructure on economic growth. Our empirical approach allowed for the simultaneous determination of telecommunications infrastructure and GDP.

While the empirical approach adopted in this paper mirrored the work of Röller and Waverman (2001), there were some notable differences. Most importantly, we examined the time-series properties of our data and detected unit roots in several variables. Accordingly, our estimates are corrected for the presence of unit roots. Estimates based on the entire set of countries revealed a positive causal relationship between telecommunications infrastructure and GDP. These estimates suggested that a 1 per cent increase in the telecommunications penetration rate might be expected to lead to a 0.03 per cent increase in GDP. Piece-wise regression models for different country groups revealed a non-linear effect of telecom infrastructure on economic output. The impact was particularly pronounced for low- and high-middle income countries and muted for other country groups. These results imply that telecom networks need to reach a critical mass or a

FIGURE 7.2 Growth of Mainlines in India



threshold level of connectivity before there is a discernible impact on economic output. In particular, we found that growth effects were strongest for a telecom penetration rate of between 5 and 15 per cent. Growth effects were limited above and below this threshold.

Given that the average telecom penetration rate in low-income countries is less than one, our estimates imply that developing countries need continued investment in their telecom networks if they are to reap positive growth effects. Marginal improvements in the telecom infrastructure are not likely to yield any discernible growth effects. If we look beyond telecom infrastructure to other information and communication technologies, the even lower level of penetration of these technologies as compared to terrestrial telephony suggests that unless there is a widespread increase in access to these technologies in low-income countries, ICT-induced growth will remain elusive.

Turning to India, our results have clear implications. India falls in the category of low-income countries. However, as mentioned earlier, within this group of low-income countries, India is an outlier. The total number of fixed-line telephones in India is about 25 times the low-income country average and India has one of the largest telecommunications networks in the world. Despite the large absolute number of telephone lines, teledensity is still quite low and there are enormous differences in teledensity between rural and urban areas.[11] After pitifully slow increases between 1970 and 1990 from a teledensity of 0.18 to 0.6 per cent, the most recent decade (1991–2000) has witnessed an increase from 0.67 to 3.2 per cent (see Figure 7.2). Since 2000, teledensity has recorded a CAGR of close to 17 per cent. Currently, the total number of fixed-line telephones in India is about 40 million or a teledensity of 4 per cent (this may be compared with China which has a teledensity of 27 per cent). The growth prognosis is a teledensity of 15 per cent by 2010. Based on our results we find that unless teledensity reaches a minimum of about 5 per cent, growth effects are limited. Combining this effect with the expected increases in teledensity, it may be argued that the positive growth effects attributable to investments in telecommunications should increase in the next few years. If the expected investments in telecommunications infrastructure do materialize, then India should experience enhanced economic performance driven by the benefits that accrue due to increasingly connected economic agents.

Appendix

TABLE 7.1A List of Countries Included in the Study

	Region					
Income Group	*Africa*	*Asia*	*Australia*	*Europe*	*North America*	*South America*
Low Income:						
	Benin	Bangladesh			Nicaragua	
	Burkina Faso	India				
	Burundi	Indonesia				
	Cameroon	Mongolia				
	C. Africa	Nepal				
	Comoros	Pakistan				
	Congo	Yemen				
	Cote d'Ivore					
	Ethiopia					
	Gambia					
	Ghana					
	Kenya					
	Lesotho					
	Madagascar					
	Malawi					
	Mali					
	Mauritania					
	Mozambique					

(*Table 7.1A contd*)

(*Table 7.1A contd*)

	Region					
Income Group	*Africa*	*Asia*	*Australia*	*Europe*	*North America*	*South America*
	Niger					
	Nigeria					
	Rwanda					
	Senegal					
	Sierra Leone					
	Tanzania					
	Togo					
	Uganda					
	Zambia					
	Zimbabwe					
Lower-middle Income:						
	Algeria	China	Fiji	Bulgaria	Belize	Bolivia
	Cape Verde	Iran (I Re)	Papua New Guinea	Romania	El Salvador	Colombia
	Egypt	Jordan			Honduras	Ecuador
	Morocco	Philippines			Jamaica	Paraguay
	Namibia	Sri Lanka				Peru
	Swaziland	Syria				
	Tunisia	Thailand				
Upper-middle Income:						
	Botswana	Bahrain		Hungary	Costa Rica	Argentina
	Gabon	Korea (Re)		Poland	Mexico	Chile
	Mauritius	Malaysia		Turkey	Panama	Uruguay
	Seychelles	Oman			St Kitts	Venezuela
	South Africa				Trinidad	

High Income Non-OECD:				
	Hong Kong		Cyprus	Barbados
	Israel		Malta	
	Kuwait			
	Singapore			
	United Arab Emirates			
High Income OECD:				
	Japan	Australia	Austria	Canada
		New Zealand	Belgium	United States
			Denmark	
			Finland	
			France	
			Greece	
			Ireland	
			Italy	
			Luxembourg	
			The Netherlands	
			Norway	
			Portugal	
			Spain	
			Sweden	
			Switzerland	
			United Kingdom	

TABLE 7.2A List of Variables and Summary Statistics for Different Income Groups

	Income Groups				
	Low Income	*Lower-middle Income*	*Higher-middle Income*	*High Income Non-OECD*	*High Income OECD*
GDP in US$ mn (1995)*	15755.73	35727.42	68404.39	33132.12	752551.27
	(49554.76)	(92365.61)	(101965.25)	(35844.59)	(1445354.68)
Total Labour Force in millions*	38.19	27.18	6.30	1.21	26.25
	(123.06)	(112.88)	(8.41)	(0.99)	(34.05)
Total Physical Capital Stock in US$ mn (1995)**	41855.14	94706.70	183438.61	89215.31	2180765.34
	(121767.55)	(203262.88)	(247650.52)	(94773.50)	(4064327.04)
Annual Investment in Telecom in US$ mn (1995)*	2166.63	2798.31	6028.50	2131.78	67653.58
	(5857.52)	(9199.73)	(9978.45)	(2672.64)	(134908.30)
Land Area in thousand sq. km*	559.85	815.71	500.43	16.70	1430.49
	(619.05)	(1765.74)	(697.60)	(26.48)	(2992.91)
Govt Budget Surplus (Deficit) in US$ mn (1995)*	–985.72	–781.10	–1833.62	135.19	–25797.30
	(3313.11)	(1909.74)	(4852.64)	(3967.68)	(53174.59)
Main Telephone Lines per 100 Inhabitants***	0.58	4.70	10.87	28.47	41.75
	(0.67)	(5.21)	(9.34)	(14.88)	(14.90)
Cellular Mobile Subscribers per 100 Inhabitants ***	0.11	0.78	2.63	8.05	9.57
	(0.51)	(2.56)	(7.55)	(17.15)	(19.37)
Telephone Service Revenue per Mainline US$ in (1995)***	995.48	667.79	791.89	28335.73	648.76
	(642.18)	(516.73)	(632.76)	(162540.96)	(216.80)

Cellular Service Revenue per Mainline	701.33	609.23	977.35	1172.61	1079.01
US$ in (1995)***	(1957.44)	(487.91)	(976.53)	(1188.79)	(1174.86)
Waiting List for Mainlines per 100 Inhabitants***	0.28	1.98	1.58	1.52	0.63
	(0.41)	(3.01)	(1.71)	(2.20)	(1.63)
Internet Users per 1,000 Inhabitants***	1.28	8.42	31.17	85.59	112.25
	(2.66)	(15.97)	(61.41)	(112.47)	(138.20)
Internet Hosts per 10,000 Inhabitants***	0.06	0.86	8.57	41.25	208.38
	(0.27)	(3.15)	(24.23)	(95.79)	(403.95)
Personal Computers per 1,000 Inhabitants***	3.31	17.63	44.12	126.05	184.81
	(3.67)	(19.89)	(45.69)	(106.70)	(138.17)

Source: **WDI* 2002; **Nehru and Dhareshwar 1993 and authors' estimation based on *WDI* data; ***ITU 2002.

Notes

* This revised, modified and shortened paper draws on our earlier work. For a more complete version, without a country-specific focus, see Torero et al. (2002).

1. In this paper, we adopt a macro-economic approach to examine the link between telecommunications infrastructure and economic output. While there are micro-oriented studies of the infrastructure–growth link, the economy-wide effects and the potential externalities ascribed to investments in ICT suggest the need for a macro-economic approach. Micro-oriented studies may lead to a deeper understanding of the manner in which infrastructure enhances output, but if the main goal is to establish the overall effect of infrastructure capital on output and productivity, a macro analysis seems to be the natural choice.
2. There is an emerging body of literature that examines the effect of the stock of computer hardware, computer software and computer labour or other information technology-related measures in influencing economic growth and output. Since the main focus of our work is on developing countries, where the stock of such capital is rather small, we do not review this body of evidence in detail. Recent macro-economic evidence on the US is provided by Gordon (2000), Oliner and Sichel (2000) and Stiroh (2002). Results based on data from other countries and a cross-country analysis of the effect of information technology expenditure on economic growth are available in Pohjola (2002).
3. Y represents the four dependent variables in the equations: log(GDP), log(PEN + WL), log(TTI) and log(PEN_t/PEN_{t-1}).
4. We follow the Arellano and Bond (1991) test for the hypothesis that there is no second-order serial correlation for the disturbances of the first-differenced equation, which assumes the consistency of the GMM estimation, given that it relies upon $E[\Delta v_{it}\Delta v_{i,t-2}] = 0$ (see Arellano and Bond 1991: 282). We also performed a test of over-identifying restrictions as suggested by Arellano and Bond (1991).
5. CAGR stands for the compounded annual growth rate, where

$$CAGR = \left[\left(\frac{Last\ Value}{First\ Value}\right)\frac{1}{N} - 1\right] * 100 .$$

   CAGR has been calculated for each of the 113 countries. The figures in the tables are unweighted averages.
6. Among the eight countries in this group, Kuwait and UAE are oil-rich countries that suffered from decline in oil prices. Exclusion of these two countries results in a correlation coefficient of 0.9.
7. Further details on the availability and growth of ICTs across geographic regions is available in Torero et al. (2002).
8. Phillips-Perron tests conducted on the GDP, capital and the real investment in telecommunications infrastructure (TTI) series showed the presence of unit roots in practically all the series for all the countries. They also showed how this problem is significantly reduced once differences are used instead of levels and when the Hodrick-Prescott filter is applied to the series. From this, it is clear that ordinary least squares or even GMM estimates in levels (such as the ones carried out by Röller and Waverman [2001]) may lead to spurious results. Detailed test results are available in Torero et al. (2002).

9. On a technical note, Sargan's test of over-identifying restrictions does not reject the validity of instruments when we subdivide the countries by level of income.
10. These studies found price elasticities ranging from –0.21 to –0.475. See Pasco-Font et al. (1999) for further details.
11. Teledensity in rural areas is about 0.4 per cent.

References

Anderson, T. W. and C. Hsiao. 1981. 'Estimation of Dynamic Models with Error Components'. *Journal of the American Statistical Association*, 76 (375): 598–606.

Arellano, M. and S. Bond. 1991. 'Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations', *Review of Economic Studies,* 58 (2): 277–97.

———. 1998. 'Dynamic Panel Data Estimation Using DPD98 for Gauss', Institute of Fiscal Studies, London (Mimeograph).

Doherty, A. 1984. 'Empirical Estimates of Demand and Cost Elasticities of Local Telephone Service', in *Changing Patterns in Regulated Markets and Technology: The Effect of Public Utility Pricing*. Institute of Public Utilities, Michigan State University.

Duncan, G. and D. Perry. 1994. 'IntraLATA Toll Demand Modelling: A Dynamic Analysis of Revenue and Usage Data', *Information Economics and Policy*, 6(2): 163–178.

Gatto, J.P., H. Kelejian and S. Stephan. 1988. 'Stochastic Generalizations of Demand Systems with an Application to Telecommunications', *Information Economics and Policy*, 3 (4): 283–309.

GOI (Government of India). 1994. *National Telecommunications Policy.* New Delhi: Ministry of Telecommunications.

———. 1999. *New Telecom Policy*. New Delhi: Ministry of Telecommunications.

Gordon, R.J. 2000. 'Does the New Economy Measure up to the Great Inventions of the Past?', *Journal of Economic Perspective*, 14(4): 49–74.

Gramlich, E.M. 1994. 'Infrastructure Investment: A Review Essay', *Journal of Economic Literature*, 32(2): 1176–96.

Harberger, A. 1978. 'Perspectives on Capital and Technology in Less Developed Countries', in M.J. Artis and A.R. Nobay (eds), *Contemporary Economic Analysis,* London: Croom Helm.

Hardy, A. 1980. 'The Role of the Telephone in Economic Development', *Telecommunications Policy*, 4 (4): 278–86.

Hirschmann, A.O. 1958. *The Strategy of Economic Development*. New Haven, CT: Yale University Press.

Holtz-Eakin, D. 1994. 'Public-Sector Capital and the Productivity Puzzle', *Review of Economics and Statistics*, 76(1): 12–21.

ITU (International Telecommunications Union). 2002. *World Telecommunication Indicators Database.*

Jipp, A. 1963. 'Wealth of Nations and Telephone Density', *Telecommunications Journal*, (July): 199–201.

Kormendi, R. and P. Meguire. 1985. 'Macro-economic Determinants of Growth: Cross-Country Evidence', *Journal of Monetary Economics*, 16(2): 141–63.

Leff, N.H. 1984. 'Externalities, Information Costs, and Social Benefit-cost Analysis for Economic Development: An Example from Telecommunications', *Economic Development and Cultural Change,* 32(2): 255–76.

Levy, A. 1996. 'Semi Parametric Estimation of Telecommunications Demand', Ph.D. Dissertation, University of California at Berkeley.

Madden, G. and S.J. Savage. 2000. 'Telecommunications and Economic Growth', *International Journal of Social Economics*, 27 (7–10): 893–906.

Mankiw, N.G., D. Romer and D.N. Weil. 1992. A Contribution to the Empirics of Growth', *Quarterly Journal of Economics*, 107(2): 407–37.

Munnell, A.H. 1992. 'Policy Watch: Infrastructure Investment and Economic Growth', *Journal of Economic Perspectives*, 6(4): 189–98.

Nehru, V. and A. Dhareshwar. 1993. 'A New Database on Physical Capital Stock: Sources, Methodology and Results', *Revista de Análisis Económico*, 8(1): 37–59.

Norton, S.W. 1992. 'Transaction Costs, Telecommunications and the Microeconomics of Macroeconomic Growth', *Economic Development and Cultural Change*, 41(1): 175–96.

Oliner, S.D. and D.E. Sichel. 2000. 'The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?' *Journal of Economic Perspectives*, 14(4): 3–22.

Pasco-Font, A., J. Gallardo and V. Fry. 1999. 'La Demanda Residencial de Telefonía Básica en el Perú', *Estudio en Telecomunicaciones*, No. 4. OSIPTEL, Peru.

Pohjola, M. (ed.). 2002. *Information Technology, Productivity and Economic Growth: International Evidence and Implications for Economic Development*, UNU/Wider Studies in Development Economics. Oxford and New York: Oxford University Press.

Roche, E.M. and M.J. Blaine. 1996. '*Information Technology, Development and Policy*. Avebury, UK: Aldershot.

Röller, Lars-Hendrik and L. Waverman. 2001. 'Telecommunications Infrastructure and Economic Growth: A Simultaneous Approach', *American Economic Review*, 91(4): 909–23.

Saith, Ashwani. 2002. 'ICT: Hope or Hype', The Hague, Institute of Social Studies (Mimeograph).

Saunders, R.J., J.J. Warford and B. Wellenius. 1983. *Telecommunications and Economic Development*. Washington, DC: The World Bank.

Stiroh, K.J. 2002. 'Are ICT Spillovers Driving the New Economy?', *Review of Income and Wealth*, 48(1): 33–57.

Torero, M., S. Chowdhury and A. Bedi. 2002. 'Telecommunications Infrastructure and Economic Growth: A Cross-Country Analysis', University of Bonn, Center for Development Research (Mimeograph).

WDI (*World Development Indicators*). Washington, DC: The World Bank.

8

Innovation Capability in India's Telecommunications Equipment Industry

Sunil Mani

The Context

India's telecommunications sector has undergone many changes, especially since 2000. The level of fixed phone density in India is low at about 8.8 lines per 100 people (January 2005), compared to the world average of 17. The situation is worse in India's rural areas, where teledensity is estimated to be roughly only 0.93 lines per 100

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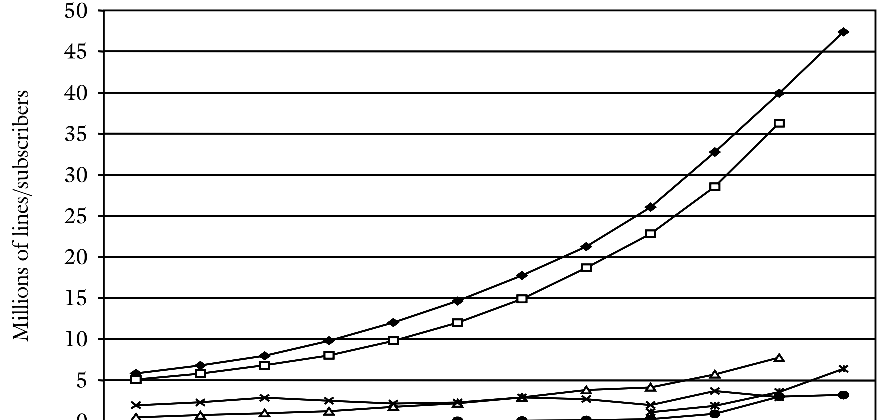
people. Out of 600,000 villages in India, just over half have access to telephone facilities. Furthermore, the growth of the cellular market—currently about 50 million subscribers compared to about 300 million in China—has been much slower than expected, although in the recent period the market has been growing at a rate of 80 per cent annually. This phenomenal growth of the sector is visible even when we take the most recent period (Figure 8.1). The recent improved performance of the Indian telecommunications sector has attracted considerable interest within the research community, although much of the attention in the literature has been restricted to understanding the nature and effect of the reforms in the telecommunications services sector. A critical summary of the reform process can be found in Jain (2001) and Mani (2000b, 2002). Further, of the eight full-length articles that were published in the journal, *Telecommunications Policy* (since its inception in 1977 and until now), all dealt with various aspects of reforms in the sector. On the contrary, although India is a sizeable manufacturer of telecom equipment, the changing nature of the country's capacities in research and production of telecommunications equipment have attracted very little attention.[1] Earlier attempts to analyse this issue, especially up to the late 1980s, can be found in Brundenius and Goransson (1985) and Mani (1992, 1995). In the context, the purpose of the present paper is to map the changing nature of research and production capacities in the Indian telecommunications equipment sector during the 1990s.

Since the industry (both the manufacture of telecom equipment and the distribution of telecom services) has undergone very many major changes, it is imperative that I place my discussion of the changes in the equipment sector against the external environment available to the actors (research agencies and production enterprises). This environment has become highly complex in recent times.

Some Conceptual Issues

The paper deals with two issues related to innovation capability. The first issue is the measurement of innovation capability in the Indian telecommunications equipment sector. I define this capability in terms of the ability of a country to conceptualize and design state-of-the-art telecommunications equipment that are suited to the specific usage pattern prevailing there.[2] There are two ways of measuring this

FIGURE 8.1 **Some Indicators of the Recent Growth of the Indian Telecom Sector**



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Switching Capacity	5.82	6.78	7.97	9.80	12.03	14.63	17.74	21.26	26.05	32.77	39.91	47.40
Direct Exchange Lines including Cellular and Private Basic*	5.07	5.81	6.80	8.03	9.80	11.98	14.88	18.68	22.81	28.54	36.28	
Annual Additions to DELs*	0.49	0.74	0.99	1.23	1.77	2.18	2.90	3.80	4.13	5.72	7.74	
Telephone Waiting List*	1.96	2.29	2.85	2.50	2.15	2.28	2.89	2.71	1.98	3.68	2.92	
Number of Cellular Mobile Phones									1.12	1.88	3.58	6.40
Number of Internet Subscribers						0.05	0.09	0.14	0.28	0.90	3.00	3.20

Note: *Refers only to fixed lines.
Source: DoT 2002.

capability in empirical terms. It may be measured in terms of factors that contribute (input) to the building up and maintenance of this capability at firm level. These factors consist of investments in R&D, availability of the requisite number of scientists and engineers, and organizational and other support measures. Needless to add, this measures only the potential to generate innovation capability. It can also be measured in terms of certain outcomes of this activity. Given the fact that the definition of innovation capability that I have adopted is better served by measures of outcomes, innovation capability in the present paper is defined in terms of actually revealed capability to design quantity of telecommunications equipment, largely in the domestic market.

The second issue dealt with is the proximate determinant of innovation capability and especially the role played by demand side instruments of intervention, such as public technology procurement, in building up this capability. This is because in high technologies, such as telecommunications, traditional supply side innovation policy measures are not sufficient. Having a ready market for the products that are developed is an important *sine qua non*. This is because complex technological innovations have two characteristics, which lead to severe market failures. The first characteristic is the lumpiness in R&D investments and second is the short life span of the innovation. This means that the availability of an assured market is the only or the main factor that can correct for such market failures. R&D in complex technologies such as telecommunications equipment is thus ideal for such a demand-oriented public policy intervention. A study by Edquist et al. (1999) has examined the role of public technology procurement (PTP) in promoting both development-oriented and adaptive innovations in digital switching systems across six developed countries (Table 8.1). The authors make two kinds of distinctions: between normal public procurement and public technology procurement. The former (public procurement) is a term reserved for cases where public authorities buy ready-made simple products such as pens and papers, where no R&D is involved. Further, the term PTP is distinguished as being between developmental public technology procurement, that is, cases where completely new products, processes or systems are created, and adaptive public technology procurement, which includes some amount of R&D to adapt a known technology to local conditions. It is in the latter sense of adaptive public technology procurement that the term is used in the present study. In understanding the determinants of innovation capability, the study employs a sectoral system of innovation perspective (Edquist 1997; Malerba 2002). Malerba (2002: 248) provides a very useful working definition of the sectoral system of innovation:

> A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and an existing, emergent and potential demand. The agents composing the sectoral system are organizations and individuals (e.g. consumers, entrepreneurs, and scientists). Organizations may be firms (e.g. users, producers and input suppliers) and non-firm organizations (e.g. universities, financial institutions, government agencies, trade unions, or technical associations), including sub-units of larger organizations (e.g. R&D or production departments) and groups of organizations (e.g. industry associations). Specific learning processes, competencies, beliefs, objectives, organizational structures and behaviors characterize agents. They interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions (rules and regulations). Over time, a sectoral system undergoes processes of change and transformation through the co-evolution of its various elements.

Based on this definition, the three major building blocks of a sectoral system of innovation involve: (*a*) knowledge and learning processes; (*b*) type and structure of interactions among firms and non-organizations; and (*c*) institutions. This useful framework is applied, albeit in an implicit manner, in understanding the innovation system of the Indian telecommunications sector.

The paper is structured into four sections. The first section maps the external environment available to the Indian telecommunications equipment industry. This environment has two main discernible components: first, changes in the world telecommunications equipment industry and reforms and changes in the Indian telecommunications distribution sector or the carrier industry. The emphasis here is on distilling the implications of these for the Indian telecom equipment sector. The second section focuses on tracing the innovation capability of the sector in terms of a number of output measures. The third section attempts to identify some determinants of the building up of innovation capability in the domestic equipment sector, while the fourth and final section summarizes the main findings of the study.

TABLE 8.1 Public Technology Procurement in Digital Switching Systems

Author	*Country*	*Effect of Public Technology Procurement on Technological Innovations (Developmental and Adaptive) in Digital Switching Systems*
Fridlund (1999)	Sweden	*Positive:* The study shows that a development pair between the public utility, the Swedish Telecommunications Administration (STA) and the main equipment manufacturer (Ericsson) led to adaptive technology procurements of an incremental character and informal collaboration laid foundations for more formal developmental procurement.
Llerena et al. (1999a, 1999b)	France and Italy	*Positive*: The study shows that both France and Italy set out to develop 'national' digital switching systems. Italy's was more of an adaptive role while the French case was more developmental. This was due to the fact that France, unlike Italy, began with (and adhered to) a long-term perspective or 'vision' of ending the domination of its domestic telecommunications sector by foreign subsidiaries and replacing the latter with a 'national champion' capable of competing in international markets with superior technology.
Husz (1999) and Tsipouri (1999)	Austria and Greece	*Positive*: Both in the case of Austria and Greece, the procurement processes were, from the outset, conceived of as 'adaptive' projects. However, they were also motivated by the desire to provide opportunities for 'development', rather restricting their aspirations to 'adaptation' alone.

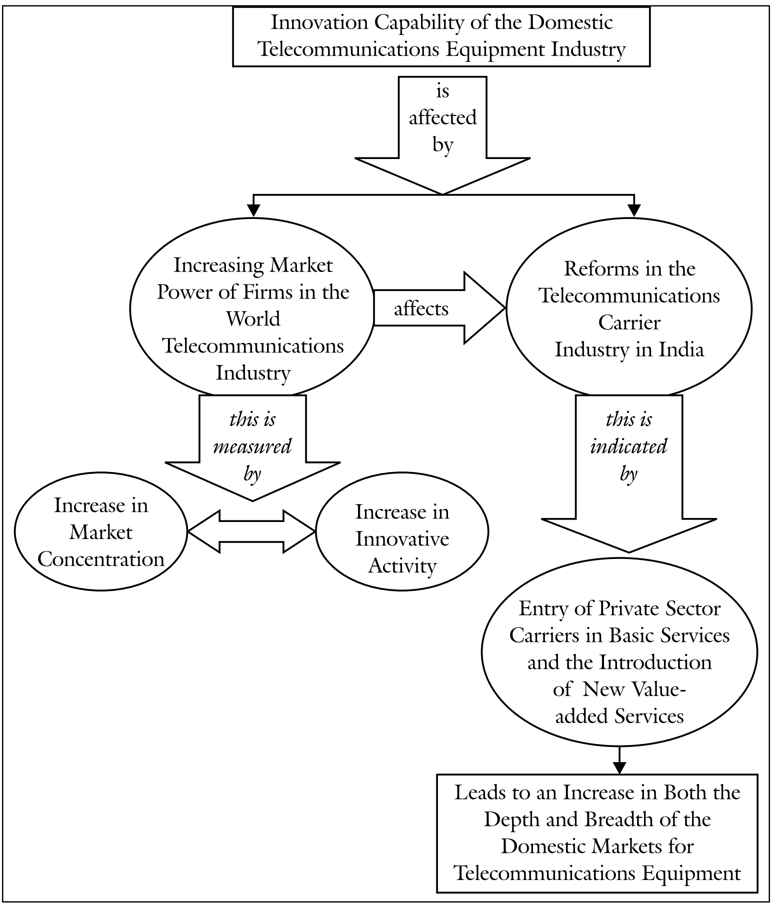
Source: Edquist et al. 1999.

From the cases presented in Table 8.1, it is very clear that wherever public procurement was part of a larger vision to develop national competencies (like the French case), it was successful. In fact, in the Indian case too, the existence of a credible procurement strategy has acted as a fillip to especially adaptive technology generation. This is the argument that is pursued in this paper.

The External Environment

It has been argued by Mani (1995) that the innovation capability of developing countries in areas of high technologies, such as the telecommunications equipment sector, are influenced in a significant manner by not only the domestic policies and support systems which favour such activity, but also by the external environment. Currently, this external environment has two main components (Figure 8.2). The

FIGURE 8.2 **External Environment of the Indian Telecom Equipment Industry**



Source: Author's own compilation.

first is the pressure exerted by powerful multinational corporations (MNCs). Since the mid-1990s, there has been increase in the market power of the MNCs, which can be measured by their hold over the market for their products and their ability to make technological innovations.

The second component of the external environment is the deregulation of the telecom network or carrier industry (or the distribution of telecom services segment). This part of the industry used to be the exclusive preserve of a state-owned monopoly, but has been gradually opened up to private sector carriers. Consequent to this, the market for telecommunications equipment has widened and many value-added services, which were hitherto not available, have been introduced for the first time. The new private sector carriers (sometimes these too are affiliates of MNCs) would like to purchase state-of-the-art equipment from abroad. Given this, despite the possible increase in the size of the domestic market, the domestic telecommunication equipment vendors may face tough competition from international vendors. Thus, faced with increasing competition, it is possible that the innovation capability of domestic agencies is adversely affected. Towards understanding this line of argument, I first present the changes in the world telecommunications equipment industry to show that the market power of the various firms in the industry has increased significantly. This is followed by the specific changes in the distribution segment of the industry in India that have a bearing on the domestic telecom equipment industry.

Changes in the World Telecommunications Industry

The international telecommunications industry has been in a state of flux, especially after the burst of the telecom bubble in 2000. The industry has become so complex that it is convenient to invoke a 'layer model' to understand what we mean by the telecommunications industry in the present century. Fransman (2002) divides the evolution of the industry into two separate phases: the old telecom industry up to the mid-1980s and the new industry which was born towards the beginning of the 1990s. Employing a layer model, he identifies the main differences between the two phases, which are outlined in Table 8.2.

TABLE 8.2 Characterization of the Old and New Telecom Industries

Layers of the Old Telecom Industry		*Layers of the New Infocommunications*		
Layer	*Activity*	*Layer*	*Activity*	*Example Companies*
III	Service Layer (voice, fax, 0800 services)	VI	Customers/Consuming	
II	Network Layer (circuit-switched network)	IV	Application Layer, including Contents Packaging (e.g., web design, online information services, broadcasting services, e-commerce, etc.)	Bloomberg, Reuters, AOL–Time Warner, MSN, Newscorp
I	Equipment Layer (switches, transmission systems, customer premises equipment)	III	Navigation and Middleware Layer (e.g., browsers, portals, search engines, directory assistance, security, electronic payment, etc.)	Yahoo, Netscape, Vizzavi, Google, Genie, etc.
			Transmission Control Protocol (TCP)/Internet Protocol (IP) Interface	
		II	Network Layer (e.g., optical fibre network, mobile network, DSI, local network, radio access network, Ethernet, frame relay, ISDN, ATM, etc.)	AT&T, BT, NTT, WorldCom, Qwest, Colt, Energis, Vodaphone, NTT DoCoMo, etc.
		I	Equipment and Software Layer (e.g., switches, transmission equipment, base stations, routers, servers, CPE, billing software, etc.)	Nortel, Lucent, Cisco, Ericsson, Nokia

Source: Fransman 2002.

The model helps us to understand the evolving structure of the telecommunications industry. The concern here is primarily with the first two layers of the new infocommunications industry. There are at least three trends in the industry that are worth noting, namely, (*a*) the industry is becoming oligopolistic consequent to a wave of mergers and acquisitions; (*b*) there has been significant increase in the innovative activity of infocom enterprise; and (*c*) the major market for telecommunications equipment is going to be in the Asia-Pacific region. China and India are the two singlemost important markets in the region. All these three trends put together have meant that telecom manufacturers and research agencies in developing countries have been completely dwarfed by these developments.

The Oligopolistic Nature of the World Telecom Equipment Industry

Owing to its natural monopoly status, the telecommunications industry (especially the network or carrier segment) has always been monopolistic. The recent wave of liberalization of the industry has sought to make the industry more competitive in terms of increasing the number and size distribution of firms constituting the industry. While there has been some deconcentration of the carrier segment throughout the world, the degree of concentration in the equipment sector has increased significantly. This is an interesting finding, as the equipment industry is largely in the private sector across the world except in some developed and most developing countries. In order to measure the degree of concentration over time, I employ the familiar Herfindahl Index (H.index).[3] Even the equipment sector is not a homogeneous one. The network industry can be divided into at least three segments, namely, switching, transmission and terminal equipment segments. For a guided tour of the equipment sector, see Box 8.1.

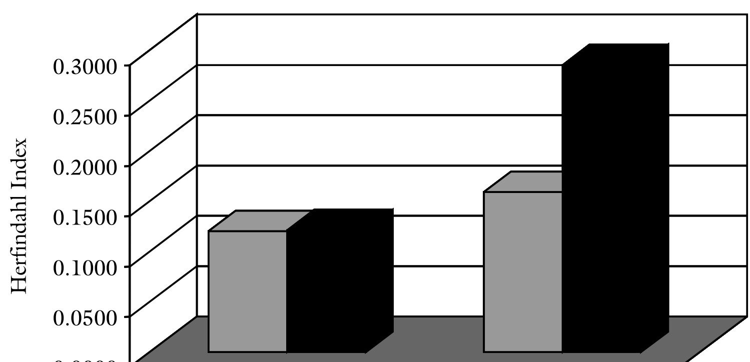
Based on this, I define two variants of the H. Index. The first, denoted as H.I.1, measures the degree of concentration in the whole equipment industry, and the second, denoted as H.I.2, measures the degree of concentration in just the switching equipment segment. Based on the data provided by Dorrenbacher (2000), the two variants of the H. Index have been computed for 1995 and 1998 (Figure 8.3).

BOX 8.1 A Guided Tour through the Telecommunications Equipment Industry

- Telephone networks are made up of three main elements: switches, transmission and terminal equipment.
- Switches allow the routing of voice, video and data signals throughout the network.
- Transmission can be decomposed into *wireline* (twisted pair of copper wires, coaxial cable, fibre optic) and *wireless* (via satellite, cellular radio, microwave, personal communication services, or PCs).
- Relative to wireline transmission, wireless transmission offers end users the benefit of mobility; however, wireless equipment, especially if they are to offer advanced services, are expensive, and wireless transmission faces interference and especially bandwidth (capacity) problems.
- Consequent to the recent technological evolution, there has been a sharp *decrease in the cost of transmission and switches.*
- Another recent key development has been the substantial increase in the *intelligence of the network.*
- Terminal equipment are those which are available at the subscriber's premises. Examples of this would be telephone instruments, fax machines and so on. Telephone instruments can also be either fixed or cordless.

Source: Laffont and Tirole 2001; Mani 1992.

FIGURE 8.3 Degree of Concentration in the World Telecom Equipment Sector (1995 and 1998)



	H.I. 1	H.I. 2
1995	0.1201	0.1591
1998	0.1211	0.2852

Source: Dorrenbacher 2000.

The following inferences can be drawn:

- The level of concentration in the overall telecom industry has virtually remained the same over the two periods under consideration;
- However, the level of concentration in the switching equipment industry has registered a significant increase of about 79 per cent. In fact, in 1998, the top four firms in the industry, namely Lucent, Ericsson, Alcatel and Nortel accounted for about three-quarters of the total switching equipment sales in the world.
- Also, the level of concentration in the switching equipment segment has always been higher than in the overall industry.

BOX 8.2 Recent Mergers between Traditional and New Telecom Equipment Manufacturers

1. Nortel–Bay Networks Merger in 1998

Nortel had 1997 revenues of US$15.5 bn and as of July 1998 had approximately 73,000 employees worldwide. It works with customers in more than 150 countries and territories to design, build and integrate their communications products and advanced digital networks. Customers include public and private institutions; internet service providers; local, long-distance, cellular mobile and personal communication services (PCS) companies; cable television companies; and utilities. Bay Networks, a Nortel subsidiary, is a leader in the worldwide networking market, providing a complete line of products that serve corporate enterprises, service providers and telecommunications carriers. The company offers Ethernet and ATM LAN switches, routers, shared media, remote and internet access solutions, IP services and network management applications, all integrated by Bay Networks' Adaptive Networking strategy.

2. Alcatel–Xylan Merger in 1999

Alcatel has devised and is implementing a comprehensive strategy to become a key worldwide player in the internet field, capitalizing on its leadership position in major telecommunications markets and technologies. This strategy encompasses the targeted acquisitions of leading IP-focused companies, leveraging Alcatel's strengths to leapfrog competition. A major step is the acquisition of Xylan, a long-time partner. The combined Alcatel/Xylan strengths in voice and data networking for enterprises will constitute a very powerful force in world corporate markets. In addition, Xylan technologies for carriers' data networks will remarkably complement other actions under way to build a leading

(*Box 8.2 contd*)

(*Box 8.2 contd*)

Alcatel offering for converged voice/data carriers' networks. Xylan provides Alcatel with a superior portfolio of data switching equipment and a fast-growing position in the enterprise data market, where Xylan is developing well above market trends. The combined Alcatel/Xylan product offering will surpass competition in the enterprise market, both in terms of performance and spread of functionalities. Xylan's strong inroads in the carriers' markets, in particular, managed LAN services and the forthcoming traffic aggregation equipment, will substantially enhance solutions developed by Alcatel for service providers. Alcatel said it has started to sell a new line of switching devices for corporations called the OmniSwitch 7000. The OmniSwitch line originated from Alcatel's 1999 acquisition of Xylan.

3. Lucent–Ascend Merger in 1999

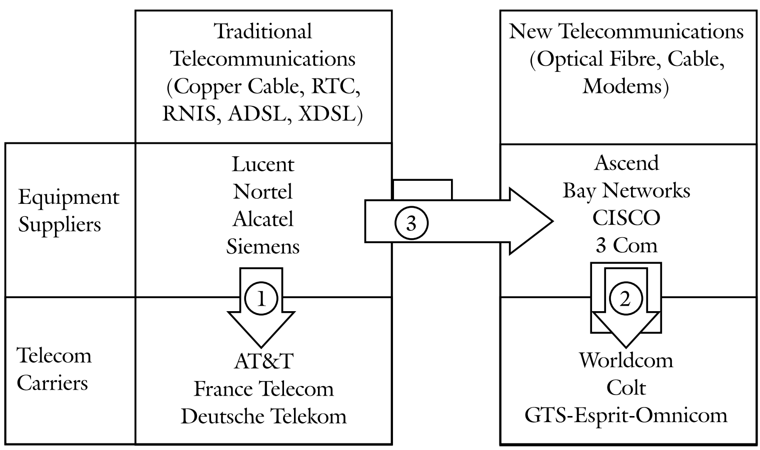
Lucent Technologies completed its merger with Ascend Communications in August 1999, creating the industry's broadest, most powerful and most reliable data networking product line. The merger, valued at about $24 bn, became one of the largest technology mergers in US history. Ascend Communications now has become part of Lucent's new InterNetworking Systems unit, which is focused on delivering next-generation, broadband networks to all classes of service providers and enterprises. Lucent already leads the communications industry in several key areas: optical, wireless and circuit switching technologies; communications semiconductors; messaging; and networking software, services and support. With Ascend, Lucent has added critical aspects of data networking leadership to its portfolio and become:

- the leading provider of ATM switching for service providers;
- the leading provider of WAN access for carriers, including internet service providers;
- the leading provider of frame relay switching for service providers;
- The leading provider of voice-over IP networks to carriers, Internet service providers and enterprises.

Source: www.nortelnetworks.com/corporate/newsreleases/1999c/8_31_9898403_bay_merger_completed.html; www.alcatel.com/vpr/index.jhtml?body-http://www.home.alcatel.com/vpr/archive.nsf/Archiveuk/03D680531626FBD6C1256A53006088DC?opendocument; www.lucent.com/press/0599/990521.coa.html.

In fact, through a recent wave of mergers and acquisitions, the traditional equipment suppliers, whose core competencies and activities are in switching and transmission for traditional telecommunications infrastructures, have extended their control over the new equipment suppliers whose core competencies are in switching and transmission for new telecommunications infrastructures. Thus the leading switching equipment manufacturers such as Lucent, Alcatel and Nortel have not only consolidated their position in their traditional fields of competence but have also amassed considerable technological and market clout in the new technologies (Box 8.2). Thus, the traditional equipment companies have become even more formidable as they have access to a wide variety of markets. Gaffard and Krafft (2000) have mapped this complex vertical integration strategy of the traditional equipment manufacturers (Figure 8.4). According to them, the different arrows contribute to explain the different stages of evolution of vertical structures between telecommunications carriers and equipment suppliers.

FIGURE 8.4 The Characteristics and Evolution of Vertical Structures in Telecom Industry



Source: Gaffard and Krafft 2000.

They identify three stages in the evolution of vertical structures in the industry. The first stage, represented by Arrow 1, describes the initial situation when the traditional equipment suppliers at the upstream level have only one category of customers, namely, the telecommunications carriers at the downstream level.[4] Arrow 2 represents the second stage denoting the role played by the new telecommunications equipment suppliers on the entry of new firms at the downstream level. Finally, the third stage represented by Arrow 3, shows the merger strategy of the traditional equipment suppliers to have access not only to the core competencies of new equipment suppliers, but also to extend their share of the new market created by the new carriers. In short, the world telecommunications equipment industry has become more oligopolistic and thereby increased its market power by a considerable degree.

Increase in Innovation in the World Telecom Equipment Industry

The telecommunications equipment industry is one of the most research-intensive industries in the world. The research intensity of the sector has averaged over 7 per cent of the sales revenue per year.[5] I have measured the innovative activity of the sector in terms of two standard indicators, namely, an input indicator such as R&D expenditure (Table 8.3) and output indicator such as the performance of these companies with respect to patenting (Table 8.4). Both the indicators show that there has been significant increase across the board in the innovative activity of these enterprises, especially after the mid-nineties. An interesting feature is the fact that the increase in the number of patents secured by all the companies are better than their performance with respect to R&D investments. Based on the data presented in the two tables, it could safely be concluded that the leading telecom equipment manufacturers have not only increased their share of the market but also of their control over the technology.

TABLE 8.3 R&D Expenditure of Leading World Telecom Equipment Manufacturers

	Billions of US$				*Billions of Euro*		
	1997	*1998*	*1999*		*1997*	*1998*	*1999*
Lucent Technologies	3.18 (11.5)	3.90 (12.3)	4.51 (11.8)	Ericsson	2.46 (12.5)	2.97 (13.7)	3.34 (14)
Nortel Networks	2.15 (13.9)	2.45 (14)	2.91 (13.1)				
NEC	3.22 (7)	3.52 (8)	3.19 (7)	Alcatel	1.77 (8.2)	1.81 (8.5)	2.06 (10.1)
CISCO	0.70 (10.9)	1.03 (12.1)	1.59 (13.1)				

Note: Figures in brackets indicate the research intensity in percentage.
Source: Gaffard and Krafft 2000.

TABLE 8.4 Patenting Performance of International Telecom Companies (1995–2000)

Name of Company (Country)	Technological Strength[a]		Number of Patents[b]		Current Impact Index[c]		Science linkage[d]		Technological Cycle Time[e]	
	2000	1995–99	2000	1995–99	2000	1995–99	2000	1995–99	2000	1995–99
Lucent Technologies (US)	2,485	1,701	1,445	881	1.7	1.9	1.3	1.8	5.4	5.4
Motorola (US)	2,035	2,148	1,241	1,193	1.6	1.8	0.6	0.7	9.4	5.5
Ericsson Telephone (Sweden)	1,651	714	775	320	2.1	2.2	1.0	1.3	5.2	5.8
CISCO Systems (US)	911	123	133	25	6.8	4.9	1.1	0.9	5.8	4.9
Alcatel (France)	478	319	423	285	1.1	1.1	0.78	1.1	6.4	6.7
Qualcomm (US)	451	350	111	63	4.1	5.6	0.7	1.5	6.7	6.4
Cabletron Systems (USA)	253	116	41	17	6.2	7.0	2.0	2.4	5.2	4.5
Ciena (US)	109	30	26	6	4.2	4.6	1.7	2.0	5.0	4.1
JDS Uniphase (US)	100	57	52	36	1.9	1.6	2.2	1.3	7.1	7.5
Qwest Communications International (US)	97	105	29	33	3.3	3.2	0.3	1.1	4.1	5.0

Note: [a]This figure, the basis of the rankings, provides an overall assessment of a firm's intellectual property power. It is calculated by multiplying the number of a company's US patents by its Current Impact Index.

[b]The total number of US patents awarded excluding design and other special-case inventions.

[c]This measure showcases the broader significance of a company's patents by examining how often its US patents from the previous five years are cited as 'prior art' in the current year's batch. A value of 1 represents average citation; so 1.4 would indicate a company's patents were cited 40 per cent more often than average, and so on.

[d]Patents sometimes cite scientific papers as prior art. This value shows the average number of science references listed in a company's US patents. A high figure indicates that the company is closer to the cutting edge than its compatriots

[e]An indicator of a firm's speed in turning leading-edge technology into intellectual property is the median age (in years) of US patents, cited as prior art.

Source: *MIT Technology Review* 2001.

The Asia-Pacific Region According to telecom revenue forecasts by Pyramid Research (2002) based on analysis of telecom markets in 85 countries, the global telecom industry will grow by a compound annual growth rate of 6 per cent, reaching US$ 1.3 trillion in revenues by 2007 from US$ 1 trillion in 2002. Further, according to these forecasts, the emerging markets in the Asia-Pacific region in general, and China and India in particular, are the fastest growing segments of the market. In fact, the share of developed markets such as North America and western Europe is expected to shrink from a whopping 65 per cent in 1999 to about 49 per cent in 2007 (Table 8.5). On the contrary, the share of developing country markets, and more specifically, those in the Asia-Pacific regions, will show significant increase in shares. This means that a major impetus for the growth of the market for telecommunications equipment will emerge from the developing economies of Asia. Therefore, MNC telecom vendors are once again going to exert considerable pressure on domestic carrier companies in these countries. These tactics have received a fillip because consequent to the deregulation of the equipment sector, a number of these MNC vendors have actually established manufacturing plants in India. This point will be analysed in some more detail in the second section on the structure of the equipment sector in India.

TABLE 8.5 **Global Telecom Revenues by Region (percentage shares)**

Region	*1999*	*2007 (forecast)*
Asia-Pacific	23	35
Western Europe	29	19
North America	36	30
Latin America	6	7
Central and Eastern Europe	3	5
Africa and Middle East	3	4
Total	100	100

Source: Pyramid Research 2002.

Reforms in the Indian Telecommunications Carrier Industry

Table 8.6 summarizes the major reforms in the sector between 1984 and March 2002. Contrary to popular impression, the reforms were initiated in the 1980s, much before the announcement of the new economic policy in 1991. Almost all the reforms were targeted at the

TABLE 8.6 Chronology of Reforms in the Indian Telecom Sector (1984–2002)

Time of Change	*Content of Change*
1984	Manufacturing of subscriber premises equipment was opened to the private sector.
1985	The erstwhile Department of Posts and Telegraphs was bifurcated and the Department of Telecommunications (DoT) was established with a separate board.
1986	Two separate corporations called Mahanagar Telecom Nigam Ltd (MTNL) and Videsh Sanchar Nigam Ltd (VSNL) were established to distribute telecom services in Delhi and Mumbai, and overseas, respectively.
1988	The government introduced in-dialling scheme. PABX services were initiated only within a building or in adjoining buildings.
1989	The Telecom Commission was established.
1991	Telecom equipment manufacturing was opened to the private sector. Major international players like Alcatel, AT&T, Ericsson, Fujitsu and Siemens entered the equipment manufacturing market.
1992	The value-added services sector was opened to private competition.
1993	Private networks were allowed in industrial areas.
1994	Licences for radio paging were issued in 27 cities.
May 1994	The new telecom policy was announced.
Sept. 1994	Broad guidelines for private sector entry into basic services were announced.
Nov. 1994	Licences for cellular mobiles were issued in four cities.
Dec. 1994	Tenders were floated for bids in cellular mobile services in 19 circles, excluding the four metros, on a duopoly basis.
Jan. 1995	Tenders were floated for a second operator in basic services on a circle basis.
July 1995	Cellular tender bid was opened.
Aug. 1995	Basic service tender bid was opened; the bids caused a lot of controversy. Most of the bids were considered low.
Dec. 1995	Letters of Intent (LOIs) were issued to some operators for cellular mobile operations in circles.
Jan. 1996	Rebidding took place for basic services in 13 circles, with poor response. The Telecom Regulatory Authority of India (TRAI) was formed by ordinance.
Oct. 1996	LOIs were issued for basic services.
Feb. 1997	TRAI began functioning as a regulatory authority.
March 1997	Licences were issued for basic telephone service in the Gujarat circle.
Nov. 1998	The New Policy on Internet Service Providers was announced.
March 1999	The New Telecom Policy was announced.
March 2000	The Telecom Regulatory Authority of India (Amendment) Bill 2000 was passed by the Parliament.
Aug. 2000	• National long-distance services were opened to private operators. Four companies were issued LOIs for this service, of which three licences were signed.

(*Table 8.6 contd*)

(*Table 8.6 contd*)

Time of Change	*Content of Change*
	• Internet service providers (ISPs) were allowed to set up international internet gateways for both satellite and landing stations for submarine optical fibre cables. Thirteen ISPs were given clearance for commissioning of international gateways for internet, using satellite medium for 29 gateways. • Free right of way was given to lay fibre-optic cable networks along highways and roads.
Oct. 2000	• The cap on foreign equity in telecom services was raised from 49 to 74 per cent. • As in the case of basic phone services, long-distance and internet services, the limit on the number of players in cellular services was removed. • The cabinet approved a proposal to allow FDI of up to 100 per cent in ISPs that do not have satellite or submarine landing stations. • Reduction in basic customs duties for several types of telecom equipment was announced. • Corporatization of the Department of Telecom Services (DTS) was finally approved and a new company called the Bharat Sanchar Nigam Ltd (BSNL) was formed on 1 October with a paid up capital of Rs 50 bn and authorized capital of Rs 100 bn.
2001–02	• Policy for voice mail/Audiotex service was announced in July 2001 by incorporating a new service called 'Unified Messaging Service'. • Two categories of infrastructure providers were allowed to provide end-to-end bandwidth and dark fibre, right of way, towers, duct space, etc. • A fourth cellular operator, one each in four metros and 13 circles were permitted. In all, 80 licences (56 private, 22 to BSNL and 2 to MTNL) were issued. • Wireless in Local Loop (WLL) was introduced for providing telephone connections in urban, semi-urban and rural areas. • The Communications Convergence Bill 2001 was introduced in the Lok Sabha on 31 August and was referred to a standing committee. • Termination of monopoly of VSNL for international long-distance (ILD) services was preponed to 31 March 2002 from 31 March 2004. LOIs were issued to five companies for ILDs of which one was converted into a licence. • The Sanchar Sagar project was initiated to meet the bandwidth demand of the IT sector. • VSNL developed its capacity to provide international bandwidth on demand. • TRAI gave its recommendations for initializing internet telephony in 2002 and these are under consideration of the government.

Source: DoT 2002: 19; Mani 2002: 122–23.

carrier industry except three, which were directed at the telecom equipment industry.[6] However, most of the reforms in the carrier industry had important implications for the telecom equipment industry as well. In a nutshell, the reforms in the carrier industry and especially the opening up of basic and value-added services have actually increased the size of the domestic market for this equipment in the country. In the following, I focus on the effect of reforms on two important dimensions of the carrier industry, namely, the basic services sector and the value-added sector.

Basic Services Sector The opening up of the basic telephone service in the country was initiated by the New Telecom Policy of 1999. The decision was to open up the sector without any restriction on the number of operators. The applicant had to be an Indian company, registered under the Indian Companies Act of 1956. The entire country was divided into 18 circles and the applicant company could apply for licence in more than one telecom circle subject to fulfilment of the conditions of entry.[7] The total foreign equity in the applicant company must not exceed 49 per cent at any time during the entire licence period. The licensed operator can provide all types of services except those for which a separate licence is required. An important consequence of the entry of basic service operators is the introduction of WLL transmission technology.[8] Some indicators of the performance of basic services in the country are presented in Table 8.7.

Admittedly, the share of the private sector at the moment is quite low, though it is fast increasing. Ninety-one per cent of the fixed lines and 21 per cent of the mobile lines are currently under public sector enterprises, such as BSNL and MTNL. But according to the demand forecasts for the Tenth Five-Year Plan (2002–07) made by the DoT, approximately 30 per cent of the additional capacity is to be met by the private sector (Box 8.3). Given the fact that private sector companies are new, they are likely to offer a whole host of new services necessitating the use of state-of-the-art switching and transmission equipment and this is likely to exert pressure on the domestic manufacturers and R&D organizations to cater to these demanding customers. Also, with the liberalization of the market to both MNCs and imports, the domestic carrier industry does have a very wide choice and this is going to enhance the pressure on the domestic production and research sector.

TABLE 8.7 Performance Indicators of the Basic Services Segment of India's Telecom Carrier Industry

Indicator	*2000*	*2001*	*2002*
Number of Licensees		31 + BSNL and MTNL	31 + BSNL and MTNL
Number of Private Carriers Actually Providing Services		6	6
Number of Direct Exchange Lines (DELs) (in million)	26.5	32.4	37.9
• Public (BSNL and MTNL)	0.0	0.3	0.6
• Private			0.01
• Ratio of Private to Public DELs	NA	0.0	2.2
Share of Private Sector in Total Revenues (%)	0.0	NA	
Number of National Long-distance Service Providers			BSNL + 4 (1)
Number of International Long-distance Service Providers			VSNL + 3 (3)

Note: Figures in parentheses indicate those with only a letter of intent which has not yet been converted into a licence.
Source: DoT, http://www.dotindia.com/plans/obj_ninth.htm.

Box 8.3 Demand Forecast: 2002–07

Demand for telephone is dependent on various parameters like the economic growth of the country, tariff, etc. As per the present trend of growth of the telephone network, over the period from 1991–97, the average growth rate was l6.5 per cent. At this growth rate, to meet the objectives of providing a telephone on demand, the additional demand during the period 1997 to 2007 comes to about 67.4 million. As the basic services are being opened to the private sector, it is assumed that about 20.4 million of this additional demand will be met by the private sector. Based on this assumption, the DoT will have to provide 40.7 million DELs during 1997 to 2007 to keep providing telephones on demand. In 2002, telephone density was about 1.5 per 100 people in the country. Assuming that the GDP growth would continue to be maintained as well as the population growth rate, telephone density will reach 9 per hundred in 2007, and in rural areas, it may cross the one per hundred population mark by that year.

Source: DoT, http://www.dotindia.com/plans/perspective19972007.htm (accessed on 21 November 2002).

Value-added Services About six different types of value-added telecom services have been introduced in the country (Table 8.8), and all of them have been opened up to private sector participation.

TABLE 8.8 Structure of India's Valued-added Telecom Carrier Industry (as on 30 June 2002)

Type of Value-added Service	*Indicator of its Size*
Cellular Mobile	The country is divided into 24 circles. About 80 licences have been issued to 26 companies (including public sector carriers).*
Total ISP Licensees	410
Who have Reported Start of Internet Service	188
Number of ISPs to Whom Clearance for Provisional Commissioning of ISP Gateways has been Given	52
Number of ISPs who have been Permitted to Offer Internet Telephony Service	49
Infrastructure Providers	55
Number of Infrastructure	49
Provider Category I** for whom Registration Certificates have been Issued	6
Number of Infrastructure Provider Category II*** for whom Registration Certificates have been Issued	Not Available.
Very Small Aperture Terminal (VSAT) Service Providers	79 licences issued to 15 companies.
Radio Paging	8 licences issued to 3 companies.
A Circle Paging	52 licences have been issued to 15 companies to operate from 26 service areas.
B Circle Paging	Two companies are expected to sign the licence agreement in terms of the LOIs issued to them for GMPCS service.
Public Mobile Radio Trunk Service Global Mobile Personal Communications by Satellite (GMPCS)	

Note: *In terms of National Telecom Policy, 1999, cellular operators will be free to provide, within their area of operation, all types of mobile services, including voice and non-voice messages, data services and PCOs utilizing any type of network equipment, including circuit and/or package switches that meet the relevant International Telecommunication Union (ITU)/Telecom Engineering Centre (TEC) standards.

(*Table 8.8 contd*)

(*Table 8.8 contd*)

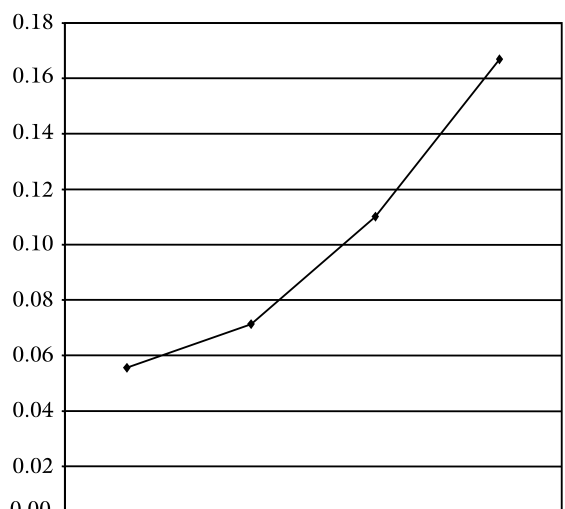
**Category I applicant companies are required to be only registered, and licences are not issued for them. There is no restriction on foreign equity and the number of entrants.

***Category II licensees can lease/rent out/sell end-to-end bandwith capable of carrying a message. The foreign equity of the applicant company should not exceed 74 per cent. The licence is valid for 20 years from the date of the licence agreement.

Source: DoT, www.dotindia.com/ip/ipindex.htm.

Within value-added services, it is cellular mobile that has registered significant growth (Figure 8.5) and this industry is almost entirely in the hands of the private sector. This shows that within a short period of time the breadth of telecom services in India has increased. Of all the value-added services, the two most important ones are the cellular mobile and internet services segments, both of which, as seen earlier, are poised for significant growth in the near future. This spectacular growth of the segment is likely to increase both the breadth and depth of the market for telecom equipment and also its complexity.

FIGURE 8.5 **Ratio of Cellular to Fixed-line Connections in the Indian Telecom Carrier Industry**



	1999	2000	2001	2002
Ratio of cellular to fixed line connections	0.06	0.07	0.11	0.17

Source: ICRA 2002.

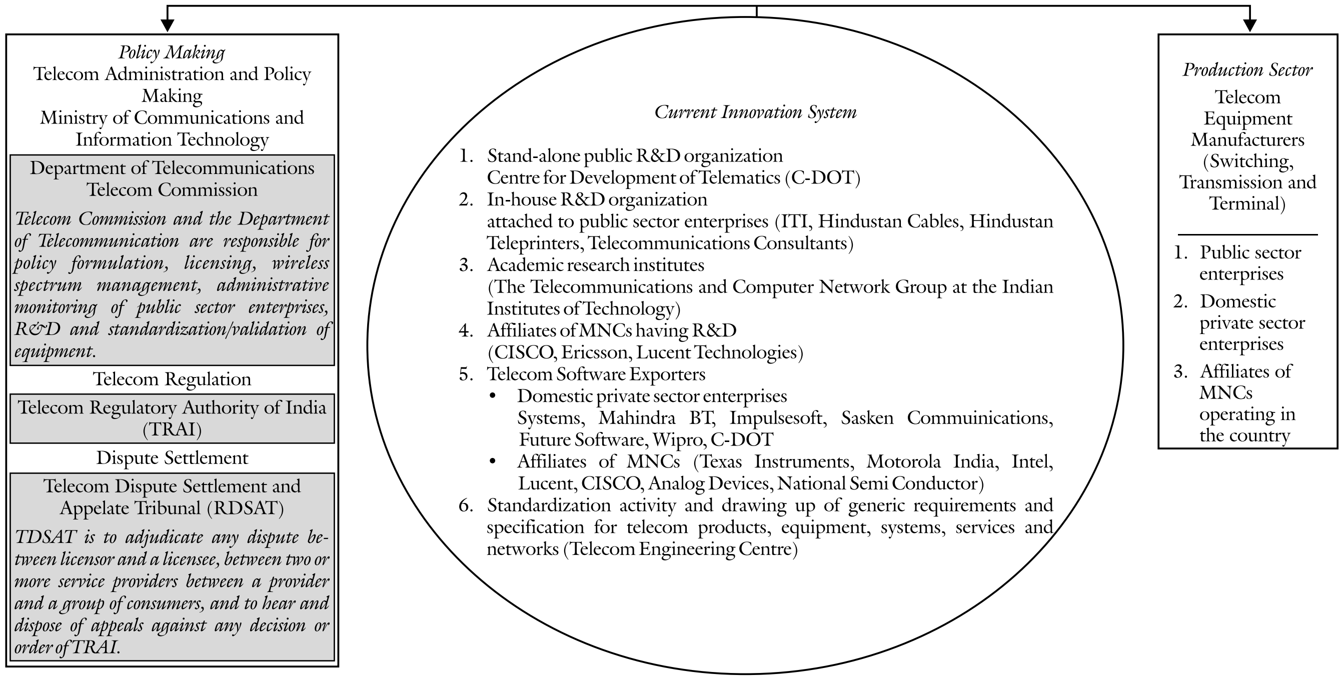
Measuring Innovation Capability of the Indian Telecom Sector

At the outset, it is necessary to map the structure of the innovation system for the telecom sector (Figure 8.6). The telecommunications innovation system of the country consists of three major components:[9] the government (namely, the DoT), the technology generating sector (the most important of which is the Centre for Development of Telematics [C-DOT]) and finally, the production sector (consisting of both state-owned and private sector enterprises).

R&D projects in the area of telecommunications are conducted by several organizations in the country. In 1999, the DoT constituted the Telecom R&D Council with a view to facilitate co-ordination of R&D efforts that are being made in various research centres and universities throughout the country. In other words, the council was a way of defining the national system of innovation for telecom research within the country. Eighteen different organizations were represented in the council. According to a survey made by this council, there were 142 R&D projects organized in seven different types of organizations (Table 8.9). But there is no information on the level of co-ordination[10] or output of these R&D projects. Based on the discussions that I had with officials of the DoT and with one of the largest telecommunications equipment manufacturers, the council appeared to be defunct. The council had not even met once since its inception in 1999. Further, no budget too was attached to this council, rendering it ineffective.

An important measure of success of these projects is the actual use of these products in the Indian telecommunications network. Based on these criteria, I choose three major projects for my measurement of innovation capability. It was found that India has built up considerable innovation capability in three different areas: (*i*) digital switching systems; (*ii*) WLL-based access technologies for fixed-line connectivity; and (*iii*) telecom software. An important feature of the innovation system is the recent growth of the telecom software segment and this segment is expected to be the fastest growing and most profitable of the software industry in India (Indiatel 2002). In fact, it is argued that the growth of the telecom software sector itself has been stimulated by domestic R&D projects.

FIGURE 8.6 **Structure of the National Innovation System of the Indian Telecom Sector (2002)**



Source: Author's compilation.

TABLE 8.9 Survey of Telecom R&D Projects in India

No.	Institution	Field of Research	Number of R&D Projects
1	Indian Space Research Organisation	Satellite Systems	21
2	BEL	Communications Equipment	9
		Raiders as System	21
		Components and Devices	9
		Telecommunications	13
3	Tata Institute of Fundamental Research	Electronic Commerce	4
		Computer Network	1
		Packet Switches	1
4	VSNL	Internet Telephony	4
5	DST-funded Projects in Academic Institutes and	IT	3
	Universities throughout the Country	Telecommunications	25
6	C-DOT	Switching	4
		Transmission	7
7	ITI		20
	Total		142

Source: Personal interviews with officials at the Telecommunications Engineering Centre.

First of all, I will discuss each of the three cases briefly and then will go on to measuring the revealed capability of each of these actors with the aid of some quantitative indicators that reflect the definition of innovation capability that I outlined earlier.

C-DOT and Innovation Capability in Switching Equipment

C-DOT was established as a stand-alone public R&D organization by the central government in 1984.[11] It was charged with the responsibility of developing a family of digital switching systems that were suitable to the Indian usage pattern and conditions. Its scope has now been broadened to include transmission and access products as well. Over time, C-DOT has developed a wide range of switching and transmission products both for the rural and urban applications. It is claimed that while the C-DOT main exchange can also function as mobile switching centre for GSM cellular services, the small rural automatic exchanges developed for rural environment can work without air-conditioning. They come complete with SS7 Intelligent Network signalling systems.[12] In addition, ISDN facilities are also available; what is unique is that these switches have been designed to operate without air-conditioning in harsh environments. About 45,000 exchanges totalling about 23 million telephone lines had been installed in India by 2001. This means that approximately 50 per cent of the equipped capacity in the country is based on C-DOT designed switches. Exports in bulk have been to about 22 countries such as Vietnam, Bangladesh, Nepal, Ethiopia, Ghana and Uganda. And this systematic vendor development shows that there have been considerable technology spillovers to downstream industries as well. It has an R&D centre in Bangalore with complete test equipment, such as microprocessor development systems, CASE Tools, object-oriented methodologies, software metrics, along with V5.1, V5.2 interface, SS7 signalling systems complete with the SSP, SCP and SMP systems. In fact, C-DOT with a total personpower of 1,300 employees has one of the fastest development cycles for digital switching systems anywhere in the world (Mani 1995). C-DOT also claims to have retrofitting capabilities—that is, it has the capability to redesign some of the older switches that it has already developed and that are being currently being used in the network with more recent technological changes. This is achieved by making the necessary software changes. I have, of course, not been able to secure an independent confirmation of this capability.

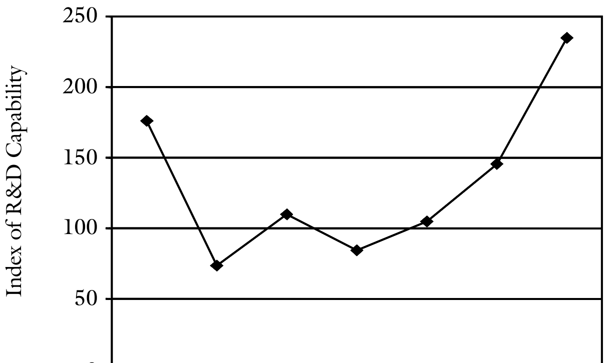
I now turn my attention to quantitatively measure the innovation capability of C-DOT. Towards this direction, I consider two separate indicators of this capability. The first is a summary measure of innovation capability based on production of C-DOT designed switches. The second is a series of evidences to show the spillover effects of the technologies developed at C-DOT.

Indicator of Innovation Capability There are two variants of this index. The first is based on the relative market share of domestically designed (namely, C-DOT designed and industrial training institute [ITI]-manufactured main automatic local exchanges [in terms of number of lines]) and foreign designed but domestically manufactured (namely, Alcatel designed and ITI manufactured) switches.[13]

On technical grounds, both technologies are considered to be equal. In very specific terms, the index is defined as follows:

$$\text{Index of innovation capability} = \frac{\text{Production of C-DOT designed exchanges at ITI} * 100}{\text{Production of Alcatel designed OCB-283 exchanges at ITI}}$$

FIGURE 8.7 Index of Innovation Capability in Switching Equipment (1995–2001)



1995	1996	1997	1998	1999	2000	2001
176.0	73.5	109.8	84.4	104.8	145.5	234.8

Source: ITI, various issues.

If the index is greater than 100 and increasing over time, one can say that the innovation capability of the domestic research sector is increasing. A major limitation of the index is that it is rather difficult to interpret short-term movements. A second limitation is the fact that the index is defined in terms of production figures, and not in terms of number of working connections. But I argue that this only affects the level of the index and not the direction of its movement. This is because the share of C-DOT designed exchanges have been rising over time. Based on the data during the period 1995 through 2001, the index has been computed and is presented in Figure 8.7. Except the initial year, the index shows a continuous rise over time implying a rising capability. This is quite significant as this had been happening at a time when the industry was going through a flux: the carrier industry was getting deregulated and MNCs were entering the equipment industry. So, despite these factors which might act against the usage of domestically designed switches, one sees a systematic and continuous increase in its market share. As seen before, this could be largely explained by the public procurement policy of the main consumer, the DoT.

The second variant is based on the number of lines of a switching technology actually commissioned within the network of the two main public telecom service providers, namely, within the DoT and the MTNL networks during a year. This variant is thus more of an index of market share of the various technologies and is measured by the share of C-DOT designed switches in the total number of lines commissioned each year (Table 8.10). It thus captures the effect of liberalization. In fact, the index shows that despite public technology procurement, the share of C-DOT designed switches have continuously fallen all through the period. This of course proves that public technology procurement in the Indian telecom equipment industry does not afford any protection to domestically designed switches. This proposition could be further explained as follows:

i. Table 8.10 tracks only the share of foreign and domestic technologies in the total annual flow of exchange lines commissioned. C-DOT's share in the total stock of exchange lines in the country is high at about 50 per cent, with the remaining 50 per cent shared by the other eight technologies.
ii. C-DOT specializes in small and medium exchanges, while imported technologies are used essentially in large and extra large exchanges. It is also a fact that C-DOT's capability is mostly in small and medium exchanges, though it also has claims of capabilities in designing large and extra large switches.
iii. It is also clear from an answer to an unstarred question in the Upper House of the Indian Parliament that the DoT procured almost five times the tendered quantity of switching equipment during the same period, supposedly for modernizing the network with ISDN facility.[14] But the number of subscribers using ISDN in the whole country was just 309 for the whole period.[15] So it is clear that DoT has purchased the 'overspecified ' equipment far in excess of its actual requirement and this 'excess purchase' appears to have eroded the market share of C-DOT.
iv. Further, the Comptroller and Auditor General of India (2000) found a number of other irregularities with this tendering process. For instance, although most of the components of the switching equipment were imported by the suppliers, DoT assumed import content

to be as low as 23 per cent, while working out reduction on rates on account of fall in customs duty in the 1995–96 budget. This inaccurate assumption by DoT led to an excess payment of Rs 405 mn to the suppliers with corresponding loss to the government exchequer. DoT also had to make an avoidable expenditure of Rs 639 mn in the procurement of these exchanges against 1997–99 tender due to failure of the Tender Evaluation Committee (TEC) to submit its report within the bid validity period. TEC took 190 days in the finalization of its report against the prescribed limit of 42 days.

v. Despite this fall in market share, C-DOT designed switches continue to occupy the single largest share.

vi. In the light of these comments, it would not be correct to interpret the fall in the overall market share of C-DOT designed switches as a fall in its innovation capability.[16]

TABLE 8.10 Share of C-DOT Designed Switches in the Total Number of Lines Commissioned in DOT and MTNL Network (1994–97)

Type of Switching Technology	*1993–94*	*1994–95*	*1995–96*	*1996–97*
1. AXE-10	74,000	169,704	128,300	113,060
2. EWSD	107,000	203,500	297,328	249,544
3. 5ESS	10,000	4,000	132,000	40,648
4. FETEX-150L	160,000	93,00	113,200	93,280
5. NEAX-61E	Nil	10,000	Nil	Nil
6. E-10B	766,327	957,330	1,119,994	523,854
7. OCB-283	79,500	311,000	405,720	490,578
Total Foreign Technology (1+2+3+4+5+6+7)	1,196,827	1,748,534	2,196,542	1,510,964
8. Domestic Technology *of which*	966,583	1,198,516	112,519	661,905
C-DOT:Large Exchange*	148,500	186,020	328,625	206,166
C-DOT: Extra Large Exchange**	Nil	Nil	18,800	11,200
C-DOT: Small Exchange***	818,083	1,012,496	774,094	444,539
Share of Domestic Technology in the Total Number of Lines Commissioned (%)	44.7	40.7	33.8	30.5

Note: *Small and medium exchanges are those having up to 3,000 lines;
**Large exchanges are those between 3,000 and 10,000; and
***Extra large are those with more than 10,000 lines.
Source: Rajya Sabha, Unstarred Question No: 1171, answered on 5 March 1997, http://164.100.24.219/rsq/quest.asp?qref=32199.

Spillover Effects of C-DOT Over the last two decades or so of its existence, C-DOT has made a number of important contributions both in money and in giving a fillip to domestic technology development in this area of high technology. These could be enumerated as follows.

Since its inception in 1984, C-DOT has recouped approximately 25 per cent of the amount that it has received in the form of parliamentary grants through the sale of its generated technologies. This rate of self-generation has increased significantly to more than two-thirds in the very recent past (Figure 8.8). This is a remarkable achievement as elsewhere in India, the network of laboratories coming under the purview of the Council of Scientific and Industrial Research (CSIR) has a record of generating only about 10 per cent of their total income through self-generation (Mani 2002).

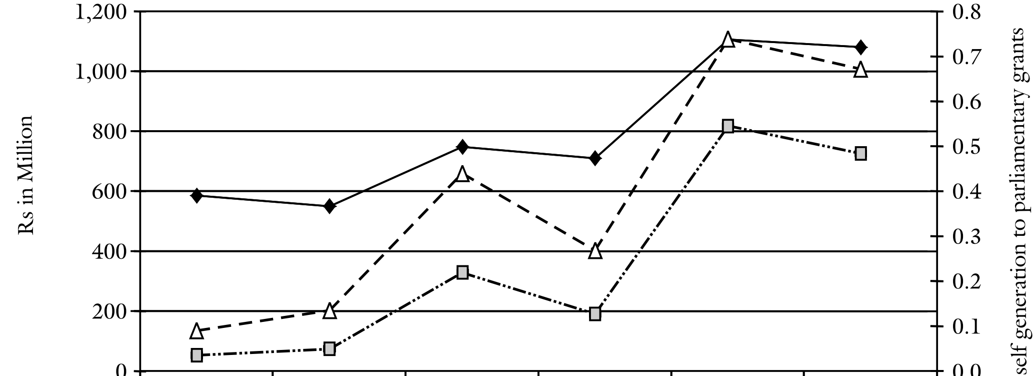
C-DOT's technological innovations have contributed to a substantial reduction in the price of switching equipment sold in the country (Figure 8.9). In fact, over the last one decade prices have fallen by as much as 75 per cent. This fall in prices has enabled the country to increase the supply of direct exchange lines.

C-DOT has transferred eight different types of technologies to about 74 manufacturers in the country (Table 8.11). These 74 companies have their own suppliers of components and spare parts numbering over 600 enterprises. C-DOT has thus effectively contributed to the creation of an indigenous telecommunications equipment industry in the country. More details of the industry are analysed in one of the subsequent sections.

C-DOT has pioneered the telecom software industry in the country. Every year, approximately 80 engineers (out of a total of about 1,200) leave the centre. Since the development of modern digital switches are largely software based, this has given engineers a strong background in the development of telecom software. The growth of the telecom software sector is analysed separately.

While C-DOT has considerable capability in the design of fixed-line switches, there is some doubt about its ability to design mobile switches. In fact, my discussions at the DoT, the TEC and C-DOT revealed that C-DOT does not have any real capability in the design of mobile switches. No state agency in India (including the Technology Information and Forecasting Assessment Council [TIFAC])[17] has done a detailed technology foresight exercise for the telecom sector, so that C-DOT, despite possessing the potential, has been totally unprepared for this changeover. This is going to be a serious shortcoming for C-DOT in the future, as the growth of mobile phones is likely to be faster than that of fixed lines (Table 8.12). MNCs such as Lucent, Motorola and Siemens have already established themselves as suppliers of state-of-the-art mobile switching centres to the cellular

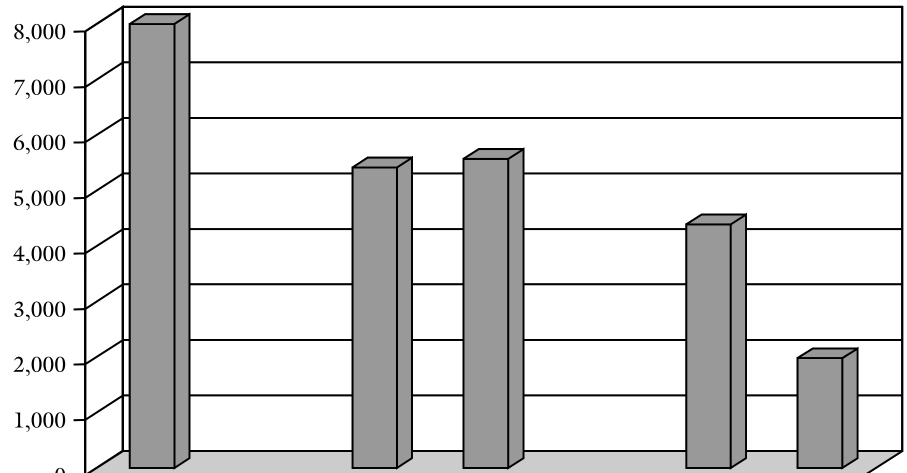
FIGURE 8.8 **Ratio of Self-generation through Sale of Technology to Total Parliamentary Grants**



	1996–97	1997–98	1998–99	1999–2000	2000–01	2001–02
External Income (Rs Mn)	52.7	74.1	328.6	190.4	817.3	725.5
Parliamentary Grants (Rs Mn)	585	550	747.5	709.7	1106.6	1080
Ratio of Self-generation to Parliamentary Grants	0.090	0.135	0.440	0.268	0.739	0.672

Source: C-DOT, various issues.

FIGURE 8.9 **Average Price of Switching Equipment (1990–91 thro ugh 2000–01)**



	1990–91	1995–96	1996–97	1997–98	1998–99	1999–2000	2000–01
Average price of switching equipment (Rs per line)	8,000		5,411.96	5,568.21		4,389.41	1,978.84

Source: Planning Commission 2002.

TABLE 8.11 **Technology Transfer by C-DOT (Completed Technologies)**

Type of Technology	*Number of Manufacturers*
256 P RAX	14
SBM RAX	14
DSS MAX	13
IVRS	10
DMX-8	9
DMX-34	3
TDMA-PMP	6
OLTE-8	5
Total	74

Source: C-DOT, various issues.

TABLE 8.12 **Actual and Projected Growth of Fixed vs Mobile Lines in the Indian Telecom Network**

	Number of Fixed Lines	*Number of Mobile Lines*	*Ratio of Mobile to Fixed*	*Rate of Growth of Fixed Lines (%)*	*Rate of Growth of Mobile (%)*
1981	2.15				
1991	5.07				
1992	5.81				
1993	6.8				
1994	8.03				
1995	9.80				
1996	11.98				
1997	14.54	0.34	0.02		
1998	17.80	0.88	0.05	22.42	158.82
1999	21.59	1.20	0.06	21.29	36.36
2000	26.51	1.88	0.07	22.79	56.67
2001	32.44	3.58	0.11	22.37	90.43
2002	48.99	9.73	0.20	51.02	171.79
2003	56.86	12.27	0.22	16.06	26.10
2004	65.31	16.60	0.25	14.86	35.29
2005	75.33	22.27	0.30	15.34	34.16
2006	86.29	30.56	0.35	14.55	37.22
2007	99.15	41.28	0.42	14.90	35.08

Notes: Value in millions of lines; actual data up to 2002;
data from 2003–07 are projections.
Source: DOT 2002a, 2002b.

service providers. The problem is so severe that according to the CEO[18] of ITI Ltd (the largest telecom equipment manufacturer in India), the company had no orders for switching equipment for fixed lines from the largest telecom service provider in the country (BSNL) for the year 2003. Already, there are reports of most of the licensees (switching equipment) of C-DOT having to close their manufacturing activities or scale them down for lack of sufficient orders.

The C-DOT case thus shows that despite possessing the requisite potential, lack of strategic direction for the laboratory is likely to lead to its eventual closure. Also, it emerged from my discussions that several attempts to co-ordinate the research activities of both C-DOT and the in-house R&D centre of ITI have not been successful. Unless C-DOT diversifies into other areas, such as telecom software, for instance, its continued existence as an R&D organization is doubtful.

Innovation Capability in a New WLL Access Technology: the Case of corDECT

In most countries, the telecom boom left an oversupply of fibre-optic cable along trunk routes, but this links directly only to the largest customers. Homes and small offices that want high-speed internet access usually subscribe to either a digital subscriber line (DSL) or a cable television service. Both are far from ideal: the phone wires used by DSL and the television cables tend to be owned by monopolies, and neither was designed for surfing the web. Retrofitting a fifties telephone line for broadband takes a lot of work, making cheap DSL hard to supply profitably. In principle, the new WLL has no such drawbacks. Indeed, many see it as an ideal solution to the local access problem as it is based on radio waves. Of course, most WLL systems require their own dedicated radio frequencies, but regulators have been fairly generous with these—selling enough licences to competing WLL operators at a fraction of the prices paid by mobile phone operators. Some can even use the same free, unlicensed frequencies in the 2.4 and 5 GHz bands. In the real world, however, wireless has lagged behind both cable and DSL.

CorDECT is a WLL access technology developed by two Indian research organizations: IIT Chennai, Midas Communication Technologies, Chennai, and a US semiconductor manufacturer. The project started towards the end of 1993 and was completed in 1994. The innovation system for this technology consisted of three different types of entities: (*a*) the Indian Institute of Technology, Chennai and Midas Communications; (*b*) four private manufacturers who funded the project through advanced licences; and (*c*) semiconductor manufacturers, including an MNC from the US. Royalty from their equipment sales goes to IIT, Chennai. The total development cost of the project was Rs 750 mn, financed mainly through advanced licensing. Between the four manufacturers, there is an installed capacity to manufacture 1 million lines per annum. This technology offers relatively low-cost and rapid installation of telecom services in areas with even high subscriber density environments. This system relies on a modest bandwidth of 20 MHz for the entire country and is very useful for rural areas where subscriber density is low and laying of cable is not economical. The following description of this technology helps one to understand the significance and utility of this technology.[19]

The corDECT system contains three subsystems—the DECT Interface Unit (DIU), compact base stations (CBS), and subscriber access units—that could be either fixed wallsets or portable handsets. The DIU is at the heart of the corDECT system. Each DIU is connected to a maximum of 20 CBS and each CBS itself serves between 30 and 70 subscribers, depending on the traffic. The CBS is a small, pole-mounted or wall-mounted electronic unit that provides 12 simultaneous speech channels. It is connected to the DIU through standard twisted copper pair links that carry data in the ISDN format. The CBS installed without the need for frequency planning is equipped with antenna for 'talking' to the subscriber wallsets or handsets. The wallset is a subscriber-premises equipment that provides the radio interface for PSTN connectivity. It is powered by an AC mains adapter and includes in-built battery backup and has very low power consumption. The wallset is an intelligent device that continuously looks for access to the strongest base station among many and locks on to the quietest channel. A wallset can be used 3 km from a CBS while a handset can be operated up to 200 m from a CBS, depending on the obstacles. The wallset can be connected to a standard fax machine or modem. CorDECT has been designed to be a modular system. It is stated that while the basic unit provides services to up to 1,000 subscribers, multiple corDECT systems can be connected together using a transit switch. Compared to other substitute technologies like Code Division Multiple Access (CDMA), the corDECT has a number of advantages (Table 8.13).

In very simple terms, corDECT technology will reduce significantly the access cost of telecom service, especially in rural areas. This will hasten the diffusion of internet services in the country and especially in the rural areas[20] and is also eminently suited to other developing countries as well. The system has also been exported to 14 different

TABLE 8.13 Comparison of corDECT with CDMA

Parameters	*DECT*	*CDMA*
Frequency Planning	Not Required	Required
Power Planning	No Power Planning	Power Planning is Complex
Voice Quality	32 kbps	9.6–13 kbps
Subscriber Density	Very High	Low
Services Supported	Voice/Fax/Data/N-ISDN	Limited Data Handling

Source: Asian Technology Information Program 1997.

countries, namely, Madagascar, Kenya, Fiji, Iran, Nigeria, Argentina, Singapore, Brazil, Tunisia, Egypt, Nepal, USA, South Africa and Angola. But there is very little quantitative data on its actual diffusion within the Indian network: about 100,000 lines are said to be in operation within the country (Table 8.14).

TABLE 8.14 WLL Technologies in Use within the Indian Telecommunications Carrier Industry

System Standard	*Start-up Date*	*Subscriber Lines*	*System Operator*	*System Supplier*
CDMA	May 1997	1,000	MTNL-Delhi	Qualcomm
CDMA	1997	unknown	Bharti Telenet	Motorola
corDECT	unknown	trial	DoT	IIT Chennai/Midas/ Analog Devices
PACS	unknown	trial (250)	MTNL	Hughes Network Systems
unknown	1998	unknown	Maharashtra	Hughes Network Systems
CDMA	unknown	unknown	DoT	Qualcomm
CDMA	unknown	unknown	DoT	Samsung
DRA 1900	unknown	unknown	DoT	Ericsson
CT2	unknown	unknown	DoT	Dassault
TACS	unknown	unknown	DoT	Motorola
DECTLink	unknown	unknown	DoT	Siemens
PHS	unknown	unknown	DoT	Array Comm
cor-DECT	unknown	unknown	DoT	Analogue Devices
cor-DECT	unknown	unknown	DoT	Shyam
E-TDMA	unknown	unknown	Hughes Ispat	Hughes
cor-DECT	unknown	unknown	MTNL	Crompton Greaves
cor-DECT	unknown	unknown	MTNL	Shyam
CDMA	unknown	unknown	Tata Teleservices	Lucent
CDMA	unknown	unknown	Telelink	Qualcomm
A 9800	unknown	trial	DoT	Alcatel
DECT	unknown	trial	DoT	C-DOT
PACS	unknown	trial	MTNL	Hughes
CT2	unknown	trial	DoT	Dassault

Source: World Resources Institute, Digital Dividend, www.digitaldividend.org/action_agenda_.01_nlogue.htm.

The diffusion of corDECT within the domestic sector received a major fillip in 2002 when one of the recent private entrants, Reliance Infocomm (which is building one of the largest broadband networks in India)[21] decided to use corDECT to extend its network to rural areas. However, the same company has chosen a rival foreign technology, CDMA 2000 1X[22] to provide services in especially urban residential areas. CorDECT has thus an uphill task against this imported technology for two reasons: first, the owner of this technology also has an equity position in one of the largest telecom operators in the country and this is likely to influence the technology purchase decisions of the latter; second, the leading vendors of the CDMA technology (Table 8.15) are all MNCs and are able to give deferred credit facilities to the operators, while the vendors of corDECT, which are all domestic companies, are not in a position to do so. Thus, corDECT is yet another instance of the country demonstrating its innovation capability despite severe competition from MNCs.

Growth of Telecom Software Exports

India's software exports have been showing some spectacular performance during the 1990s. But an oft-repeated complaint is that much of the software exports from India is low technology. Over time, however, the enterprises involved in this effort have been attempting to move up the value chain. A clear manifestation of this effort is the emergence of telecom software exports from the country. It is generally believed that the impetus for this originated from C-DOT. This fledgling sector of the software industry consists of three different types of firms:

- Indian companies (some with foreign collaboration) focusing only on telecom software. Examples of this would be Hughes Software Systems, Future Software, Sasken and Mahindra-BT.
- Information technology companies (domestic) working on telecom software. For example, Wipro, Infosys, HCL Technologies, Satyam Computer and Tata Consultancy Services.
- Subsidiaries of MNCs. Examples of this would be Alcatel, CISCO systems, Lucent Technologies, etc.

Telecom software is of three types: (*i*) embedded software (*ii*) system software; and (*iii*) application software used by service providers.

TABLE 8.15 Diffusion of CDMA WLL Technology in India (2002)

Operator	*2G/3G*	*Type of System*	*Status*	*Infrastructure Vendor(s)*	*CDMA Coverage*
BSNL	3G-CDMA 2000 1X	WLL 800 MHz	Launch 2Q 2003	ZTE	Karnataka, Kerala, Maharashtra
Bharti Telenet Ltd	2G-IS-95A	WLL, 800 MHz	Commercial	Motorola	Madhya Pradesh
HFCL Infotel	2G-IS-95A	WLL, 800 MHz	Commercial	Lucent	Chandigarh, Ludhiana, Punjab
MTNL	2G-IS-95A	WLL, 800 MHz	Commercial	Motorola	Delhi
Reliance Infocomm Ltd	3G-CDMA 2000 1X	WLL, 800 MHz	Commerical	Lucent	Nationwide
Shyam Telelink Ltd	2G-IS-95A	WLL, 800 MHz	Commercial	Lucent	Jaipur, Rajasthan Region
Tata Teleservices Ltd	3G-CDMA 2000 1X	WLL, 800 MHz	Commercial	Lucent	Delhi
Tata Teleservices Ltd	3G-CDMA 2000 1X	WLL, 800 MHz	Deployment	Motorola	Goa, Maharashtra, Mumbai
Tata Teleservices Ltd	2G-IS-95A	WLL, 800 MHz	Commercial	Lucent	Eluru, Guntur, Hyderabad, Nellore in Andhra Pradesh Circle, Rajahmundry, Vijayawada, Vizag
Tata Teleservices Ltd	2G-IS-95A	WLL, 800 MHz	Deployment	Lucent	Delhi Circle, Gujarat Circle, Karnataka Circle, Tamil Nadu Circle.

Source: CDMA Development Group, http://www.cdg.org/worldwide/index.asp#result.

A wide variety of telecom software, such as SDH, DWDM and optical networking, soft switches and intelligent networking, VoIP, ATM and SS7 gateways, wireless networking, broadband, home gateways and access network solutions, operations support systems, and so on are being developed. According to the Telecommunications Equipment Manufacturers Association (2002), the total size of the telecom software industry in India is about Rs 41 bn. This includes export of telecom software as well as domestic sales. While the export revenue includes embedded systems software, domestic sales refers only to the software that is sold to Indian service providers like OSS/BSS and network management. An indirect evidence to show that much of these exports are in the value-added segment is given by the fact that over 94 per cent of the exports of telecom software is meant for telecom equipment manufacturers and only about 6 per cent is for the telecom carrier industry (Laishram 2002: 74–75).

Consistent time-series data on telecom software exports from India are not available: it is estimated that over 97 per cent of the output of this sector is exported (Laishram 2002). However, available data from industry sources (Table 8.16) shows that telecom software exports form about 14 per cent of total software exports from the country and have also registered more or less the same rate of growth. Thus, our discussion shows that the country has built up considerable innovation capability in the area of both telecom hardware and software.

TABLE 8.16 Telecom Software Exports from India (US$ mn)

	Software Exports from India	*Estimated Telecom Software Exports from India*
1998–99	2,626	262.60 (10)
1999–2000	4,015	461.73 (11.5)
2000–01	6,341	883.09 (14)
2001–02	7,174	993.83 (14)

Note: Figures in parentheses indicate percentage share of total software exports.
Source: Indiatel 2002; Reserve Bank of India 2002.

Another important dimension of India's capability in the telecom software industry is the fact that a number of MNC telecom companies have established their software development centres in India. Of late, some of them have closed down their own R&D centres in India, but have outsourced their telecom R&D to Indian software companies.

The first such initiative was the recent deal between Ericsson and Wipro (Box 8.4).

BOX 8.4 Innovation Capability in India's Telecom Software Industry: Case of the Ericsson–Wipro Deal in Outsourcing of R&D

According to the LOI that Wipro has signed, the deal will involve Wipro picking up assets, including personnel, of Ericsson's R&D centres in Bangalore, Hyderabad and New Delhi. Around 300 software professionals who were part of Ericsson's units would be now on Wipro's payroll. This would take Wipro's overall Ericsson-related team size close to 400 software professionals, as the software major already has around 100 people working on Ericsson's projects. While the financial terms of the agreement are yet to be worked out, the deal does throw up interesting pointers on what Indian companies can do to gain a competitive edge.

Rather than term this deal as an acquisition, Wipro is calling it an 'outsourcing deal'. Wipro intends to run the centres in the form of an outsourcing contract, wherein it will undertake the entire responsibility for all the R&D work of the Swedish firm done in India by taking over assets and people.

While MNCs have been outsourcing R&D requirements for a long time to Indian software companies, the current competitive scenario has changed things a bit. At present, the R&D outsourcing services market is taking on a hue similar to the IT services scenario. For instance, when companies first began outsourcing their R&D services to India, the billing rates quoted were premium rates. But as more and more Indian companies ventured into this market, billing rates fell drastically and MNCs started dividing their work between their own Indian R&D centres and a handful of Indian software companies. Due to the turmoil in the global telecom industry, these MNCs have been looking at the best way to cut costs without compromising on R&D. For instance, a year ago Ericsson had announced that it wanted to increase investments in its Indian R&D centres. The telecom giant had plans of scaling up personpower in these centres even though it cut personpower requirements massively in other centres. But in the light of the massive slowdown in the telecom sector, Ericsson thought it prudent to write off its assets in the Indian centres, while still retaining its competitive advantage by selling the centres and the people working there to its partner, Wipro. As a result, the deal has created a win–win situation for both companies, or so it seems.

Source: R.P. Srikanth, Express Computer, http://www.expresscomputer online. com/20021111/cover.shtml.

Determinants of Innovation Capability in the Equipment Sector

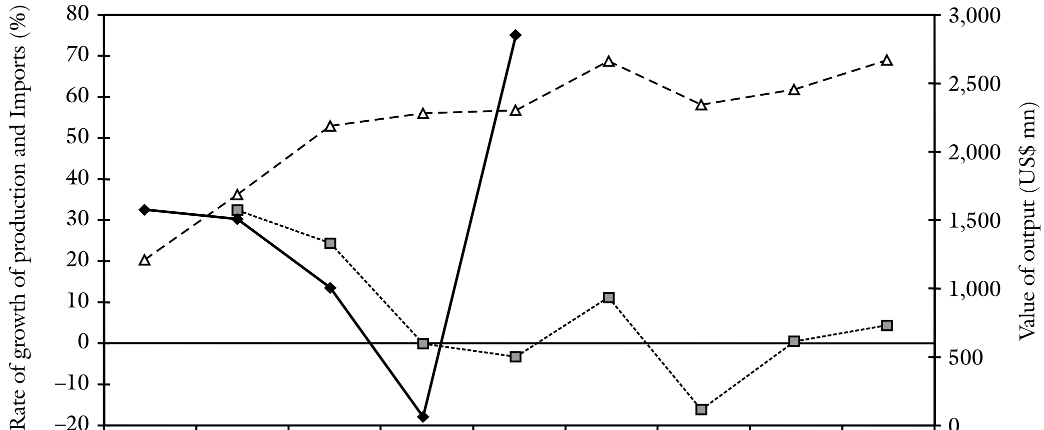
It was seen earlier that the country has a sizeable domestic manufacturing industry. Although in value terms, the domestic output has virtually doubled itself during the period under consideration, its rate of growth has actually come down over time (Figure 8.10). But according to the DoT (2002), this fall in the rate of growth is entirely due to fall in prices and not in quantity. This fall in price realization is the combined effect of two factors: technological innovation and competitive bidding by vendors. This is a direct evidence showing that the public procurement policy of the DoT based on the price performance ratio of equipment is really a competitive process. Another interesting inference that can be drawn from Figure 8.10 is the fact that there appears to be a direct relationship between the rate of growth of domestic production and imports. This is perfectly understandable as imports of externally assembled switching equipment are not encouraged by the public procurement policy, and domestically manufactured switching equipment has an import component of 45–50 per cent (Swaminathan 1998),[23] being directionally proportional to the capacity of the switch.

The normal practice in the literature is to identify certain input factors such as investments in R&D, availability of requisite quantum of scientists and engineers, etc. as the factors that determine innovation capability. However while these factors are a necessary condition, they are not sufficient. Three factors that have important implications for domestically designed and manufactured equipment and hence on the building up of domestic research capability are discussed here.

Public Technology Procurement Policy

As seen earlier, technology procurement policy is an indirect incentive to R&D activities by domestic firms.[24] Korea is one developing country which has used this policy very successfully as a way of encouraging private sector enterprises to commit more resources to local technology generating activities. While several developed countries such as Sweden and France have used this specifically in the realm of digital switching systems, it is the procurement policy of the DoT which has to a large extent promoted domestic innovation capability in the

FIGURE 8.10 **Rate of Growth of Production and Imports (1993–2001)**



	1993	1994	1995	1996	1997	1998	1999	2000	2001
Growth Rate in Production (%)		34.85	27.15	3.93	0.91	14.64	–11.32	4.47	8.18
Growth Rate in Imports (%)	34.90	32.77	16.85	–12.99	75.34				
Production (Millions of US$)	1,300.16	1,753.27	2,229.30	2,316.89	2,338.03	2,680.30	2,376.99	2,483.27	2,686.30

Source: DoT 2002; Mani 2000a.

sector.[25] The DoT purchases switching equipment only from local manufacturers and does not allow imports of finished switching products.[26] This really does not afford any protection to domestically assembled switches, but in fact quite the contrary. First, imported equipment attracts a customs duty of 15 per cent *ad valorem* (2002–03). At the same time, the imported components for domestically assembled switches also attract customs duties, and given the nearly 50 per cent import content of domestically assembled switches, the procurement policy does not afford any specific protection to domestically assembled or manufactured switches. Second, as noted earlier in Figure 8.9, the fall in price realization of domestically manufactured equipment signals increased competitive pressures. Further, the rate of rejection of indigenously manufactured switching equipment by the DoT has been as high as 25 per cent in the early eighties (Mani 1992: 97).

It has a decentalized telecom switches procurement policy. In order to simplify the procurement process, the department receives tenders and sets a fixed rate through a tendering process commonly known as 'rate contract'[27] after which the chief general managers of the various telecom circles are authorized to purchase their requirements from approved vendors. The Telecommunications Engineering Centre (TEC)[28] within the department sets the technical standards of all telecom products, including switches. Thirty per cent of the total requirement of switching equipment is reserved for public sector enterprises. However, the price at which this percentage is procured is at the lowest quotation received for the remaining 70 per cent for which an open tender is invited. This reservation price is referred to as the L1 price. It is thus seen that the public sector producer of switching equipment has to bid for 30 per cent of the switching requirements without actually knowing the price at which the bid is going to be made. Thus, it is clear that the public procurement process followed in the case of switching equipment does not afford any protection to the public sector producer, which in this case is ITI Ltd at Bangalore. The price–performance ratio is thus the main criterion for selection and not other non-technical considerations such as deferred credit facilities. At least for some more years, given the near-monopoly position of the government carriers, public procurement policy will be an effective instrument for stimulating local R&D activities. However, with the growth of private service providers, this will be less effective, especially when the private sector providers, who are in the initial years of establishment, would also take into account deferred credit facilities which only the MNC vendors can offer.

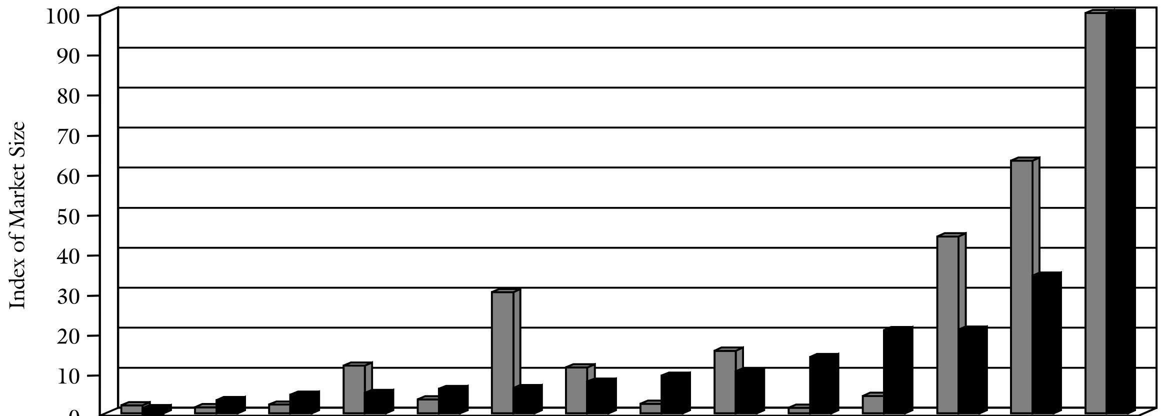
Expected Growth in the Size of the Market for Telecom Equipment in the Country

From the earlier discussion, it is clear that the market for telecommunications equipment is bound to increase significantly in the next 10 years or so, and even now the market is considered to be very large not only by developing country standards but by developed country standards as well. This is based on an estimate of the market for various countries by the Office of Telecommunications Technologies, International Trade Administration of the US Department of Commerce. The size of the market given in value terms has been converted into an index against the size of the market for telecom equipment and services revenue in Japan: Japan was chosen as the reference country as it has the largest size in both equipment and services segments in the sample of countries for which such data are available (Figure 8.11). As discussed before, the plan for raising India's teledensity to seven by 2005 and 15 by 2010 will require 75 million telephone connections by 2005 and 175 million by 2010. At 2002 prices, this translated into additional investments of $36 bn by 2005 and $69 bn in the following five years.[29] The investment potential is not limited to basic telephony, but is spread across a wide range of services and technologies, including cellular internet, radio trunking, GMPCs and other value-added services. But as seen earlier, the main area of growth is in cellular switching equipment and manufacturing of this equipment is largely concentrated in private foreign companies. This increase in the size and breadth of the market is likely to have important implications for the domestic equipment manufacturing industry.

Entry of MNCs in the Telecom Industry

This is yet another factor that has important implications for the equipment sector. In terms of FDI approvals, the telecom sector has received one of the highest FDI inflows—20 per cent of all FDI approvals during the period 1991 through 2002.[30] The actual inflow of investments over the period 1993–2001 is plotted in Figure 8.12.

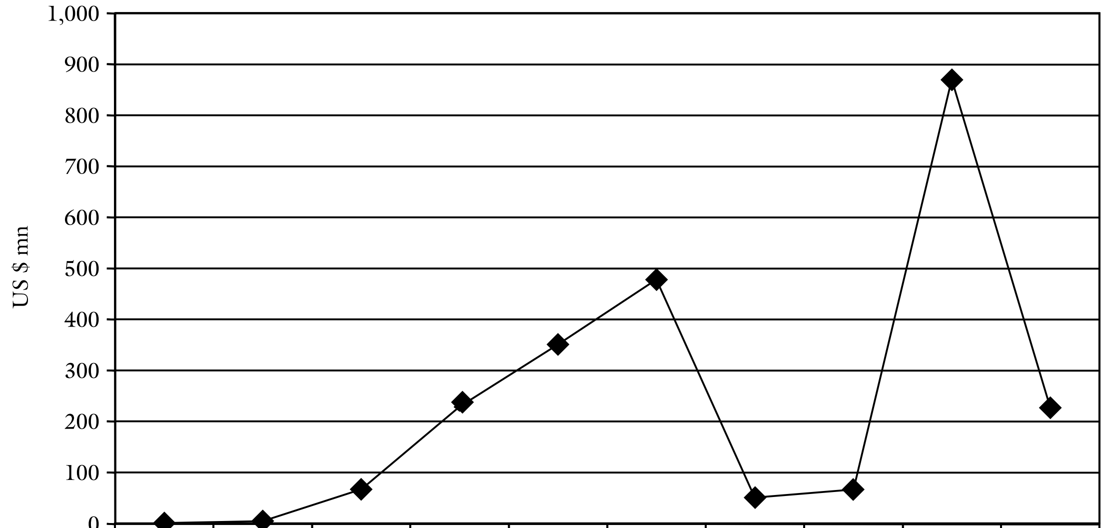
FIGURE 8.11 **Relative Size of India's Market for Telecom Equipment and Services (1998–2001)**



	Indonesia	Hungary	Thailand	Argentina	Singapore	Brazil	Taiwan	Philippines	Mexico	Czech Republic	India	China	UK	Japan
Telecom Services Index	2	2	2	12	3	30	11	2	16	1	4	44	63	100
Equipment Market Index	1	3	5	5	6	6	8	9	10	14	21	21	34	100

Source: Office of Telecommunications Technologies, www.telecom.ita.doc.gov/accessed on 25 November 2002.

FIGURE 8.12 Actual Inflow of FDI in the Indian Telecom Sector (1993–2002)



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
FDI Inflows	0.7	4.5	66.8	228.6	350.8	477.8	50.6	66.6	869.2	226.6

Source: DoT, www.investindiatelecom.com/Investment%20Policy/FDI%20Approved.htm, accessed on 24 November 2002.

It essentially shows two peaks—the first one in 1998 and then in 2001. It is interesting to note that the highest actual inflow of FDI into the sector was in 2001, a year after the crisis in the world telecom industry. Another interesting feature is the fact that India has actually received more foreign private investment than domestic private investment in the telecommunications sector: the ratio of proposed foreign private investment to domestic private investment works out to 2.26 (during the period 1994–2000). Analysis of the industry-wise distribution within the telecom sector (Table 8.17) shows that the carrier industry, and within it, the cellular mobile segment, has received the maximum share: all the holding companies too are in the mobile telephone carrier industry. Nevertheless, the entry of MNCs either in the equipment or the carrier industry will have serious implications for the demand for domestically designed and manufactured equipment.

TABLE 8.17 Industry-wise Distribution of Actual FDI Inflows in the Indian Telecom Sector (August 1991–December 2002)

Industry	*Percentage Shares*
Basic Telephone Service	4.12
Cellular Mobile Telephone Service	24.41
Holding Companies	50.34
Radio Paging	0.91
E-mail	0.72
VSAT	0.29
Cable TV Network + Internet	1.68
Satellite Telephone Service	0.50
Radio Trunking	0.07
Other Value-added Services	0.10
Manufacturing and Consultancy	16.51
Automatic Route	0.31
Total	100.00

Source: DoT, www.investindiatelecom.com/Investment%20Policy/FDI%20 Approved.htm, accessed on 24 November 2002.

As seen earlier in Table 8.6, the telecom switching equipment industry was thrown open to FDI in 1991. (The present policy on FDI in the sector is summarized in Box 8.5.) Consequent to this, there are now five of the leading MNCs having manufacturing facilities in the country.[31] Most of these firms have actually commenced manufacturing

Box 8.5 FDI Policy of Government of India in the Telecom Industry

1. In basic, cellular mobile, paging and value-added services, and global mobile personal communications by satellite, FDI is limited to 49 per cent (under automatic route), subject to the grant of licence from DoT and adherence by the companies (who are investing and those in which investment is being made), to the licence conditions for foreign equity cap and lock-in period for transfer and addition of equity and other licence provision.
2. Foreign direct investment up to 74 per cent permitted, subject to licensing and security requirements for the following:

   (i) Internet Service (with Gateways)
   (ii) Infrastructure Providers (Category-II)
   (iii) Radio Paging Service

3. FDI up to 100 per cent permitted in the following telecom services:

   (i) ISPs not providing gateways (both for satellite and submarine cables)
   (ii) Infrastructure Providers providing Dark Fibre (IP Category I)
   (iii) Electronic Mail
   (iv) Voice Mail

The above would be subject to the following conditions:

(i) FDI up to 100 per cent would be allowed subject to the condition that such companies would divest 26 per cent of their equity in favour of the Indian public in five years, if these companies are listed in other parts of the world.
(ii) The above services would be subject to licensing and security requirements, wherever required.
(iii) Proposals for FDI beyond 49 per cent shall be considered by FIPB on case to case basis.

4. In the manufacturing sector, 100 per cent FDI is permitted under automatic route.
5. FDI up to 49 per cent is also permitted in a company set up for making investment in the telecom companies licensed to operate telecom services. Investment by these companies in telecom service is treated as part of domestic equity and is not set against the foreign equity cap.

Source: DoT, www.investindiatelecom.com/Investment%20Policy/FDI%20Approved.htm,accessed on 24 November 2002.

operations in the early nineties. Alcatel, the French major in telecommunication equipment, maintains a joint venture with the government-owned ITI, manufacturing large capacity switches. Alcatel also has a second collaboration in India— in collaboration with the Modi group. The US major, Lucent Technologies, assembles switches in its Bangalore manufacturing facility. Its state-of-the art ISO 14001 certified plant employs just 310 employees. The plant is responsible for the manufacture and sale of 5ESS central office digital switching products. Ericsson is active in almost every area of Indian telecommunications—switching, wireless, business communication and trunking. It has a good presence in India through its large and medium switches which are used by DoT. Ericsson, in collaboration with Ericsson India Limited (an existing Ericsson collaboration which manufactures electronics connectors), has established a manufacturing facility in Jaipur in 1994. The factory assembles the AXE Digital Switching System, such as local exchange, for use in the Indian network, as well as for export to international markets. Siemens manufactures large capacity switches and supplies to both the DoT and MTNL. Fujitsu of Japan, in association with Punjab Electronics Limited, has a facility in Punjab to manufacture large digital switches. Some of these companies and specifically both Lucent and Ericsson have R&D facilities in the country. One of the reasons that MNCs have entered the Indian market with manufacturing and research facilities has got to do with the public procurement policy of the hitherto main consumer, the DoT, or since October 2000, BSNL.

Conclusions

The study was primarily concerned with measuring the innovation capability of the domestic telecommunications equipment sector and to provide an explanation of its determinants. The study was conducted against the backdrop of the world telecommunications equipment industry becoming not only more concentrated but also significantly increasing its innovative activity. Another feature has been the deregulation of not only the equipment market but also the telecommunications carrier industry to private sector participation. India has a sizeable and growing market for telecommunications equipment. The country has assiduously built up considerable capability in the design, manufacture and sale of digital switching equipment. The domestically designed switches have managed to corner considerable market share in the domestic network. A major explanation for this needs to be found in the public technology procurement policy of the government. However, it was also seen that the procurement policy, while helping the sustenance of this capability, has at times worked against it too. The DoT's overspending during the mid-1990s is a case in point. The future growth of the telecom equipment market is likely to be in mobile switches, and the domestic research sector does not appear to have any capability in this specific area. This lack of capability building can be attributed to the lack of proper technology forecasting. The absence of a credible innovation policy for the equipment sector is thus evident. In addition, capability has also been built in certain WLL access technology and also telecom software, but the ability of the research organizations to sustain this capability, especially in the switching equipment area, will crucially depend on the procurement policy of the state. It is interesting to note that unlike in the case of Brazil (Szapiro 2000), deregulation and the entry of MNCs is yet to have a perceptible deleterious effect on the domestic innovation capability in the Indian context.[32] However, whether it will continue to be so, especially when public technology procurement will become less effective, is a moot point.

Notes

This paper is part of a larger UNU/INTECH research project on *Development and Sustainability of R&D Capabilities and their Linkage to Manufacturing and Services in the Telecoms Industry: Cases from India, Brazil, Korea and Hungary.*

1. There are very few studies on the telecommunications equipment industry elsewhere in other developing countries. However, for an interesting study on the development of switching technologies in Brazil and Korea during the period up to the early nineties, see Mytelka (1999). A more recent analysis of the Brazilian experience can be found in Szapiro (2000).
2. Since teledensity in India is very low, each available telephone is used much more frequently than it is under those situations where teledensity is high. Consequent to this, the throughput of switching equipment required for the Indian network, for instance, is much higher. An analysis of the history of technology import in this sector has shown that very often considerable investments had to be made for successfully adapting imported technologies to local conditions.

3. This index is computed by summating the squared market shares of all the firms in a specific industry. The index ranges from zero to one, and higher the value of the index, higher is the degree of concentration.
4. At this time, AT&T and Lucent were the same company.
5. While the R&D-to-sales ratio reflects the relative tendency of companies within an industry to devote their own resources to R&D activities, they do not reflect the additional resources provided by governments that increase the actual amount of R&D performed. Such governmental support for R&D varies from industry to industry. But since the telecommunications equipment industry has many dual applications, both in defence and civilian situations, they are very likely to receive large amounts of governmental funding. Therefore, any study of the broader question of the total R&D performed by an industry would require supplementary data on governmental support, which is very often difficult to obtain. I have calculated an average of 7 per cent by taking the average R&D to sales ratio of the entire US communications equipment industry during the 11-year period, 1986–96. Given the fact that most of the telecommunications equipment firms are US based, this is a very plausible assumption to be made. See National Science Foundation (1999).
6. These were: (*i*) deregulation of the manufacture of subscriber-premises equipment industry to the private sector in 1984; (*ii*) opening up of the manufacture of telecom equipment to private sector enterprises, including foreign enterprises in 1991; and (*iii*) announcement of the reduction of basic customs duties on various types of telecom equipment in 2000.
7. Licences were to be issued without any restriction on the number of entrants for provision of basic telephone service in a telecom circle. The licence for basic telecom service operator was also proposed to be issued on a non-exclusive basis for a period of 20 years, extendable by 10 years at one time, within the territorial jurisdiction of a licensed telecom circle.
8. WLL is a communication system that connects customers to the public switched telephone network (PSTN) using radio frequency signals as a substitute for conventional wires for all or part of the connection between the subscribers and the telephone exchange. There are at least two situations under which a wireless access network is advantageous. First, wireless access promises quick deployment —an aspect particularly important to the new operator. Second, and perhaps more surprisingly, wireless access is proving to be more cost-effective than other access technologies as a permanent access network in mid-sized Indian towns and rural areas.
9. The Telecommunications Equipment Manufacturers Association (TEMA) has proposed that a part of the Centre for Development of Telematics (C-DOT) be hived off and dedicated to developing technologies suggested by the association. The equipment manufacturers would fund the activities of this new division. But nothing more is known about this proposal. See the *Economic Times* (4 October 2002), http://economictimes.indiatimes.com/cms.dll/html/comp/articleshow?artid=24100018&sType=1.
10. The Steering Committee (Chairman: N.K. Singh) on Communications and Information (of the Telecom Working Group) of the Indian Planning Commission has sought to consolidate the national system of innovation of the telecommunications sector. In specific terms, the committee made the following

three recommendations: (*a*) setting up of a communications research council as the apex body to prioritize plans and finance R&D projects. The council should basically be an industry financed and governed body in which the government provides a one-time corpus fund; (*b*) the present infrastructure available with C-DOT, being of very high quality, can be converted into a national research organization. The industry shall be fully associated with financing and managing this organization; and (*c*) the companies in the organized sector of the telecom industry must earmark a percentage of their turnover for R&D activities.

11. For a detailed history of the centre up to the early 1990s, see Mani (1992, 1995). In the past, many attempts were made to pare down the research activities or even close down the activities of C-DOT supposedly on time overruns in its R&D projects. Mani (1995) has attempted to show that these attempts could largely be attributed to the 'machinations of MNCs', whose market in the country was challenged by C-DOT. It is surprising to note that the centre has survived these attempts very admirably only to face such an attempt once again in the last few months of 2002.
12. These are the systems that are used to find out if a number is busy or available and involve a separate technology that checks the databases of phone numbers; they also provide toll-free services. In this way, the main telephone network does not get overloaded. These systems are also used to interconnect mobile and land-based telephone numbers.
13. The Indian telecom carrier industry employs eight different types of switching technologies like C-DOT, E-10B and OCB-283 (Alcatel), 5ESS (Lucent Technologies), EWSD (Siemens), FETEX-150L (Fujitsu) and NEAX 61E(NEC). Of all these technologies, C-DOT is the single largest, with a market share of 50 per cent.
14. See Rajya Sabha Unstarred Question No: 4125, http://164.100.24.219/rsq/quest.asp?qref=21560. According to the answer given by the Ministry of Communications, the DoT has actually ordered 0.91 million lines of digital switching equipment in response to a tender for just 0.2 million lines.
15. See response to the same question No: 4125. From this, it is also clear that the number of ISDN subscribers even in developed countries range between 0.5 million in the USA and 40,000 in Italy.
16. According to some commentators, the functioning of C-DOT throughout the nineties was characterized by a lack of proper direction in the research projects that it undertook. For instance, according to a recent newspaper report, 'While the rest of the telecom world moved on to wireless and IP (Internet Protocol)-based technologies, C-DoT rested on past laurels earned from its wonderfully robust small-port RAXs (rural automatic exchanges). Throughout the 1990s, it made small incremental steps to a MAX (main automatic exchange); came up with an IN (intelligent network) platform; an ATM (asynchronous transfer mode) switch; some ISDN (integrated services digital network) boxes and satellite products' (Puliyenthuruthel 2002).
17. The TIFAC did a major technology foresight exercise covering nearly 17 different areas, including the telecommunications sector. Known as the 'Vision 2020' reports, these were published in 1996. Going through the list of seven major recommendations (and specifically recommendations iii through vi) of the report

on telecommunications, one finds that the study did not anticipate at all the phenomenal growth of mobile telecommunications in the country. It stipulated:

i. extensive deployment of optical fibre in the existing network as well as for the network to be laid in coming years to support new broadband services is stressed to be more important;
ii. taking necessary steps to ensure sufficient use of radio frequency spectrum, maximum economic benefit and significant role to effective wireless technologies;
iii. targeting R&D activity to strategic areas to work on specific socially relevant applications and efforts to raise funding through collaborative R&D in strategic alliances and regional initiatives should be pursued in the field of R&D;
iv. orientation of the Indian telecommunications industry from being technology, equipment and product focused to being services focused is brought out as an immediate specific action;
v. introduction of new technologies in the network to accelerate the development of telecommunications infrastructure in rural and remote areas also requires immediate action;
vi. upgradation of quality of human resources in telecommunications industry and strengthening of India's core competence in software and design are stressed to be important; and
vii. appropriate modifications of rules and procedures to ensure that the above-stated recommendations are implementable have also been discussed so that urgent attention may be given to these aspects as well.

Source: TIFAC 1996.

18. Private communication with the author at Bangalore on 7 March 2003.
19. This description is largely based on the information contained in the Asian Technology Information Program (1997), James (2003) and Jayaraman (2002).
20. CorDECT technology effectively and inexpensively addresses the problems of distance and of lack of infrastructure in rural areas. Installing a fixed WLL does not require expensive digging, and the system consists of only four major components. Because the CBS/DIU handles traffic of 200–1,000 subscribers, it works ideally in small, dispersed markets and does not require the large subscriber base that traditional landline or cellular systems require for profitability. This low infrastructure investment, combined with low usage costs, makes the proposition affordable both for suppliers and customers in capital-constrained economies (World Resources Institute, Digital Dividend, http://www.digitaldividend.org/action_agenda/action_agenda_01_nlogue.htm).
21. Reliance Infocomm is part of a large Indian conglomerate, Reliance Industries. About 4 per cent of the shares of Reliance Infocomm are held by the American telecom company, Qualcomm, which pioneered the CDMA technology. Qualcomm makes money from royalties every time a chipset is inserted into CDMA phones and other network equipment as well as from licence fees. Further, based on my discussions at Midas Communications, it could be seen that the order from Reliance Infocomm has led to a large quantum of orders from both elsewhere within the country and from abroad. For instance, following test-run

with 25,000 corDECT systems in 24 cities across nine states for over a year, BSNL has recently awarded a contract for over 0.6 million corDECT lines. The BSNL contract is worth around Rs 7 bn and is divided among Himachal Futuristic Communications Ltd (HFCL), Indian Telephone Industries Ltd (ITI), Electronic Corporation of India (ECI), Shyam Telelink and Hindustan Teleprinters Ltd (HTL) The BSNL contract for corDECT systems is mainly for smaller towns and rural areas in these states, according to Midas Communications Director, Shirish B. Purohit.

22. According to reliable sources, CDMA 2000 1X has a much faster data transferring capacity at 144 kbps as against corDECT's capacity of 35–70 kbps (India Bandwidth, http://www.indiabandwidth.com/dir1/wireless8.html).
23. According to him, these imports of components will continue for several years because uneconomic production volumes, higher start-up costs and fast-changing technology deter entrepreneurs from choosing locally manufactured telecom components. The central government-owned Semiconductor Complex produces a limited range of small- and medium-scale integrated circuits. Large- and very large-scale integrated circuits are essentially imported.
24. The WTO already has the Government Procurement Agreement (GPA), with detailed rules on procurement. However, this agreement only binds 26 parties out of the 135 WTO members. For this reason, the WTO has pursued a work programme on transparency in government procurement (TGP). The aim is to draw up an agreement to which all WTO members will be party. In principle, the agreement does not seek to eliminate preferences to domestic suppliers, it simply aims to make these preferences transparent.
25. The procurement policy of the main telecom consumer, whether the DoT or BSNL, needs to be distinguished from that of other government departments. In the former case, the telecom products are selected on the basis of price—performance ratios (or the rate performance contract), while in the latter case, it is very often through a fiat. The procurement policy of the DoT or BSNL, especially for non-switching telecom equipment, has drawn some flak in recent times. Owing to pressure from the Parliamentary Standing Committee, BSNL constituted a committee 'Shift in Procurement Policy of BSNL'. On a more general note, following the Singapore Ministerial Meeting of the WTO, the central government constituted an Inter-Ministerial Working Group on Transparency in Government Procurement at the level of additional secretaries and headed by the additional secretary (commerce).
26. It must of course be added that the new private entrants are not governed by this stipulation and are free to import switching equipment.
27. The DoT receives and evaluates bids from domestic firms (including affiliates of MNCs) and awards rate contracts based on price and performance.
28. Through its core group, TEC is responsible for drawing up the standards' and Generic Requirements (GRs) for networks, systems, equipment and products to be used in the Indian telecommunications network. The centre, through its regional offices, is also responsible for co-ordinating and evaluating these products, equipment and systems. TEC also provides advice to the DoT in respect of products and networks used by DoT. The switching division of TEC is responsible for all activities related to switching products either working in the DoT's network or interworking with the DoT's network. This includes preparation of

specifications of state-of-the-art digital switching systems, validation of switching systems to be inducted in the DoT's network, interface testing of PABX and switches for GSM and basic services, testing of hardware and software upgradation of various switching systems, providing software maintenance support and field support to switching systems working in the DoT's network.

29. It must be mentioned that there are various estimates of these likely investments. The present ones are based on the estimates by the Office of Telecommunications Technologies of the US Department of Commerce, http://www.telecom.ita.doc.gov/.
30. Maximum FDI approvals were, however, in fuels (power and oil refining). See DoT, http://www.investindiatelecom.com/Investment%20Policy/FDI%20Approved.htm, accessed on 24 November 2002.
31. The information for this section is largely based on the data contained in Swaminathan (1998).
32. For a comparative study of the efforts of three research organizations in the developing world, namely, that of CPqD (Brazil), C-DOT (India) and ETRI (South Korea), see Mani (forthcoming).

References

Asian Technology Information Program. 1997. *CorDECT—A New Indian Wireless Local Loop System,* ATIP97.002.

Brundenius, Claes and Bo Goransson. 1985. 'The Quest for Technological Self-reliance, The Case of Telecommunications in India', *Research Policy Studies*, Discussion Paper No. 176, Lund: Research Policy Institute.

C-DOT. Various issues. *Annual Report*. New Delhi: C-DOT.

Comptroller and Auditor General of India. 2000. *Report of the CAG on Union Government for the Year ended March 1999*, Union Government Post & Telecommunications (6 of 2000). New Delhi: Government of India.

DoT (Department of Telecommunications). n.d. *Perspective Plan 1997–2002*, www.dotindia.com/plans/perspective1997–2007.htm.

———. 2002a. *Annual Report 2001–2002*. New Delhi: Government of India.

———. 2002b. *India Telecommunication Statistics 2002*, New Delhi: Department of Telecommunications.

Dorrenbacher, Christoph. 2000. 'Between Global Market Constraints and the National Dependencies: The Internationalisation of World's Leading Telecommunications Suppliers', *Transnational Corporations*, 9(3): 1–32.

Edquist, Charles (ed.). 1997. *Systems of Innovation*, London: Frances Pinter.

Edquist, Charles, Leif Hommen and Lena Tsipouri (eds). 1999. *Public Technology Procurement and Innovation*. Boston: Kluwer Academic Publishers.

Fransman, Martin. 2002. 'Mapping the Evolving Telecoms Industry: The Uses and Shortcomings of the Layer Model', *Telecommunications Policy*, 26(9–10): 473–83.

Fridlund, Mats. 1999. 'Switching Relations: Government Development Procurement of a Swedish Computerised Switching System', in Charles Edquist, Leif Hommen and Lena Tsipouri (eds), *Public Technology Procurement and Innovation*. Boston: Kluwer Academic Publishers.

Gaffard, Jean-Luc and Jackie Krafft. 2000. 'Telecommunications: Understanding the Dynamics of the Organization of the Industry', www.telecomvisions.com/articles/pdf/jackie.pdf.

Husz, Martin. 1999. 'On Implementing the Austrian Computerized Digital Switching System', in Charles, Edquist, Leif Hommen and Lena Tsipouri (eds), *Public Technology Procurement and Innovation*. Boston: Kluwer Academic Publishers, 259–80.

Jain, Rekha. 2001. 'A Review of the Indian Telecom Sector', in Sebastian Morris (ed.). *India Infrastructure Report 2001, Issues in Regulation and Market Structure*, Delhi: Oxford University Press, 189–216.

Jayaraman, K.S. 2002. 'India Online', *Nature 415*, 358–59.

ICRA. 2002. *The Indian Telecommunications Industry*, Mumbai: ICRA (Revised Edition).

Indiatel. 2002. *India Telecom Software Report*. Mumbai: Indiatel.

ITI. Various issues. *Annual Report*. Bangalore: ITI Ltd.

James, Jeffrey. 2003. 'Sustainable Internet Access for the Rural Poor? Elements of an Emerging Indian Model', *Futures*, 35(5): 461–72.

Laffont, Jean-Jacques and Jean Tirole. 2001. *Competition in Telecommunications*. Cambridge, MA: The MIT Press.

Laishram, Nareshchandra. 2002. 'For the Focused', *Voice and Data*, July: 74–75.

Llerena, Patrick, Mireille Matt and Stefania Trenti. 1999a. 'Public Technology Procurement: The Case of Digital Switching Systems in France', in Charles Edquist, Leif Hommen and Lena Tsipouri (eds), *Public Technology Procurement and Innovation*. Boston: Kluwer Academic Publishers, 197–216.

———. 1999b. 'Public Technology Procurement: The Case of Digital Switching Systems in Italy', in Charles Edquist, Leif Hommen and Lena Tsipouri (eds), *Public Technology Procurement and Innovation*. Boston: Kluwer Academic Publishers, 217–39.

Malerba, F. 2002. 'Sectoral Systems of Innovation and Production', *Research Policy*, 31(2): 247–64.

Mani, Sunil. 1992. *Foreign Technology in Public Enterprises*, New Delhi: Oxford and IBH.

———. 1995. 'Technology Import and Skill Development in the Micro-electronics-based Industry: The Case of India's Electronic Switching Systems', in A. Bagchi (ed.), *New Technology and the Worker's Response: Micro-electronics, Labour and Society*. New Delhi and London: Sage: 98–122.

———. 2000a. 'Exports of High Technology Products from Developing Countries: Is it Real or a Statistical Artifact?', UNU/INTECH Discussion Paper #2000–1, Maastricht: United Nations University/Institute for New Technologies.

———. 2000b. 'Deregulation and Reforms in India's Telecommunications Industry', in M. Kagami and M. Tsuji (eds), *Privatization, Deregulation and Economic Efficiency, A Comparative Analysis of Asia, Europe and the Americas*. Cheltenham, UK and Northampton, MA: Edward Elgar, 187–205.

———. 2002. 'Private Financing Initiatives in India's Telecommunications Sector', in Sanford V. Berg, Michael G.Pollitt and Masatugu Tsuji (eds), *Private Initiatives in Infrastructure, Priorities, Incentives and Performance*. Cheltenham, UK and Northampton, MA: Edward Elgar, 118–54.

Mani, Sunil. forthcoming. Innovation Capability in Developing Countries, Analysis of the Telecommunications Industry in Brazil, China, India and Korea. Cheltenham, UK and Northampton, MA: Edward Elgar.
MIT Technology Review. 2001. 'The TR Patent Scorecard 2001', May: 1–8.
Mytelka, Lynn. 1999. 'The Telecommunications Equipment Industry in Brazil and Korea', in Lynn Mytelka (ed.), *Competition, Innovation and Competitiveness in Developing Countries*, Paris: OECD, 115–61.
National Science Foundation. 1999. *National Patterns of R&D Resources, 1998*, Division of Science Resource Studies, Directorate for Social, Behavioral and Economic Sciences, NSF-99–335. Arlington, VA: National Science Foundation.
OECD. 1996. *Reviews of National Science and Technology Policy, Republic of Korea*. Paris: OECD.
Planning Commission. 2002. *Working Group on the Telecommunications Industry*. New Delhi: Planning Commission.
Puliyenthuruthel, Josey. 2002. 'Sanchar Bhavan's No Mecca Any More', *Business Standard*, 18 December.
Pyramid Research. 2002. *Worldwide Telecoms Revenue Forecasts and Analysis 2002–07*. Cambridge, MA: Pyramid Research.
Reserve Bank of India. 2002. *Annual Report 2001–02*. Mumbai: Reserve Bank of India.
Swaminathan, R. 1998. *Telecom Switching Equipment, Industry Sector Analysis*. Chennai: US and Foreign Commercial Service and US Department of State.
Szapiro, Marina Honorio de Souza. 2000. 'Technological Capability in the Telecommunications Industry in Brazil: Development and Impacts of the Structural Reform in the 1990s' (paper presented at the fourth *International Conference on Technology Policy and Innovation*), Curitiba, 28–31 August.
Telecommunications Equipment Manufacturers Association. 2002. *TEMA Member Directory 2002*. New Delhi: TEMA.
TIFAC (Technology Information and Forecasting Assessment Council). 1996. *Technology Vision 2020*. New Delhi: TIFAC.
Tsipouri, Lena. 1999. 'Public Technology Procurement: The Case of Digital Switching Systems in Greece', in Charles Edquist, Leif Hommen and Lena Tsipouri (eds), *Public Technology Procurement and Innovation*. Boston: Kluwer Academic Publishers, 241–58.

Websites

www. investindiatelecom.com
www. telecom.ita
www. nortelnetworks.com
www. alcatel.com
www. lucent.com
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9

Adoption of Communication Standards in Developing Economies: Issues and Options for India*

Rakesh Basant
G.R. Ramadesikan

Introduction

Given the importance of communications in today's world, its spread in developing economies is critical for their development. Emergence of standards reduces market and technological uncertainty and lays the foundation for market creation. This in turn enhances the diffusion of communication technologies partly through advantages of economies of scale. Due to these network externalities, adoption of standards is very important for developing countries. A variety of approaches exist regarding the adoption of standards. Which approach is most suitable for a country like India? What are the critical issues that are relevant for standards adoption? Can we come up with

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some broad parameters of a framework that can be used to analyse various issues relating to setting of communication standards?

Standardization has become increasingly important with the rise in cross-fertilization between information technology (IT) and other technologies, especially in communications. Large-scale use of PCs by the corporate sector, government departments and households has created new needs to link PCs within networks. This is essentially because consumers are increasingly demanding compatibility and interoperability. At the same time, the growing diversity of satellite and other telecom equipment and of software renders standardization very complex and difficult. Moreover, rapid changes in IT-related technologies has put the standardization system under pressure: while standards have become urgent to create markets, consensus among interested groups is more difficult to achieve due to uncertainties and the magnitude of vested interests.

Under these circumstances, strategic implications of IT standardization are huge because standards can determine the growth potential of individual firms, affect the competitive advantage of nations and even development of technologies and their diffusion. It is recognized that market mechanisms do not provide adequate assurance that the best technology will prevail or that an obsolete one be replaced at the right time.

Implementation of communication networks, when there are different competing networks, poses a challenge in choosing an appropriate standard. The standard selection is not a straightforward decision of choosing the standard that promises the best performance. When standards compete, the best possible standard may lose out in the market. Customers locked into losing standard may face the situation of slow or no upgradation. The critical choice is between remaining standard neutral and specifying a standard to be deployed. Each policy decision has its advantages and disadvantages. For example, one of the advantages of implementing a single standard is market creation and the associated faster technology diffusion. At the same time, there exists a possibility of being stranded with a standard that might lose out in the standard war (technological lock-in) or with an inefficient standard (regulatory failure). In the same vein, some of the advantages of remaining standard neutral are that the market determines the standard and there is no regulatory inefficiency in the standard setting. However, standard neutrality may mean that an inefficient standard may win the battle (market failure). Neutrality may also lead to problems arising from the refusal by network operators to make their networks compatible to some applications. Similar problems may exist in implementing a single standard if owners of the intellectual property (IP) that goes into making a standard refuse to license it to others.

Given the advantages and disadvantages for each policy decision, it becomes imperative to follow a dynamic strategy towards standard adoption. The standard setting also has to take into account the interdependence of various technological domains so that it can facilitate innovation in the information and communication technology (ICT)-related technologies. This paper will explore these questions in the context of the experience of standard setting elsewhere in the world and identify key issues and options for India. The rest of the paper is divided into three sections. The first section briefly discusses the general approaches to standard setting and highlights the role of standards in network industries. This is followed, in the second section, by a discussion on standard setting approaches adopted by Europe, the United States and South Korea in the context of mobile standards. The third section pools together the key issues related to the standard setting process and identifies policy options for India, once again in the context of cellular standards. The final section broadens the scope of the discussion and raises some general issues with respect to standardization processes and IT in India.

Standards and Networks[1]

For example, if the market structure is non-competitive, economic outcomes may be inefficient. Some market decisions might fail to incorporate or account for environmental, safety and other social externalities. Regulatory standards play a crucial role when standards are needed in a short span of time, because the decisions based on authority can be made and implemented fast. To create standards, governments use a variety of mechanisms.

Standards can also be set through organizational processes that reduce transaction costs and facilitate information exchange and negotiation among key players. Such a process, known as the voluntary consensus process, can provide for better co-ordination than the market when levels of uncertainty are high, when there are frequent recurring exchange activities among the parties and/or when information exchange is complex. Organizations may participate in the voluntary standards development process for a number of reasons. They may, for example, want to influence the development of standards, or may wish to keep abreast of technological developments. The incentive to participate in such exercises is likely to vary among industries. In industries such as telecommunications, for example, the incentive to participate in standards setting is likely to be high. If communications systems fail to work together, there can be no services to sell.

Network Externalities, Economies of Scale and Scope

As mentioned, in the case of networked technologies, standards become very important. To understand the importance of networked technologies, it is essential to understand the concepts of 'network externalities' and the economies of scale and scope.[2]

Standards can be broadly defined as an agreed upon set of specifications that define a particular product or that allow products to interoperate. Standards can be achieved through market selection, a regulatory process of the government or a voluntary consensus process.

Standard Setting Processes

When the market operates effectively, appropriate standards are expected to emerge at the right time through the process of supply and demand. Producers will agree on the best standard in the face of competition from other suppliers and the demand of users. Producers may press for the adoption of their own standards or select strategically from among other competing standards, evaluating each in terms of its potential impact on costs of production, profitability and market share. Users, on the other hand, may demand standards that reduce purchasing prices, improve utility and are easily integrated with other products and systems. The market may, however, fail when appropriate (efficient) standards do not emerge in a timely fashion. Some kinds of technologies are subject to greater market failures than others. For example, networked technologies, such as information and communication technologies, often have large installed bases, making it particularly costly for users to shift to new, more technologically advanced standards. Thus, they may fail to adopt the socially optimal standard, due to sunk costs and the technology or standard 'lock-in'.

At the same time, these technologies also exhibit increasing returns to adoption, a situation that occurs when the benefits to the user of a technology increase with the number of users. Under these circumstances, the wrong standard might be chosen due to excess momentum. Not wanting to be left out of the network when a major adopter moves to a new standard, users may rush too quickly to jump on to the bandwagon.

Regulatory standards are established by legitimate government authorities and mandated from the top. If the market standards are established by exchange relationships, regulatory standards are based on authoritarian relationships. The government, for a number of reasons, might set standards.

There are many products for which the utility that a user derives from consumption of the good increases with the number of other agents consuming the good. There are several possible sources of these externalities. The consumption externalities may be generated through a direct physical effect of the number of purchasers on the utility of the product. The utility that a consumer derives from purchasing a telephone, for example, clearly depends on the number of other households or businesses that have joined the telephone network. These network externalities are present for other communications technologies as well. Significant diffusion of specific products and/or technologies can result in the development of a wider variety of related products and technologies. Consumers can also hope to get better post-purchase services.

There may be other indirect effects that give rise to consumption externalities. The central feature of the market that determines the scope of the relevant network is whether the products of different firms may be used together. For communications networks, the question is one of whether consumers using one firm's facilities can contact consumers who subscribe to the services of other firms. If two firms' systems are interlinked or compatible, then the aggregate number of subscribers to the two systems constitutes the network. If the systems are incompatible, such as cable and telephone, then the size of an individual system is the proper network measure for users of that system. These can also be seen as 'consumer side scale and scope economies (Morris 2002).

Due to network externalities, the co-existence of incompatible products in network markets is often unstable, with a single winning standard dominating the market. Given the demand side of economies of scale and scope, expectations about the ultimate size of a network are crucial. Buyers who join what turns out to be a losing network must either switch, which may be costly, or else content themselves with smaller network externalities than those associated with the winner. Since buyers' purchase decisions are strongly influenced by their expectations of future sales, there can be large rewards in influencing these expectations. And these can be generated strategically by firms or by governments by mandating/preferring certain standards. In these circumstances, victory need not go to a better or cheaper product: an inferior product may be able to defeat a superior one if it is widely expected to do so. For example, the initial success of MS-DOS is usually attributed not to any technical superiority, but to the fact that IBM supported it.

Just as communications or IT technologies (hardware as well as software) exhibit large consumer side scale and scope economies, supply side economies are also widespread. This is particularly so for software, where the marginal cost of producing an additional unit is extremely low (Morris 2002). Thus, if standards creation can facilitate rapid growth of the market, both supply and demand side economies can be reaped, and costs can decline significantly. But as mentioned, consumers can get locked in to specific technologies. Add to this the learning-by-doing effect and 'sunk' investments of producers, and the lock-in becomes complete. Consequently, specific technologies and standards can get locked in for a long time.

Thus, the main problem with standards is that once a standard is established, it may be very difficult to modify or replace it. The standards gain value by the sheer size of the installed base. Therefore, superior technology (standards) may not be able to enter the market as network effects may carry over from one generation of the entrenched technology to the next, defining the future path of development of the market. This creates entry barriers for new technologies.

While standardization has lock-in related problems, multiple standards can have their own problems. Fragmentation in the market can lead to small (but viable) poorly supported standards. Network economies are not reaped and users locked into standards having small installed bases get orphaned, not having the benefit of new complements to their standards. The key advantage of multiple standards is that the market retains variety. Variety is important because better standards may lose out to an inferior standard in the standardization process. Given high technological uncertainties, some competition among standards is desirable. However, the issue of the trade-off between loss of variety and fragmentation is difficult to resolve.

Standard Setting Processes: Some Experiences

The earlier section has highlighted the importance of standard setting. Many countries have recognized this importance and have given it a significant policy focus. This section highlights key issues of cellular standards setting. The cases discussed involve elements of a variety of standards setting processes, market driven, regulatory, as well as consensual.

The European Experience: Political, Economic and Technological Imperatives

In the early 1980s, European governments recognized the problems associated with a plethora of standards. Given the small markets for customer and network equipment, the costs for the same were high, as economies of scale could not be achieved. Besides, the use of mobile equipment and access to network services were limited to national boundaries, making it difficult for people travelling to avail these services. Thus, network externalities were not being reaped. In 1982, the Conference of European Posts and Telegraphs (CEPT), an inter-governmental organization that comprises national telecommunications administrations of European countries, formed a study group to develop a pan-European public land–mobile cellular telephone system. It was mandated that the new system achieve (*a*) spectrum efficiency, (*b*) good speech quality, (*c*) low mobile and base station costs, (*d*) ability to support new services and facilities, and (*e*) compatibility with integrated services digital networks. Subsequently, the European Telecommunications Standards Institute (ETSI) got involved in this exercise, which resulted in a digital standard called global system for mobile (GSM) communications that was commercialized in 1991. The process of creating this standard brought out a variety of issues that are relevant for developing countries (see, for example, Ramadesikan and Basant 2001).

European governments realized that localized solutions for mobile communications did not make long-term economic sense. Given the high R&D costs for operators and manufacturers, it was essential to exploit economies of scale afforded by global market penetration. Home market revenue simply would not justify sustained investment in a specific technology. While governments recognized that protection of their national industries might constrain the standard setting process,[3] national interests could not be ignored. For example, the choice between narrow band and broadband alternatives brought to the fore the conflicting interests of Scandinavian (Ericsson/Nokia) and Franco-German firms (SEL, AEG and Alcatel). The deadlock would have derailed the standardization process if the European Commission had not worked hard to develop a political consensus and persuaded member states to reserve a frequency band (900 MHz) for the pan-European digital standard. This was critical as inter-operability depends not only on the use of the same digital technology, but also on the system operation in the same frequency bands. The formation of ETSI by the Commission further facilitated the standardization process.

Eventually, a narrow-band architecture was used for the proposed GSM standard, but several features of the Franco-German proposal were also incorporated. In fact, the standard was derived from eight candidate proposals submitted by the European Industry Consortia. This 'basket' standard provided just returns to the opposing camps as the initial competitive advantages were in GSM subsystems, not in the entire system. Thus, though the narrow band architecture gave an initial small advantage to Nokia and Ericsson over their French and German counterparts in some sub-systems of the GSM network, no manufacturer commanded hegemonic advantage. Besides, given the monopolies in their domestic telecom markets, French and German governments were free to order GSM equipment from the manufacturers of their choice (like, Alcatel, Siemens and SEL), ensuring that these firms would get a fair share of the new market. The only requirement was that EU members use European standards in public procurements.

Although GSM is a communication system designed by Europeans for deployment in Europe, the system has been exported to countries all over the world. In 2001, the number of GSM subscribers was 564.6 million, while Code Division Multiple Access (CDMA), the closest competitor technology, had a subscriber base of only 99.8 million.[4] The dramatic success of GSM has been attributed to the early rollout of the technology and the tremendous economies of scale GSM enjoyed due to the single standard in Europe. The dramatic success of GSM can also be partly attributed to the entry of non-European equipment manufacturers, notably Motorola, which got entrenched into this market through the ownership of many essential patents necessary for the implementation of GSM. Subsequently, Lucent and Nortel also entered the fray. The interests of a wide spectrum of manufacturers made the market competitive, which, combined with economies of scale, led to higher penetration with lower costs.

The US Experience: A Case of Market Determination

In 1987, the US Federal Communications Commission (FCC) began the transition from analog (AMPS) to digital technology by declaring that cellular operators could employ any technology as long as it did not interfere with the operations of other networks. In 1988, the Cellular Telecommunications Industry Association (CTIA) came up with a set of user performance requirements (UPR) for the new cellular technologies. These included: (*a*) a 10-fold increase in system capacity compared to the analog systems; (*b*) dual mode (AMPS/digital) capability; (*c*) new data feature capabilities (like fax, short message service); (*d*) early availability of equipment; and (*e*) standards for high quality of service.

The actual task of setting the standard was left to the Telecommunications Industry Association (TIA), the industrial body of the equipment manufacturers. Responding to the UPR, after considerable debate, the TIA adopted IS-54, a Time Division Multiple Access (TDMA) standard. Despite apparent shortcomings of the IS-54 standard vis-à-vis the UPR, it was formalized in 1991 and the equipment was tested the same year. Three months after the adoption of this standard, Qualcomm proposed another standard based on CDMA. In 1993, Qualcomm's CDMA-based mobile standard was modified and adopted by the TIA and the first system based on CDMA was tested in 1995, with commercial operations beginning in 1996. The IS-54 standard was also modified to a standard named IS-136 and released in 1996.

A few aspects of the US standardizing system are worth highlighting. The FCC believes in market-determined standards. Therefore, the TIA has approved both CDMA and TDMA proposals, subject to the satisfaction of performance requirements. The spectrum auction winners can deploy wireless networks with the technology of their choice, including GSM. Since there is no obligation to have US-earned revenues, America and European firms can participate equally. Finally, the voting process in the TIA is open to all members, with each member having only one vote. The votes are weighted at ETSI. *Ceteris paribus*, the policy of standards neutrality makes the US market more contestable. The large market size, combined with absence of local manufacturing requirements, probably allows various standards to co-exist without losing out on economies of scale.

The South Korean Experience: The Role of Industrial Policy[5]

When Korean firms and the Korean government considered development of the cellular phone system, the analog system (AMPS) was dominant in the US, while the GSM system was dominant in Europe. The Korean Ministry for Information and Telecommunications focused on the CDMA system that was emerging in the US due to the efforts of Qualcomm. The Korean government was interested in CDMA, mainly because of its efficiency in frequency utilization and higher quality and security in voice transmission. Korea concentrated on CDMA when there was great uncertainty about this technology. The Korean government also overruled the reservations expressed by telephone service providers and system manufacturers like Korea Telecom, Samsung and LG. The ministry, along with the Electronics and Telecommunications Research Institute (ETRI), decided to go along with CDMA. One of the reasons reported to be of main consideration was that if Korea only followed already-established TDMA (GSM), the gap between Korea and its forerunners would never be reduced, and thus catching-up would take even longer. Although the first CDMA test system was available only in 1995, the Korean government had declared the CDMA system development as a national project in 1989. In 1991, the contract to introduce the core technology and also to develop the system was signed with Qualcomm. In 1993, the ministry declared CDMA as the national standard. As of early 2000, Korea had more than 6 million CDMA subscribers. The success of this technology strategy is evident from the fact that Korean companies have 15–20 per cent of the US cellular handset market.

The 3G Standardization Process

The standard creation process for the third generation (3G) wireless communication technologies under the auspices of the International Telecommunications Union (ITU) has brought to the fore a variety of issues similar to the ones discussed earlier. Ten proposals were submitted, including two by TIA and ETSI. Obviously, TIA and ETSI proposed standards closer to the dominant standards in the two regions, CDMA in the US and GSM (WCDMA) in Europe. The proposals also led to a bitter feud between Ericsson and Qualcomm regarding CDMA patents, the latter accusing the former of infringement. The strategic intent of the firms was similar to that observed at the time of GSM standardization process, where many companies, especially Motorola, used their patent portfolios to their strategic advantage.

To push the essential elements of their proposals, ETSI and TIA initiated alliances.[6] The idea was to evolve a consensus around a set of standards and to harmonize their proposals. Interestingly, representatives from many countries were present in the two partnership projects, Japan and South Korea being the most noteworthy. The 'dual' memberships reflected the fact that many countries were not clear about which standard would emerge as the winner. ITU finally recommended five standards. These included WCDMA (also known as Universal Mobile Telecommunications System—UMTS) standards recommended by the ETSI-sponsored group (3GPP), CDMA2000 recommended by the TIA group (3GPP2), TDWCDMA, a standard proposed by China but close to the ETSI proposal and two other non-CDMA standards.

The choice of standards made by various countries is interesting. The European Union has mandated the use of WCDMA and two other standards that are compatible with existing GSM networks. In Japan, where a unique second-generation standard was used, the dominant players (NTT, DoCoMo) decided to adopt WCDMA to capture the world market of user–producer equipment. At the same time, they tried to protect the domestic market. Some smaller rivals (like, KDDI Corporation), however, opted for CDMA2000. South Korea, which had invested heavily into CDMA and related technologies, has decided to move into GSM-compatible (WCDMA) standards. Despite the heavy cost in the form of incompatibility with the existing infrastructure, Korean firms expect a larger and faster growing user base in GSM-compatible technologies. In any case, once the new investments are made, they would be well positioned to deal with both types of standards. While the Japanese and the Korean behaviour seems to be guided by the huge market for terminals and handheld devices that is likely to be generated by 3G networks, China has opted for a separate standard to benefit from a huge GSM market at home. The Chinese probably wish to leverage the scale economies in the home market to become an important player in the equipment and handheld markets at a subsequent stage. They have used the same strategy for several other electronic products.

Policy Options for India

When the Indian government opened mobile services for private participation in 1992, policy makers were significantly influenced by the spread of GSM in Europe. Consequently, the tender conditions specified that the digital mobile services should fully conform to GSM standards. The services were also to conform to system interworking and interface with the existing Public Switched Telephone Network (PSTN). However, the introduction of other standards was taken cognizance of when the tenders for the fourth licence were issued in 2001. By then, the tenders had become technology neutral. In spite of the shift to technology neutrality, it was unlikely that the licence winners would adopt any standard other than GSM. This was so because all the operators had already sunk in investments in GSM networks. Besides, they wanted to provide roaming facilities between circles they currently operated in and the circles where they were to start operations. This facility would not be possible if different standards were selected.

Given the fact that most mobile operators have sunk in their investments in the second-generation (2G) GSM networks, what options does India have vis-à-vis 3G standards? India seems to have lost out on the manufacturing of telecom equipment and the handset market. Nor is the country in a position to enter the components market in any significant manner. Therefore, strategies adopted by the players in Europe, US, Japan, South Korea and China to penetrate these markets is not very relevant for India. In fact, the bidding points allocated for the use of domestic equipment has been low (about 3 per cent) in the recent telecom-related bidding processes. This was presumably due to the inability of the Indian manufacturers to deliver the latest technologies (Singh 1999). This low weightage brought to an end the saga of domestic equipment manufacturing that had resulted in many controversies during the 1980s and delayed the entry of foreign equipment manufacturers.[7] Unlike China, India has failed to create a large base in telecom equipment manufacturing. There is still a potential to attract equipment/handset manufacturing firms to India to develop a manufacturing base. Equipment orders for the cellular industry were estimated to be worth $10 bn for the 1995–2005 period (Singh 1999: 186). While the rollout has been not as rapid as expected, India is by no means a small market. The current trends do not suggest any major improvement on the manufacturing front. Even if we are able to attract manufacturing-related FDI in telecom or become part of the global production networks of telecom equipment manufacturing, it does not seem desirable that we should get tied to specific telecom standards. While we need to make efforts to become part of the global production networks, given the technological uncertainties and other concerns, discussed later, it may be useful for India to keep its options open vis-à-vis telecom equipment manufacturing. A technologically diversified manufacturing base may be more useful for both hardware and software industries as Indian firms can be part of alliances to make software (embedded and others) for telecom equipment following different standards. A policy of neutral telecom standards makes sense at this stage from the perspective of broad-based learning through alliances and networks. A large and growing telecom market in India can support such a strategy without compromising economies of scale.

The other strategic concern identified in the earlier discussion relates to intellectual property rights (IPRs) that are relevant or essential for specific standards like GSM or CDMA. Unlike Motorola or Qualcomm, no Indian firm owns intellectual property that is important for specific standards.

Given these conditions, India's standards policy cannot be strategically based on the interests of the existing domestic manufacturers or IP holders. There is one segment, however, that can potentially benefit from the policy vis-à-vis telecommunications standards, and that is the IT sector. Many Indian IT firms can actively participate in the solutions business. In fact, some of them have been actively participating in ITU standard-setting fora, including those initiated by European and American interests, to get exposure and penetrate the market for solutions. The telecom software market is large and growing and this can be an important area of growth for the Indian IT industry. Moreover, the price of mobile telephony has been declining, and the population of mobile phones is now expected to have crossed the PC population. If the standards policy facilitates further reduction of these prices and enhances usage of low-cost access devices, R&D in areas of embedded software and mobile commerce can take place in the country. This in turn may enable software firms in India to tap these rapidly growing segments in the international markets. Given the scope for working with different standards, Indian firms may even be able to get IPRs in important sub-systems of different networks through developments in the solutions business.[8] Adherence to a single standard may reduce learning possibilities for IT firms and eventually result in some kind of a lock-in.

One could argue that persistence with GSM standards, instead of shifting to technology neutrality will reduce future uncertainty and enlarge the market faster. However, the supremacy of GSM and GSM-compatible standards like WCDMA has not yet been established. Some comparisons, in fact, show that CDMA technologies may be better (Ramadesikan and Basant 2001). Given this, and the fact that technologies are changing very rapidly, the possibility of regulatory failures is high. Therefore, technology neutrality seems justified. Technology neutrality vis-à-vis mobile standards (especially 3G) also seems desirable for a variety of reasons.[9]

Large volumes of GSM have been a major driver for declining costs of GSM-related equipment. Countries like Japan and South Korea that stayed away from GSM-compatible technologies will be present in the WCDMA market. There is, therefore, a possibility of WCDMA equipment and handset costs being lower than the other competing technologies. This is expected to benefit the existing GSM operators and enhance their user base. However, recent trends worldwide show that the transition from GSM to WCDMA has been rather slow. In fact, CDMA2000 is selling more handsets than WCDMA. This trend is expected to continue in the near future, giving economies of scale advantages to CDMA2000 instead of WCDMA. Even in Japan, where the dominant player had opted for WCDMA, the user base was only 127,400 in July 2002 as against the user base of 1.64 million of CDMA2000.[10]

Moreover, India is not entirely locked into the GSM legacy. Wireless in Local Loop (WLL) operators who have deployed the CDMA base for the local loop can eventually graduate to 3G standards by using CDMA-based advanced technologies. Thus, the existence of WLL CDMA provides an opportunity for CDMA2000 to be introduced in the country. Effectively, therefore, both GSM and non-GSM-based operators can compete to provide 3G services. This will enhance contestability in the market and avoid lock-in.[11] Given the possibilities of 'entry' into 3G services and the fact that the superiority of either of the two major standards is yet to be established, technology neutrality seems desirable. Besides, a new operator interested in rolling out 3G networks and services with other technologies is also possible in this scenario. If technological superiority and lower costs due to competition of CDMA-based equipment do not emerge as viable options, operators will automatically discard it.

Finally, it can also be argued that it is too early for India to start worrying about 3G standards, as we are yet to fully utilize the potential of the second-generation technology. Since applications for 3G that require high data speeds will take some time to develop, the need for 3G may not occur in India for a while. Besides, it is possible to enhance data speeds of the existing second-generation networks with some modifications.

Some Concluding Observations

Several characteristics of effective regulation have been identified in the literature. These include independence, accountability, transparency, fairness, simplicity, clarity, speed, consistency, etc. In general, the regulation relating to telecommunications standards also needs to satisfy these criteria. In addition, any regulation in the telecommunications sector also has to deal with technological convergence in this sector. Given the natural monopoly characteristics of telecommunications (especially local fixed) networks, ensuring effective competition in this segment has been an important regulatory problem. Since inter-network competition is difficult to obtain, the focus has been on fair access and reasonable interconnection arrangements. The emerging convergence in telecommunications technology may change this condition. Telecommunications networks that were highly differentiated in the services they previously delivered (for example, broadcasting versus voice technology) now deliver somewhat equivalent services. Different ways of providing the same type of services and the provision of totally new type of services are developing rapidly. These are changing the rules of competition; not only is the competition across networks emerging, with various networks becoming close substitutes, competition in service provision is also on the rise. Broadly, technological changes are leading to growing demand (especially of internet services), and innovations are significantly modifying the structural features of the telecom industry, with emerging convergence across fixed and mobile services and across the IT and media sectors.

What implications do these developments have for policy vis-à-vis standards? The final impact of the technology convergence is still largely unknown. Meanwhile, these developments cut across the existing set of regulatory rules and regulations challenging the conventional definitions of the telecom industry. In such a scenario, a heavy-handed and inconsistent regulation across different delivery mechanisms, arbitrary service classifications and narrow choices of standards can distort markets. If the regulation is unnecessarily restrictive, it may also result in economic inefficiency, with customers failing to get the full benefit of technological convergence.

While convergence is bringing different types of networks closer to equivalence, it is not making them the same, at least, not as yet. The particular points of bottleneck (for example, scarce resources like radio spectrum), incumbency dominance, natural monopoly in some elements in the local loop or the particular way customers are locked into specific network by their purchase of equipment, will continue to vary for economic and technical reasons. Broadly, issues relating to network interconnection will remain very significant in terms of policy, due to the persistence of (*a*) fixed costs of a subscriber being connected to a network (both for fixed and mobile networks); and (*b*) network externalities among subscribers. In other words, anti-competitive behaviour in terms of setting excessive access and interconnection charges will remain a reality and will have to be dealt with. The issue of standards would also have to be seen in this broader context. Insistence on narrow standards may create possibilities of anti-competitive situations. Given the technological uncertainties and convergence possibilities, it can also result in significant regulatory failure.

The problems associated with market and government failures have led to a rise in interest in functional standards. These include standards such as 'Open System Interconnection, which define performances to be achieved at different levels (or layers) of technological systems, but retain important degrees of freedom in deciding how the standards will be met' (OECD 1991: 7–8). The implementation of open standards, however, remains difficult, as with rapid technological change, two machines that satisfy functional standards may not be able to satisfy the need for inter-operability and compatibility (OECD 1991: 8). These two conditions, may therefore be an essential part of the acceptable standards, apart from performance requirements, so that the consumers can keep pace with the evolving technologies. One essential feature of the standardization processes needs to be the ability of one technology to interact with another. The Indian government and firms should participate in standard-creating procedures at the ITU and other fora to insist on more open standards and to gain exposure for entry/penetration in the solutions market.

The key need for the Indian economy is that the telecom infrastructure should grow rapidly. This requires, among other things, rapid decline in the cost of equipment. Recent reductions in customs duties on telecom equipment have already resulted in lower prices; the tariffs declined from over 40 per cent in 1997–98 to 5–15 per cent on various types of telecom equipment in 2001–02. In general, the prices of telecom equipment have been falling very rapidly in recent years.[12] Given the developments referred to earlier, a neutral standards policy with inter-operability and certain performance requirements is unlikely to create an upward pressure on price in the future. Costs are going to fall for all equipment using widely prevalent standards.

A rapid increase in telecom infrastructure and a decline in costs of mobile and other types of telephony will create new opportunities for IT firms in the solutions and embedded software business. E-governance can be given a boost, as more people would have access to low-cost internet connectivity. A large base would also boost the development of localized content, which in turn would increase usage and revenues of telephony (NASSCOM 2002: 85). This would not only lead to further price reductions, but also create the potential for growth and learning for the IT firms. Moreover, widespread use of mobile telephony may also facilitate the growth of the IT-enabled services (ITES) market. With a drastic fall in equipment prices, employees can be given access to mobile phones in case troubleshooting is required. This would enhance the quality of services and provide flexibility to ITES workers, especially women.[13] This is very important in the current context. Employment in ITES markets was estimated to be of the order of 106,200 in 2001–02 with a revenue stream of Rs 69.6 bn. The forecast is that this market can provide employment to about 1,100,000 persons in 2008 and generate revenues worth Rs 810 bn (NASSCOM 2002: 41). For this to happen, maintenance of high quality of services is critical. And access through mobile phones or other wireless devices can go a long way in ensuring quality in this industry.

The recent controversy around the provision of mobile services through WLL has created market uncertainty for GSM service providers and equipment manufacturers; but it has also added to the competition in the market. Apparently, a better allocation of spectrum can partly ameliorate the concerns of the GSM operators.[14] While this needs to be explored, it highlights a general issue vis-à-vis standardization. It has been found that dominant/formal standards obtain better terms (especially in Europe) in the allocation of radio frequency spectrum, network operator licensing practices, terminal equipment type approval rules and procurement rules. Thus, formal (globally dominant) standards have much higher chances of success. This leads to a strategic increase in the licensing fees for the essential IPRs (Bekkers et al. 2002). This, in turn, enhances costs of equipment. Indian policy makers should avoid such tendencies and lobby for the removal of such practices in other countries through international fora. After all, lower costs of equipment are what we are interested in.

Finally, there are problems specific to the Indian economy, or other similar economies, which may not be important for global R&D. Usually, market players are unwilling to experiment or deliberately search for information. Search for technology options other than those which are easily accessible, and which are known to be profitable elsewhere, is typically not done. If policy makers can facilitate and support such experimentation, especially for problems that are typical to one's economy, more information will get generated and choices of standards might be more rational. If such experiments succeed, local entities may be able to create standards for specialized problems and commercialize them in the domestic sphere and in other economies with similar problems.[15] Such experiments also have a potential of creating IPRs for domestic entities in small sub-systems of a network. The web flourished into a new medium on the basis of freely accessible communications standards of the internet. More recently, the wireless data technology, Wi-Fi, has been made possible because the US federal government decided to set aside a strip of unlicensed radio frequencies and allowed everyone who followed a simple set of rules to share these among themselves (Markoff 2002). Today, Wi-Fi has opened up a variety of options to reach inaccessible areas with a multitude of applications.

Researchers at the Indian Institute of Technology (IIT), Kanpur are working on Wi-Fi technologies to tackle the 'last mile' and other problems that confront countries like India. They may be able to come up with very interesting solutions as IIT, Chennai did with the corDECT technology. India's standards and spectrum allocation policies need to facilitate all such experiments and more to build domestic capabilities in these domains.

Notes

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1. This section draws extensively from Ramadesikan and Basant (2001).
2. The discussion on network externality builds on Liebowitz and Margolis (1994).
3. Earlier efforts for setting analog standards had failed due to these 'nationalist' tendencies shown by UK, France and Germany, while the Scandinavian countries were able to achieve common standards and were able to benefit from it. In fact, in 1985, Scandinavian firms (Nokia and Ericsson) controlled about one-fifth of the world market of mobile phones, when all other European manufacturers together held a share of less than 10 per cent.
4. Other Time Division Multiple Access (TDMA) standards (GSM is also a TDMA-based standard) had 81.3 million subscribers and Personal Digital Communications (PDC), a second-generation Japan-specific technology, had a base of only 54.7 million subscribers.
5. The discussion in this sub-section is based on Lee and Lim (2001).
6. The ETSI initiative was known as Third Generation Partnership Project (3GPP) and the one initiated by TIA was known as 3GPP2.
7. Singh (1999) provides an interesting account of how foreign equipment manufacturers were discriminated against during the phase when C-DOT was developing switches indigenously. While this experiment was immensely successful in developing small robust switches for Indian conditions, large switches could not be developed. During this period, C-DOT not only avoided any tie-ups with firms like Alcatel, AT&T and Philips, it scuttled DOT's attempts to join with multinationals to manufacture switches. It was only after liberalization initiatives were introduced in 1992 that five large foreign equity-owned joint ventures by AT&T, Siemens, Alcatel, Fujitsu and Ericsson were set up. Subsequently, 100 per cent ownership was allowed on a case-by-case basis.

8. We understand that something of this kind is already happening on a small scale and might increase with larger scales of operation.
9. Ramadesikan and Basant (2001) provide technical and other details.
10. The data on the CDMA2000 and WCDMA rollout given here is based on a press briefing by Irwin Jacobs, the Chief Executive of Qualcomm (Reuters, 4 September 2002). Qualcomm not only owns most of the patents for the CDMA technology standard, it also collects royalties from the usage of rival WCDMA technology.
11. Recent developments in the telecom market in India provide further support to this argument.
12. For example, prices of high-end routers came down from US$ 120,000 per OC-48 to about US$ 20,000 in 2003. Throughput costs per GBPS declined from US$ 210 in 1994 to US$ 4 in 2001 (NASSCOM 2002: 84).
13. We are thankful to Rekha Jain for pointing this out to us.
14. Thanks are due to Partha Mukhopadhyay for pointing this out to us.
15. This idea emerged from a discussion with Partha Mukhopadhyay.

References

Bekkers, R., B. Verspagen and J. Smits. 2002. 'Intellectual Property Rights and Standardisation: The Case of GSM', *Telecommunications Policy*, 26: 171–88.

Lee, K. and C. Lim. 2001. 'Catching-up and Leapfrogging: Findings from Korean Industries', *Research Policy*, 30: 459–83.

Liebowitz, S.J. and S.E. Margolis. 1994. 'Network Externality: An Uncommon Tragedy', *Journal of Economic Perspectives*, 8(2): 133–50.

Markoff, J. 2002. 'Business, Big and Small, Bet on Wireless Internet Access', *New York Times*, 18 November.

Morris, S. 2002. 'Competition, Regulation and Strategy in Industries with Consumer Side Scale and Scope Economies: An Essay in the Context of the Information Technology Industry', Working Paper No. 2002-07-04, Indian Institute of Management, Ahmedabad, India.

NASSCOM (National Association of Software and Service Companies). 2002. *The IT Industry in India: Strategic Review 2002*. New Delhi: NASSCOM.

OECD. 1991. *Information Technology Standards: The Economic Dimension*. Paris: OECD.

Ramadesikan, G.R. and R. Basant. 2001. 'Communication Standards Adoption: An Analytical Framework and Its Application to the Case of 3G Standards'. Centre for Telecom Policy Studies, Indian Institute of Management, Ahmedabad (Mimeograph).

Singh, J.P. 1999. *Leapfrogging Development? The Political Economy of Telecommunications Restructuring*. Albany, NY: State University of New York Press.

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Role of ICT in the Development of the Indian Stock Market

Meena Abraham Chacko

From the 1990s, the growth of information and communication technology (ICT) in India has been rapid and has played a transformative role in the economic, social, political and cultural spheres of life. This has spawned a growing interest in its nature and impact on these spheres. Rapid and significant developments in ICT from the second half of the last century have resulted in the internet becoming a critical platform for countries to become 'knowledge' or 'new' economies. There has been an increase in investments in information technology (IT), with the service sector being its biggest consumer. Within the service sector, finance, insurance and real estate are the major investors (Hobijn and Jovanovic 2000) in ICTs.

The intrinsic characteristics of ICTs explain their rapid adoption in the financial sector. The use of ICTs to transfer information across the world rapidly and easily leads to the reduction in costs of transaction and creates transparency in the business environment. Besides these, there are other economies of scope and spillover effects arising from the application of ICTs in the financial sector, which give various players a competitive edge in the industry.

In keeping with the worldwide trend, the Indian financial sector also saw the application of ICTs in its functioning. In 1994, ICTs were introduced in stock exchanges throughout the country as part of the reform process, with the objective of building a modern and efficient stock market. This paper examines the impact of the adoption of ICTs on the development and functioning of the Indian stock market. The paper is organized into three sections. The first discusses the diffusion of ICTs in the financial market from a global perspective. The next briefly outlines the growth and the structural weakness that prevailed in the Indian stock market prior to the policy reform and adoption of ICTs in the 1990s. The last section examines the trends in the market indicators in the post-computerization period in order to understand the impact of ICTs on the stock markets.

Diffusion of ICTs in the Financial Sector

ICTs have created paradigm shifts in the securities market operations. Stock exchanges all over the world have realized the potential of the new technologies and have moved on to electronic trading systems. The major changes that have swept the international financial markets since 1975 have been accelerated by the use of computers (Freund 1989). In the 1970s, the US began making changes in commission rates on stock transactions, and soon the New York Stock Exchange (NYSE) and other US markets opened their doors to new members. At about the same time, European, Japanese and US investors sought greater portfolio balance through international diversification. New York was the leader in attracting foreign investors and NYSE made significant progress towards becoming an open and competitive international market. Enormous strides were taken towards the computerization of trading systems in both financial markets and brokerage offices. In 1986, the London stock exchange went in for a dramatic deregulation—the 'Big Bang', and soon other European countries like Germany, France and others, where the markets had been slow for some time, followed suit. Tokyo, taking into consideration the changes occurring around the world, also embarked on a slow liberalization process of its market.

In the late 1980s, the developing countries also moved towards liberalization of stock markets as part of their reform programmes and attempted to attract foreign capital. The entry of foreign capital into stock markets was expected to 'improve efficiency of market through foreign competition and its technologies resulting in efficient allocating, risk sharing and monitoring the use of capital. Improvement in market efficiency through internationalization would improve liquidity and thus lower cost of capital further'(Kim and Singhal 1994). However, liberalization has been shown to sometimes result in uncertainty and instability of stock markets and even major financial crises (Singh and Weisse 1998) due to volatile capital flows and stock prices. Further, the speed and scale of stock transmission between markets can also increase enormously due to technological advances in trading and settlement (Fitzgerald 1999). Thus, besides the paradoxical scenario characterizing portfolio investments, the adoption of ICTs raises another issue affecting the stability of emerging economy stock markets. This is examined below, taking the Indian stock market as a case.

Electronic Trading System

The electronic trading system (ETS) pioneered by the US plays a critical role in stock trading. An ETS is a set of computer terminals connected via high-speed communication lines to a central host computer. It involves the use of the internet as the medium to communicate orders to the exchange through the broker's website. Bids (buying), offers (selling) and trade requests can be entered from even remote terminals. Once a trade is done, confirmation is almost instantaneous and reported immediately to the investor. Computerized order routing and trading has not only enhanced the efficiency of order execution but also led to the development of new products and trading techniques. The ETS was employed in some instances to replace and in others to complement traditional physical open outcry markets (floor trading). Different markets adopted different models of computerization (Amihud and Mendelson 1988).

An analysis of country-wise experience of ETS shows interesting results. In the US, about 30 per cent of retail securities trades were done online in 2000. However, the highest online stock trading in the world, as of end-July 2000, was in South Korea where the value of online stock trading captured 61 per cent of the total stock trading value. Germany had the largest number of internet brokerage accounts, and Finland and Sweden reported the highest online transaction levels, also being among the countries with the highest levels of internet banking and broking penetration in the world (*Investor Digest* 2000).

There are numerous reasons that computerization is now widely prevalent in the bigger stock markets. First, there is the flexibility factor. With automated trading, investors can transact in securities directly, track investment and access research/investment advice, transact with other markets (cross-border trading) and manage portfolios. Another reason is speed: securities transactions can be done instantaneously and confirmation of trades is immediate, once trade is matched. Thus, with faster transactions, one can expect trade volumes to increase. Accessibility to the market is also enhanced: an investor is able to access the market from anywhere in the world as long as s/he is connected to the internet. Transactions in multiple markets are made possible, which can further increase trading activity and expand the population of the 'global' investor group. In a liberalized brokerage commission environment, transaction charges for trades through the internet are generally lower than for conventional trading, due to the reduced level of intermediation by brokers. With lower transaction costs, trading activity can also be expected to increase, which in turn would increase the volume of trade.

ETS versus Floor Trading The introduction of ETS led to considerable debate centred around the efficiency of computerized execution versus floor trading with respect to the availability of information, efficiency of the market in terms of price setting and the amount of liquidity available under the two systems. As noted earlier, ETS is flexible in terms of trade, facilitates faster transaction, provides more accessiblilty, reduces transaction costs, and thus, contributes to increased trading.

At the same time, critics point out that ETS cannot 'capture the features that account for its success (that of floor-based trading) and liquidity' (Massimb and Phelps 1994). Sato (1992) argues that liquidity suffers under computerization because order flows are partly the result of human interactions on the trading floor. He warns that ETS can lead to higher volatility due to overshooting or undershooting because traders using screens do not understand the reasons for price movements as well as the traders on a trading floor do. Several studies have been carried out to examine the effects of ETS and floor trading on stock markets. In a study of mechanics and operational efficiency of three computerized trading systems in North American stock markets, Domowitz (1990) found that computerized markets offer better trader's profits than floor trading and also better price discovery. Massimb and Phelps (1994), however, observed that electronic markets are less liquid than physical trading for reasons pointed out by Sato. Freund and Pagano (2000) have studied the effect of ETS on the efficiency of share pricing of the NYSE and Toronto Stock Exchange (TSE). They concluded that both markets are efficient in a 'weak form'. They have also compared the relative efficiency of the two stock exchanges. Naidu and Rozeff (1994) found that liquidity and volume increased after the computerization of the Singapore stock exchange, and so did volatility in returns. Shah and Thomas (1996) have studied the effects of computerization and competition on the market characteristics of the Bombay Stock Exchange (BSE) in relation to the National Stock Exchange (NSE), Mumbai, and have reached conclusions quite similar to Naidu and Rozeff's results.

Role of ICTs in the Indian Stock Market

In this section, I have examined the role of ICTs in the development of the stock market. The study begins with a brief sketch of the growth of the stock market, including a discussion of the weakness of exchanges along with its probable causes, and highlights how the adoption of ICTs can contribute to the efficient functioning of the market. As a corollary, various regulatory measures are reviewed and their concomitance to advancements of ICTs is discussed. Finally, the influence of ICTs on select market outcomes is pointed out.

Growth

The Bombay Stock Exchange (BSE) is one of the oldest stock exchanges in India, which began functioning in the late nineteenth century. Over the years, the number of stock exchanges in the country grew. In the post-Independence era, the stock market passed through varying phases of development. In the initial years following Independence, the demand for long-term funds was not significant, due to the weak industrial base and the low savings rate. The greater thrust on industries should have increased the role of the stock market in the 1960s and 1970s, but the government-controlled banking system which played a fundamental role in financing investment (Rajakumar 2001), proved to be a hindrance.

Hence, the stock market played a limited role in the mobilization of resources until the 1980s, when its scope both widened and deepened through rapid increases in the number of stock exchanges, listed companies and their market capitalization. The stock market's role in the Indian financial system was therefore transformed from a peripheral to a central one. The methods of transacting business, attitude of stockbrokers and infrastructure of the stock markets were however seen to be antiquated (Misra 1997). This was an impediment to the operational efficiency and fair dealings in stock trading. Therefore, in 1991, the government initiated policy reforms with the objective of building a modern efficient capital market in the country. The large-scale irregularities in securities transaction in 1992 provided further impetus for market reform. The process of change has been gradual and the new system has evolved over the years.

Structural Weakness Prior to 1992

BSE was the dominant and central exchange—the hub of more than 20 stock exchanges in India. Most of the exchanges were an association of brokers protected by high entry barriers, which resulted in elevated costs of intermediation. Membership was limited to individuals and limited liability firms could not become brokerage firms. This was an important factor underlying the structural weaknesses experienced by the Indian stock market. It affected not only trading activities, but also the clearing and settlement systems of the markets.

Trading Securities trading in the Indian stock markets occurred through the floor-based 'open outcry' system. Access to markets was only through registered brokers. It was routine for brokers to charge investors a price that was different from that actually transacted at. In fact, the normal market practice involved brokers charging users a single consolidated price, instead of unbundling the trade price and the brokerage fee. Further, since there was no price–time priority, the investors were not assured that a trade was executed at the best possible price.

Markets outside Mumbai (erstwhile Bombay) had prices that were often quite different from those in the city, and these pricing errors served as a barrier to any increase in order flow to these markets. Retail investors, particularly from outside Mumbai, accessed the city's market through a chain of intermediaries called sub-brokers. Each sub-broker in the chain introduced a mark-up on the price and it was not uncommon for investors in small towns to face up to four intermediaries with mark-ups in excess of 10 per cent of the actual trade price. Several manipulative practices were prevalent which landed the external users of a market at the losing end of price movements. Moreover, since the governance of the exchange was with BSE brokers, the quality of enforcement undertaken against errant brokers was limited.

The findings of a study by L.C. Gupta (1992) on Indian exchanges give a clear picture of the situation in the late 1980s, which was characteristic of 'wild speculation'. This was highlighted by (*a*) extremely high concentration of the market's activity in a handful of shares to the neglect of the remaining shares; (*b*) very high trading velocities (four to seven times) of the 'speculative counters'. Trading in Mumbai was concentrated in a small fringe of the market. The top five shares in terms of trading volume on BSE accounted for as much as 40.9 per cent of the entire trading volume in BSE, and the top 50 shares had a trading volume of 82.1 per cent. The trading volume outside these shares was so deficient that their average trading velocity was only 0.19. About 80 per cent of the shares listed on the BSE were solid in various degrees. Another measure of speculative trading is the extent of share transfers registered by companies. Analysis of trading data of the BSE showed that 65 per cent of the trades were offset within the same settlement period which comprised a fortnight, 25 per cent were carried forward to the next settlement and only 10 per cent or even less resulted in actual delivery. Thus, though BSE had high daily trading volume in terms of number of transactions and value, it did not represent a liquid market but a speculative one.

Clearing System The efficiencies of the exchange's clearing house only applied to the largest 100 stocks. For other stocks, clearing and settlement were done bilaterally, which introduced further inefficiencies and costs. The market practice of *badla* (carry-forward system) was fraught with counter-party risk. Normally, collateral (margin) requirements are used to ensure capital adequacy and to reduce the fragility of the clearing system, but here the incumbent margin system suffered from serious deficiencies. Not only did the margins frequently fail to match the risk from price volatility, but evasion of margins was also common. Their entirely discretionary nature provided room for laxity in a broker-dominated management of Indian exchanges. The BSE clearing house functioned on a best-efforts basis—if shares or funds appeared at one end, they would be delivered to the other; the clearing house itself took no interest in measuring and containing counter-party risk. Problems of partial or delayed payments took place on every settlement, and major crises, which required closing down the exchange while a compromise was worked out, took place once every two or three years.

Settlement The final stage of the trade was physical settlement, where share certificates in physical form were used. This was intrinsically vulnerable to theft, counterfeiting, inaccurate signature verification, administrative inefficiencies and a variety of other malpractices. Involuntary and deliberate delays in settlement could take place both at the BSE and at the firm. Many firms used the power of delaying settlement as a tool to support manipulation of their own stock prices. The settlement period on most exchanges was usually two weeks. Open positions on the expiry date were supposed to go into actual settlement, where funds and securities were exchanged. In practice, there was little discipline in ensuring a reliable fortnightly settlement cycle. Investors were exposed to greater risk of default on the part of intermediaries because payment and delivery were not simultaneous. The investors made full or part payment while placing orders with their brokers, but could receive securities two or even three months later. Investors and even brokers of smaller stock exchanges experienced delays of more than two to three months or even longer in receiving payments/deliveries when a transaction was executed on the BSE.

Reform in Indian Stock Exchanges in the 1990s

In the early 1990s, it was realized that these structural weaknesses had to be eliminated for the organized development of the stock market and this depended on improvements in market mechanisms. Thus, the market regulatory structure was overhauled in 1992, with most of the powers for regulating the capital market being vested in the Securities and Exchange Board of India (SEBI). The new regulatory body was given the responsibility of (*a*) protecting the interests of investors in securities; (*b*) promoting the development of the securities market; and (*c*) regulating the securities market. The process of securities market reforms covered all these aspects. The principal focus of the activities was on improving the disclosure standards and simplification of procedures for public and rights offerings, strengthening the market infrastructure, including computerization of every segment of the market, improvement in market transparency and protection of market integrity, and strong enforcement action.

Special efforts were undertaken to make markets more modern in terms of infrastructure, practices and attitudes. Measures were also adopted to maintain the safety and integrity of markets. A comprehensive system of margins and other steps taken to reduce settlement risks helped the process. Clearing and settlement systems also improved significantly. These measures combined with surveillance and effective implementation of regulations of these areas helped in fostering the confidence of domestic and foreign investors. SEBI encouraged stock exchanges to become effective as self-regulatory organizations. In the primary market, reforms included restructuring of pricing norms, information disclosure and the costs of raising capital. The market intermediaries were also subject to some major reforms, such as changing membership norms, market surveillance and risk management. Policies to prevent fraudulent trade practices were made more stringent. Reforms of the clearing and settlement systems were also initiated by focusing on reforming carry-forward trades and trading cycles. Another major change was the opening up of the Indian stock market to foreign institutional investment (FII) and mutual funds, domestic and foreign. To achieve its objectives and to avoid being constrained by the limitations of physical infrastructure, electronic trading was introduced in the stock exchanges. As mentioned earlier, policies were reviewed annually and appropriate changes made. These changes were made with a view to bringing about a major transformation in the design of the Indian stock market for greater efficiency, liquidity and transparency.

Computerization It was noted that introduction of electronic trading was an integral component of the overall reform measures initiated by SEBI. The National Stock Exchange was the first exchange to commence screen-based trading (SBT) in the Indian capital market. NSE started trading debt instruments in June 1994 and equity in November 1994. In March 1995, BSE shifted from trading based on open outcry system to SBT.[1] All other exchanges also gradually shifted to this kind of trading.

In an online fully automated SBT system, a member need only punch into the computer the quantity and price of the securities s/he wishes to transact in and the transactions get executed as soon as a matching sale or buy order is found from a counter party. SBT systems electronically match orders on a strict price/time priority and hence cut down on time, cost and risk of error, as well as on fraud. This allows a faster incorporation of price sensitive information into prevailing prices and thus increases the informational efficiency of markets. The system also enables market participants to see the full market on a real-time basis, making the market transparent, and also making it possible for a large number of participants, irrespective of their geographical locations, to trade with one another simultaneously, improving the depth and liquidity of the market. It provides full anonymity by accepting orders from members without revealing their identity, and also a perfect audit trail, which helps resolve disputes, since the entire trade execution process has been logged in. Technology was used to provide a trading platform to the premises of brokers and later even to the residences of investors through the internet and to hand-held devices of mobile investors. As of date, all exchanges in India are fully computerized and offer online trading.

Trading Mechanism With the introduction of the new technology, the authorities also brought in policy changes in the trading cycle. Earlier, the trading cycle varied from 14 to 30 days or longer, providing incentives for either party to default on its promise. In order to reduce the uncertainty created by these prolonged open positions, the trading cycle was shortened over a period of time to a week, and it also became mandatory for all exchanges to follow a uniform cycle.

Clearing System The fact that an anonymous electronic order book ushered in by the market did not allow members to assess credit risk of the counter-party necessitated some innovation in this area. To effectively address this issue, the concept of a novation was introduced where the clearing corporation adopts legal responsibility for the net settlement obligations of each clearing member. If either A or B defaulted, the clearing corporation would meet the obligation for the other leg of the trade. Thus, every trade that took place would be freed from the risk of counter-party defaulting. SEBI directed stock exchanges to establish a clearing house, a clearing corporation or a trade/settlement guarantee fund to improve their clearing mechanisms. A clearing corporation or settlement fund was a precondition for granting approval to the expansion of training terminals of any exchange outside the city limits.

The NSE set up the National Securities Clearing Corporation Ltd (NSCCL), which acts as a counter-party to every trade executed on the capital market segment of the exchange. This has helped streamline the clearing system. SEBI also gave 'in-principle' approval to the BSE for its trade/settlement guarantee fund. This automatically ended the risk of cascading failures generating a payments crisis.

Settlement System Settlement in Indian stock markets has also suffered from several bottlenecks in the face of expanding volumes. Because clearing and settlement infrastructure in the stock exchanges has not kept pace with the paper work, the exchanges have been unable to shorten settlement cycles or to move to rolling settlements, both of which are essential for reducing settlement risk and are a feature of all modern markets. Recognizing the far-reaching benefits that would accrue to the market through the removal of physical securities, SEBI moved towards the dematerialization process by setting up depositories following the promulgation of the Depositories Ordinance. A depository is an institution which maintains electronic records of ownership of shares. This dematerialization of securities and transfer of securities through electronic book entry helps to reduce risks. The storage and handling of certificates are hence immediately eliminated. Further, criminal activities like counterfeiting and theft of certificates become impossible once a depository is operational. India's first depository, the National Securities Depository Ltd (NSDL), was inaugurated in 1996 and the second depository is the Central Depository Services Ltd (CDSL).

SEBI introduced some degree of compulsion in trading and settlement of select securities in a dematerialized form. Therefore, the process has progressed at a fast pace and gained acceptance amongst participants in the market. It is expected that as the network of depositories expands and the proportion of securities in depositories increases, these benefits would extend to the vast majority of market participants. Dematerialization of securities is one of the major steps for improving and modernizing markets, enhancing the level of investor protection through elimination of bad deliveries and forgery of shares, and expediting the transfer of shares. A positive development in the operations of the stock market has been the decline in the ratio of bad deliveries to net deliveries. The measures taken by SEBI through the issue of guidelines for deliveries and the setting up of complaint cells for bad deliveries at stock exchanges have contributed to the improvement of the system. This is believed to lead to improved investor protection and service, reduced risk and lower transaction costs. Dematerialization of shares has become popular with the investors as well as the companies, as technological progress has become a part of stock markets in India.

The clearing and settlement agencies operate two major types of settlement: account period settlement and rolling settlement. Under account period settlement, trades accumulate over a trading period of five working days and at the end of the period, these are clubbed together, positions netted and the balance settled about a week after the end of the trading period. Under rolling settlement, all trades executed on a trading day are settled 'X' days later. This is called 'T+X' rolling settlement where 'T' is the trade date and 'X' is the number of business days after the date on which settlement has taken place. Currently, most shares have been incorporated under rolling settlement.

Risk Management and Surveillance To prevent market failures and protect investors, exchanges have put in place a comprehensive risk management system, which is constantly monitored and upgraded. The risk management process encompasses capital adequacy of members, adequate margin requirements, limits on exposure and turnover, indemnity insurance, online position monitoring, automatic disablement, etc. Counter-party risk is guaranteed through a fine-tuned risk management system and an innovative method of online position monitoring and automatic disablement. A large Settlement Guarantee Fund provides the cushion for any residual risk. The exchanges strictly monitor each trading member's open interest or exposure on a real-time basis, and as soon as a specified limit is crossed, all terminals are automatically disabled.

The stock exchanges also administer an efficient market surveillance system to curb excessive volatility, and to detect and prevent price manipulations. The trading terminals of the SBT systems of Mumbai and NSE were installed in SEBI for monitoring abnormal movements in prices. To assist market participants to manage risks through hedging, speculation and arbitrage, the Securities Contracts (Regulation) Act SCRA was amended in 1995 to lift the ban on options in securities. The SCRA was again amended in 1999 to expand the definition of securities to include derivatives so that the regulatory framework governing trading of securities could apply to the trading of derivatives. Derivative trading took off in June 2000 on the two national exchanges.

With the improvement in disclosure norms, automation of the stock exchanges, and the easing of clearing and settlement difficulties with the setting up of depositories, Indian stock markets have embarked on a move to becoming more transparent and efficient. There will thus be improved investor protection and service.

Assessment of Reforms and Computerization: Market Outcomes

As discussed earlier, the reforms implemented covered all functional areas of the stock exchange. The adoption of ICTs was critical in the entire process of promoting an orderly development of these exchanges. In this section, we examine the effect of ICT adoption on different functions of the stock exchange, namely, trading, clearing, settlement, risk management and surveillance systems. Screen-based trading was introduced in India in 1994 in the NSE and the other exchanges also adopted it soon after, so 1994–95 is taken as the starting year of the study.

Trading

ETS ETS improves market accessibility which is, in turn, supposed to increase trade volume and liquidity. It also results in the reduction of transaction costs. Some studies have reported an increase in volatility.

Turnover and Liquidity Growth in terms of volumes traded indicates the huge success of the market reforms. Trading volume at the stock exchanges has been witnessing phenomenonal growth from the mid-1990s, as is evident from the figures given in Table 10.1.

The turnover ratio that reflects the volume of trading in relation to the size of the market (market capitalization) has been increasing by leaps and bounds after the advent of screen-based trading.[2] It increased from 34 per cent in 1994–95 to 375 per cent in 2000–01, which was one of the highest in the world. The increase in turnover has not been uniform across exchanges. Only three exchanges, NSE, BSE and the Ahmedabad stock exchanges improved their market share. The increase in turnover took place at the big stock exchanges and it was mostly at the cost of the small exchanges. The top six exchanges accounted for 99 per cent of turnover. NSE was the market leader with 85 per cent of total turnover market share in 2002–03. NSE even reported higher turnover from its trading terminals in most of the cities than the corresponding regional exchange (SEBI). This is the direct impact of ICT, which provided access to national-level markets like NSE and BSE that are more liquid than regional stock exchanges.

TABLE 10.1 Secondary Market: Selected Indicators

	Capital Market Segment of all Stock Exchanges				
Year	*No. of Brokers*	*No. of Listed Companies*	*Market Capitalization*	*Traded Volume*	*Turnover Ratio (%)*
1994–95	6,711	9,077	473,349	162,905	34.4
1995–96	8,476	9,100	572,257	227,368	39.7
1996–97	8,867	9,890	488,332	646,116	132.3
1997–98	9,005	9,833	589,816	908,681	154.1
1998–99	9,069	9,877	574,064	1,023,382	178.3
1999–2000	9,192	9,871	1,192,630	2,067,031	173.3
2000–01	9,792	9,922	768,863	2,880,990	374.7
2001–02	9,687	9,644	749,248	895,826	119.6
2002–03	9,519	9,413	6,319,212	9,689,098	153.3

Source: RBI 1999–2000.

Although the upward trend in the turnover ratio indicates improvement in market liquidity, trading continues to be concentrated, and particularly so in comparison to that in other comparable markets (see Table 10.2). Market capitalization in the 10 largest index stocks led to their holding 43.3 per cent of shares in 2002. This percentage was lower in 2000 but increased over the next two years and was almost at par with the market shares observed in other Asian countries, such as South Korea and Thailand. However, the 10 most active securities accounted for 49.6 per cent of turnover in India, which shows higher concentration in the Indian market compared to other Asian countries.

TABLE 10.2 **Market Concentration in Emerging Asian Markets (End 2002)**

	Index Stock's Share		*Share of 10 Largest Index Stocks in Market Capitalization*	*Share of 10 Most Active Stocks in Turnover*
	Market Capitalization	*Turnover*		
China	55.5	38.6	26.6	10.9
Thailand	66.7	54.9	41.0	27.8
Taiwan	63.8	58.7	30.9	22.2
Korea	82.7	59.0	47.8	25.1
Malaysia	73.6	67.0	34.6	28.4
India	76.4	72.8	43.3	49.6

Source: Standard & Poor 2002–03, here 2003.

It has also been observed that many of the securities listed in stock exchanges are not traded at all in the market. This trend can be seen in Table 10.3, which shows the percentage of traded companies to listed companies in the BSE. The number of listed companies increased between 1999–2000 and 2000–01, but the number of companies being actively traded in the market declined. This suggests that the trading concentration in the stock market has been increasing steadily. Thus, though the adoption of ICTs has facilitated increased volumes of trade, the activity has been concentrated in a limited number of securities.

Transaction Costs To a large extent, liquidity depends on transaction costs. The lower the transaction cost, the lower is the bid-ask spread and higher the volumes. The transaction cost is a sum of trading, clearing and settlement fees, it came down quite substantially in 1999 compared to 1994 (Table 10.4). Following the new regulation, an increasing number of scrips are being traded in dematerialized form and instances of bad delivery have come down substantially. Increasing competition has also put pressure on trading costs. To a large extent, these new outcomes were facilitated by the implementation of ICTs.

TABLE 10.3 **Share of Traded Companies to Listed Companies on the BSE**

(Rs bn)

	Companies Listed			*Companies Traded*			*% Traded*		
Month	*1999–2000*	*2000–01*	*2002–03*	*1999–2000*	*2000–01*	*2002–03*	*1999–2000*	*2000–01*	*2002–03*
April	73.83	81.03	73.94	27.19	27.13	20.97	36.83	33.48	28.36
May	74.38	82.73	74.58	26.31	26.43	21.18	35.37	31.94	28.40
June	74.72	83.68	75.79	26.42	26.47	22.40	35.36	31.63	29.56
July	75.06	84.75	73.19	28.55	26.33	23.63	38.04	31.06	32.29
Aug.	75.49	85.88	73.24	29.64	26.05	23.04	39.26	30.33	31.46
Sept.	75.84	87.82	73.27	29.92	25.71	22.63	39.45	29.27	30.87
Oct.	76.50	89.63	72.78	31.71	24.16	22.25	41.45	26.95	30.51
Nov.	77.25	91.95	72.73	30.30	24.94	22.42	39.22	27.12	30.83
Dec.	78.45	93.94	72.79	33.47	25.35	23.07	42.66	26.98	31.69
Jan.	78.45	95.69	74.03	33.76	25.88	23.11	43.03	27.04	33.03
Feb.	79.66	96.90	73.55	32.85	25.94	22.21	41.24	26.76	41.24
Mar.	80.27	98.10	73.63	33.18	25.98	21.91	41.34	26.48	41.34

Source: NSE, *ISMR*, various issues.

TABLE 10.4 Trends in Transaction Cost in the Indian Stock Market

Transaction Cost	*1994*	*1999*	*Global Best*
Trading (%)			
Fees	2.5	0.25	0.2
Impact Cost	0.7	0.25	0.2
Clearing			
Counter-party Risk	Present	Nil	Nil
Settlement (%)			
Paperwork	0.7	0.1	0.0
Bad Delivery	0.5	0.0	0.0
Stamp Duty	0.2	0.0	0.0

Source: NSE, *ISMR* 2001.

Clearing and Settlement

The reform of the clearing system has resulted in the market having full confidence that settlements will take place in time and will be completed irrespective of default by isolated trading members. The Depositories Act has also helped improve the settlement system with the dematerialization of shares. Three benchmarks are available to evaluate the efficiency of settlements, namely, settlement, safekeeping and operational risk.

The settlement benchmark compares settlement efficiency of different markets and tracks the evolution of settlement performance of individual markets by incorporating four components which reflect overall cost to market participants of failed trades. These include the average trade size, local market interest rates, the proportion of trades that fail, and the length of time for which they fail. The safekeeping benchmark provides efficiency to the market in terms of collection of dividends and interest, reclamation of excess withheld taxes, and protection of rights in the event of corporate action. The operational risk benchmark takes into consideration settlement and safekeeping, and other operational factors such as the complexity and effectiveness of the regulatory and legal structures of the market and counter-party risk.

From the mid-1990s, the clearing and settlement mechanism in India has improved considerably. The figures in Table 10.5 give an indication of the level of post-trade efficiency in securities markets. The settlement performance improved from 8.3 in 1994 to 59.6 in 2000 and 89.3 in 2002, on a score of 100. There was improvement in dematerialized settlement as well, which accounted for 98 per cent of total delivery-based settlement in value terms in 2000–01 and 99.8 per cent in June 2001(SEBI 2002).

TABLE 10.5 **India: Benchmarks of Settlement Efficiency (score out of 100)**

Benchmark	*1994*	*1998*	*1999*	*2000*	*2001*	*2002*
Settlement	8.3	10.0	41.9	59.6	75.8	89.3
Safekeeping	71.8	69.7	78.1	81.8	86.7	89.7
Operational Risk	28.0	47.3	43.6	51.4	59.1	65.2

Source: Standard & Poor 2002–03, here 2002.

There has been substantial reduction in short and bad deliveries since physical shares have been replaced by electronic ownership of shares. The ratio of bad deliveries to net deliveries progressively declined to being almost negligible in 2000–01(SEBI 2002).

Risk Management and Market Surveillance

Risk management and market surveillance play a key role in ensuring stability and integrity of the markets. SEBI keeps a proactive oversight on the surveillance activities of stock exchanges. The stock exchanges administer trade halts, impose price bands, deactivate brokers' trading terminals and suspend trading in scrips wherever required. The exchanges have developed and implemented an online market monitoring and surveillance system on the basis of basic parameters specified by SEBI. Major exchanges have implemented real-time alert generation systems at a basic level. The introduction of ICTs and appropriate surveillance policies has enhanced risk management capabilities of stock exchanges.

Role of ICT in the Indian Stock Exchange: An Evaluation

The survey of market outcomes of the Indian stock market after computerization has provided some interesting results. The growth in trading volume has been substantial. The clearing system has been modified to guarantee risks arising in the trading process. Payments and delivery are being more efficiently carried out. The dematerialized settlement system with its uniform trading cycle has reduced the number of bad deliveries, fraud and theft, apart from reducing the transaction costs.

However, it is not clear how much of this success can be attributed to the employment of ICTs, in view of the influence of other factors such as regulatory changes and increased flow of foreign investment. While a part of market outcome, desired for an orderly development of the stock market, has largely been achieved through the adoption of ICTs, we still need to isolate their effects from those of other new regulatory measures initiated simultaneously. It may be noted that many earlier empirical studies on the impact of stock market computerisation have showed mixed evidence regarding trading volume, volatility and efficiency, because of the difficulty in separating the effect of computerization from the influence of other factors. This exercise falls outside the scope of this study, and one might conclude by pointing out that a great deal of regulatory measures implemented currently is the direct offshoot of advancements in the arena of ICT.

Another point that needs to be highlighted is that while there has been a surge in the turnover ratio during the post-computerization period, trading tends to be concentrated in a few shares. This suggests that though the introduction of new technologies has increased trade volumes in select securities, they have not had much of an impact in making trading more broad based. A major portion of the market remains solid. Volatility in the market is still present. Price rigging and manipulation was seen to be prevalent, despite improved risk management and surveillance systems. This prompts one to raise the question of whether computerization can by itself help achieve an efficient stock market. Amihud et al. (1985) point out that '. . . with respect to each of these issues,[3] regulators will be challenged to specify appropriately the rules of the game . . . . To achieve the best possible trading system for financial markets we need discretionary planning'.

Notes

1. BSE (BOLT) has 7,400 trading terminals in 375 cities.
2. The indicators studied here can also be influenced by the entry of institutional investment, especially FII, which have not been taken into consideration here. It is true that the increase in volumes, liquidity and volatility can be the effect of

either FIIs or electronic trading. Both FIIs and electronic trading have dictated trade at specific periods of time, but without SBT high volumes could not have been achieved because of the infrastructural bottlenecks that would have crippled the exchange.

3. They refer to the major design issues such as order exposure rules, electronic trading, competition with international markets and the introduction of new financial instruments.

References

Amihud, Y. and H. Mendelson. 1988. 'Liquidity, Volatility and Exchange Automation,' *Journal of Accounting, Auditing and Finance*, 3, (Fall): 369–95.

Amihud, Y., Thomas Ho and R.A. Schwartz. 1985. 'Overview of the Changing Securities Markets', in *Market Making and the Changing Structure of the Securities Industry*. Lexington Books: Lexington, MA.

Domowitz, Ian. 1990. 'The Mechanics of Automated Trade Execution Systems', *Journal of Financial Intermediation*, 1: 167–94.

Freund, William C. 1989. 'Electronic Trading and Linkages in International Equity Markets', *Financial Analysts Journal*, May–June: 10–15.

Freund, William C. and Michael S. Pagano. 2000. 'Market Efficiency in Specialists Markets Before and After Automation', *The Financial Review*, 35: 79–104.

Fitzgerald, E.V.K. 1999. 'Policy Issues in Market Based and Non Market Based Measures to Control The Volatility of Portfolio Investment', Working Paper No. 129, QEH, International Development Centre.

Gupta, L.C. 1992. *Stock Exchange Trading in India: Agenda for Reform*. New Delhi: Society for Capital Market Research and Development.

Hobijn, Bart and Boyan Jovanovic. 2000. 'The Information Technology Revolution and the Stock Market: Evidence', NBER Working Paper No. 7684. Cambridge, MA: National Bureau of Economic Research.

Investor Digest (Malaysia). 2000. 'Trading Shares in Cyber Space', EBSCO, http://search.epnet.com/login, accessed on 16 October.

Kim, Han and Vijay Singhal. 1994. 'Opening up of Stockmarkets by Emerging Economies: Effect on Portfolio Flows & Volatility of Stock Prices', World Bank Discussion Paper. Washington, DC: World Bank.

Massimb, Marcel N. and Bruce D. Phelps. 1994. 'Electronic Trading, Market Structure and Liquidity', *Financial Analysts Journal*, Jan–Feb: 39–48.

Misra, B.M. 1997. 'Fifty Years of the Indian Capital Market: 1947–97', *RBI Occasional Papers*, 18(2–3).

Naidu, G.N. and Michael S. Rozeff. 1994. 'Volume, Volatility, Liquidity and Efficiency of the Singapore Stock Exchange Before and After Automation', *Pacific-Basin Finance Journal*, 2: 23–42.

NSE. Various issues. *Indian Securities Market: A Review* (*ISMR*). Mumbai: National Stock Exchange of India Ltd.

Rajakumar, J.D. 2001. 'Financing Patterns and Investment: A Study of the Private Corporate Sector in India' unpublished Ph.D. Thesis submitted to Jawaharlal Nehru University, New Delhi. Thiruvananthapuram: Centre for Development Studies.

RBI (Reserve Bank of India). 1999–2000. *Report on Currency and Finance*. Mumbai. RBI.

Sato, M. 1992. 'Tokyo Equity Market—Its Development and Policies', in S.G. Rhee and R.P. Chang (eds), *Pacific Basin Capital Markets Research*, vol. III. Amsterdam: North Holland.

SEBI (Securities and Exchange Board of India). 1995–96 to 2001–02. *Annual Report*. Mumbai: SEBI.

Singh, Ajit and B.A. Weisse. 1998. 'Emerging Stock Markets, Portfolio Capital Flows and Long-term Economic Growth: Micro and Macroeconomic Perspectives', *World Development*, 26(4): 607–21.

Standard & Poor. 2002–03. *Emerging Stock Market Factbook*. Washington, DC: International Finance Corporation.

Shah, Ajay. 1999. 'Institutional Change in India's Capital Markets', *Economic and Political Weekly,* 34(3–4):183–94.

Shah, Ajay and S. Thomas. 1996. *How Automation and Competition Changed the BSE*, Technical Report. Mumbai: Centre for Monitoring Indian Economy.

11

E-Business, Entrepreneurship and Organizational Restructuring: Evidence from Indian Firms

Kaushalesh Lal

Introduction

As argued by proponents of globalization, the integration of economies has led to a faster diffusion of the latest technological developments in developing countries. In the 1990s, technological development has been largely led by information and communication technologies (ICTs). The diffusion of ICTs across countries in general and developing countries in particular has been very perceptible in the last decade. Electronic-business (e-business), which is the latest development in ICTs, has taken a pivotal place in business activities.

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It can be used in almost all business activities, such as marketing, enterprise resource planning, customer relation management, supply chain management, and in production processes.

E-business technology has experienced the fastest rate of diffusion for the last few years. According to International Data Corporation (IDC) data sources, the compound annual growth rate (CAGR) of e-business in the global market has been 105 per cent since 1995. Although there are several models of e-business, two models, namely, business-to-business (B2B) and business-to-consumer (B2C), have experienced the highest growth. Of these two, B2B grew from US$ 3.5 bn in 1995 to US$ 34.0 bn in 1998, while the growth of B2C was US$ 1.0 bn in 1995 to US$ 4.0 bn in 1998. The share of B2B increased from 77.78 per cent in 1995 to 89.47 per cent in 1998.

The theory of technological change (Lefebvre and Lefebvre 1992; Pennings and Buitendam 1987) suggests that the decision-making process has a bearing on the adoption of new technologies. This process is more formal in large firms than in small and medium-sized enterprises (SMEs). For instance, large firms evaluate the pros and cons of a new technology through feasibility studies, while SMEs depend on technology suppliers. Theoretically, the mere adoption of new technologies does not guarantee benefits (Gatignon and Robertson 1989; Geipel 1991). This is particularly relevant for e-business technologies, because the adoption of these technologies is a necessary but not a sufficient condition for increase in productivity, augmentation in competitiveness and improved export performance (Lefebvre and Lefebvre 1996). E-business technologies in fact differ in many respects from previous technological transformations. First, unlike other technological changes, e-business tools require customization according to their functions and applications. Second, the technology involved is continually evolving. Firms need to develop the mechanisms for a continuous learning process. Learning processes are important for the adoption of and innovations in new methods of production (Lundvall 1992; Soete 1987).

A recent study (Brynjolfsson and Hitt 2000) postulates that organizational structures along with other firm-specific characteristics have a significant impact on the value of ICT investment. The authors further argue that the benefits of ICT investments are often intangible and difficult to measure. For instance, the complementary innovations in product designs, which are by and large facilitated by ICTs, cannot be easily quantified. They suggest that the studies carried out in the early 1990s could not capture the benefits of IT partly because of the intangible nature of its contributions and lack of information on relevant organizational restructuring, which is very crucial for efficient utilization of ICTs.

There have been several studies (Lefebvre and Lefebvre 1996; Mansell and Wehn 1998) in the context of developing countries as well. It has been argued that the adoption of ICTs is likely to be influenced by factors that are internal or external to firms. The possible external factors could be buyers' pressure, the macro-economic environment, national technological policies and industry-specific characteristics. The last, again, may be identified as concentration of the industry, competitive environment, access to technology and availability of technological know-how. The internal factors encompass entrepreneurial abilities of the chief executive officer (CEO), technological profile, size and strategies of firms. Many of these factors have indeed been crucial in influencing the adoption of new technologies in developing countries (Lefebvre and Lefebvre 1996).

The central theme of the paper is to investigate an effect of the adoption of e-business technologies on productivity of firms. There are mainly two sources of productivity gains. First, the adoption of new technologies in production processes, and second, the introduction of cost-saving mechanisms in non-production technologies. Earlier technological evolutions have mainly targeted improvements in production technologies. E-business, on the other hand, is capable of augmenting productivity in almost every business activity. E-business technologies enable firms to reduce the search costs of new production technologies substantially. For instance, a list of manufacturers of production technology of a particular product can be obtained instantaneously through the internet. Not only the list of manufacturers, but also benchmark outputs of technologies are available on the internet. These can be used for the selection of the appropriate technology. Hence, use of the internet not only reduces search time but also allows the selection of the most productive technology.

Productivity gains can also be realized by adopting e-business technologies in non-production processes. For instance, the networking of activities at firm level, single-unit as well as multi-plant firms, is expected to reduce co-ordination costs drastically. Similarly, the networking of all business partners (buyers and suppliers) will enable firms to process orders, invoices, queries, bills, etc., at much lower costs. This in turn will lead to lower processing costs and hence contribute to higher productivity. Therefore, it can be argued that e-business technologies are poised to contribute productivity gains in production as well as non-production processes.

This study uses primary data. It was found during the survey that a few firms were using enterprise resource planning (ERP), customer relation management (CRM) and supply chain management (SCM) technologies. All such firms had a relatively large size of operation and a very strong technological collaboration with multinationals. Two of these engaged in the manufacture of auto components were using international digital-leased lines to communicate with their foreign partners. One firm had collaboration with Sumitomo Corporation of Japan, while the other had collaboration with Huf, a German automobile company. Another firm dealing in the design of electronic components was a branch of IKOS systems of the US. The firm had many clients in the US and in other parts of the world. The company was using an integrated services digital network (ISDN) line for e-business related activities and to communicate with the parent company and other clients. The sample firms were using these technologies for reduction in search cost, as well as for collaborating business activities with foreign partners.

While most of the earlier studies are either based on macro-level data or on case study methods, an attempt has been made in this paper to explore the linkages between entrepreneurship, organizational adjustment and the adoption of e-business technologies and their impact on productivity using firm-level data. E-business technologies such as electronic messaging systems, uniform resource locator (URL), and portal-based technologies have been covered. The new customer relation management (CRM), enterprise resource planning (ERP), and supply chain management (SCM) technologies have also been included in the analysis. These technologies have been discussed in detail in a later section. The main objective of the paper is to examine the role of e-business technologies and organizational changes in augmenting productivity.

The rest of the paper is organized as follows: The hypotheses and theoretical framework are presented in the next two sections, while the third section discusses data and measurement issues. Empirical findings are analysed in the fourth section, whereas the last section contains the summary and conclusions.

Hypotheses

This section delineates hypotheses that are aimed at addressing the issues raised in this study. Although the hypotheses are framed with regard to relationships between the adoption of e-business technologies and other firm-specific characteristics, the literature on these issues related to the general technological development has also been discussed.

> Hypothesis I: *The knowledge base of managing directors in owner-managed enterprises plays an important role in the search and selection of appropriate e-business technology and consequently influences the performance of firms.*

Schumpeterian and neo-Schumpeterian literature (Heertje 1981; Nelson and Winter 1982; Pavitt 1984; Soete and Dosi 1983) emphasize with the role of entrepreneurship in the growth of firms. Entrepreneurship takes a pivotal place particularly in owner-managed enterprises, which all the sample firms are. Owner-managed firms are those where the managing director (MD) is also the owner of the firm. This implies that decisions are taken by the owners and do not go through a complicated decision-making process as happens in large corporations. The decisions of MDs are influenced by their own knowledge base and potential benefits of new technologies and not by the users of technology within the firm. Therefore, the decision to adopt a new technology solely depends on the perception of the owner or MD. By and large, owner-managed firms fall into the SME category in India. The size of operation of SMEs is normally not sufficiently large to warrant a feasibility study or a cost–benefit analysis of new technologies before they are adopted. It is rather the knowledge base of the MD that helps in identifying and selecting new technologies that are beneficial for the business.

Apart from this knowledge base, the qualification of the managing director and other entrepreneurial abilities, such as quality consciousness and desire to manufacture new products, play an important role in the acquisition of new technologies. Entrepreneurial role has been important in the case of other technologies, but it assumes a pivotal position for the selection of technologies led by ICTs in general and e-business technologies in particular. E-business technologies are meant to induce efficiency in managerial activities. Hence, the ability of the MD to use these technologies will have a bearing on the acquisition of such technologies.

This analysis might not be relevant to large firms that have enough resources at their disposal to study all aspects of new technologies before they are adopted. Moreover, the decision to employ any new technology in large firms does not depend on a single person, but is debated by a board.

In this study, we use the concepts of entrepreneur and entrepreneurial abilities as defined by Schumpeter. According to Schumpeter (1943: 132), the

> function of entrepreneur is to reform or revolutionize the pattern of production by exploiting an invention or, more generally, an untried technological possibility for producing a new commodity or producing an old one in a new way, by opening up a new source of supply of materials or a new outlet for products by reorganizing an industry and so on.

We have used the degree of the adoption of e-business technology as a proxy of entrepreneurship. Although MDs are different from entrepreneurs, we have used these words interchangeably because the MDs of sample firms are owners and not employees. Hence, in this case, an MD could be an entrepreneur.

> Hypothesis II: O*rganizational restructuring is very crucial for the successful adoption of e-business technologies. Hence, the impact of their adoption is expected to be more visible once the new organizational set-up is fully functional. This means that the performance of firms is expected to be influenced only after some lag since its adoption.*

More or less all the studies on ICT investment and productivity until the early 1990s did not show any significant improvement in the productivity of firms. Several explanations were offered for this phenomenon. These arguments were mainly focused around the lack of data and non-availability of process- and function-specific ICT tools. Brynjolfsson and Hitt (1993), perhaps for the first time, and subsequently Kraemer and Dedrick (1994) reported productivity gains due to the adoption of IT. Thereafter, several other studies (Doms et al. 1997; Lal 2001) have found a significant impact of ICTs on the performance of firms. Pohjola (2001) discusses several studies that present mixed findings with regard to ICT investment and their contributions to economic growth. These are industry- and country-specific and cross-country studies (Greenan et al. 2001; Pohjola 2001a, among others) on economic growth and investment on ICTs. Greenan's firm-level study in France confirms the significant and positive impact of

ICT investments on productivity, whereas the cross-country (39 countries, developing as well as developed) study by Pohjola reveals that although cross-country growth can not be explained by ICT investments, there is evidence of a strong influence of ICT investment on economic growth in developed (OECD) countries.

In the context of organizational restructuring and the adoption of ICTs, a study by Bresnahan et al. (2002) on IT and organizational changes suggests that investment in IT and capabilities of firms lead to changes in work organization and firm strategy. Brynjolfsson and Hitt (2000), on the other hand, emphasize that the investment in organizational restructuring exerts a large influence on the value of ICT investment. The authors have shown through several case studies that changes in the organizational set-up take some time before they become fully functional. These changes may not be limited to the parent firm and might result in similar changes in those organizations that are either suppliers or customers. Although the changes within the firm can be managed by itself, the firm has no control on changes to be made in associated firms. Full benefits of the adoption of ICT-led e-business technologies cannot be realized unless all business partners restructure themselves. This process might take some time. Therefore, the hypothesis is that organizational restructuring, which might be fully functional after some time has lapsed since the adoption of e-business technologies, is expected to influence the productivity of firms significantly.

Theoretical Framework

In most studies (Greenan et al. 2001; Pohjola 2001a), the Cobb-Douglas form of production function has been used to investigate the impact of ICTs on productivity. Brynjolfsson and Hitt (2000) suggest that using other functional forms has little effect on the measurement of output elasticity. In view of the emphasis on entrepreneurship in Schumpeterian and neo-Schumpeterian literature and Hypotheses I and II, we shall use the following form of production function:

$$Y_p = f(Ent_p, K_p, X_p) + \mu_p \quad (1)$$

where Y_p is the value added per worker[1] of plant *p*, Ent_p is a vector of entrepreneurial characteristics of managing director of plant *p*, K_p is per worker investment in ICTs in plant *p*, X_p is a plant-specific vector of variables that represent organizational restructuring, and μ_p is the random error term. Entrepreneurial characteristics (Ent_p) include the search for new methods of production or transportation, new forms of industrial organization and exploration of untried technological possibilities for producing a new commodity or an old one in a new way.

The adoption of e-business technologies is expected to reduce search and co-ordination costs. It is also likely to strengthen the competitiveness of firms. However, the focus of the study is to analyse the performance of firms due to the adoption of e-business technologies. Therefore, a proxy of performance, that is, labour productivity, has been analysed in this study. The OLS estimates of the parameters of the model have been computed using the data described in the next section and the results are analysed subsequently.

Data and Measurement Issues

The study is based on primary data collected from firms located in the New Okhla Industrial Development Area (NOIDA). This is a newly developed industrial town near the national capital, New Delhi. There are four main internet service providers (ISPs), namely, Videsh Sanchar Nigam Limited (VSNL), Software Technology Park of India (STPI), Satyam and Mantraonline, operating in NOIDA. Mantraonline and Satyam are private sector ISPs, whereas VSNL and STPI are state-owned public sector companies that are involved in providing internet services. In addition, M/s India Markets is another private sector e-business solution providing firm located in NOIDA. All ISPs and India Markets were approached to get information about firms that have adopted e-business technologies in NOIDA. A list of 68 firms was obtained, which included the names of MDs and addresses of firms. It may be mentioned that ISPs are not included in the sample. The sample firms are users of e-business technology.

It may be safely assumed that all firms using some form of e-business model located in NOIDA have been covered in this study. All 68 firms were approached during the survey. However, we could get data from only 51 firms, a response rate of 75 per cent. The survey was conducted during December 2000 and February 2001. Historical, financial and technological data were collected through a semi-structured questionnaire. Historical data include the background of MDs and age of firms, whereas financial data (1999–2000) consist of sales turnover, workforce, investment on ICTs, wage bill, exports, imports, profit after tax, value added, etc. Technological data include the type of e-business tool adopted and bandwidth being used by firms. Data on technological and financial collaborations with multinational companies were also collected.

As mentioned earlier, the three sample firms were using ERP, CRM and SCM technologies. These firms also had their own portals. The remaining sample firms were using the electronic messaging system, URL, and portals that were either owned or shared for customer relations, supply chain management and marketing activities. The description of all the variables that have been used in this paper is presented in Table 11.1A of the Appendix. The measurement of qualitative variables and ICT capital has been discussed in the following subsections.

Classification of Firms (EB-TYPE)

All the sample firms have been grouped into three categories depending on the type of e-business technologies adopted by them. The first category of firms was doing e-business through offline technologies. Firms that were using electronic mail systems for business activities have been categorized as using offline e-business technology. During the survey, it was found that many firms have their presence on the net. They have their URLs with some degree of online e-business facilities such as active server pages (ASPs). All those firms that have dynamic URLs have been categorized as conducting e-business online. The third category of firms includes those that were doing e-business using the latest technology, that is, portal-based e-business. The percentages of firms using offline and online e-business tools were 49 and 29, respectively, while 22 per cent of the sample firms were using portal-based e-business technologies. The firms were assigned ranks depending on the type of e-business technology used, that is, 1 for offline, 2 for online, and 3 for firms using portals.

Managing Directors' Education (MDEDU)

The actual data on entrepreneurs' qualification were collected and education was converted on a quantitative scale. Entrepreneurs with graduate degrees/diplomas were thus assigned the lowest rank, that is, 1, whereas the MDs with a PG degree/diploma were given a rank higher than the graduates, that is, 2. It was found during the survey that a large number of MDs were engineering graduates, and they were treated as more qualified than ordinary postgraduates, with a rank of 3. There were many entrepreneurs who had either a master's degree in engineering or a professional degree such as master of business administration (MBA). All such MDs have been assigned the highest rank, that is, 4. Engineering graduates have been given higher rank than ordinary graduates and postgraduates because a BE degree is a professional graduation degree and the duration of the course is longer than for ordinary postgraduation courses in India. The distribution of firms according to MDs' qualification and type of e-business technology adopted by firms is presented in Table 11.1.

TABLE 11.1 Managing Directors' Qualification and Adoption of E-business

	Qualification of Entrepreneurs								
EB-TYPE	*Graduate*	*%*	*PG*	*%*	*BE*	*%*	*BE and MBA*	*%*	*Total*
Offline	4	16.0	9	36.0	9	36.0	3	12.0	25
Online	1	6.7	3	20.0	7	46.7	4	26.7	15
Portal	1	9.1			3	27.3	7	63.6	11
Total	6	11.7	12	23.5	19	37.2	14	27.4	51

Note: % is row percentage.
Source: Author's calculations.

It can be seen from Table 11.1 that the percentage of graduate MDs decreases as the intensity of e-business adoption increases from offline to portal, whereas the percentage of MDs, who have the highest technical qualifications, increases from 12 per cent in offline e-business using firms to 63.6 per cent in firms that were doing business through their own or shared portals. This indicates that firms that were managed by technically qualified persons had adopted a higher degree of e-business technologies.

Information and Communication Technology Capital (ICTCAP)

Capital generated by ICTs has been measured as a ratio of total value of ICT hardware and software to the total number of workers. The value of ICT has been converted in rupees hundred thousands.

The ICTCAP was taken from the balance sheet of the firms that takes care of 66 per cent depreciation per year. Table 11.2 presents the distribution of firms according to ICTCAP and value added, while the distribution of ICT capital in relation to value added per worker is presented in Table 11.3.

TABLE 11.2 **Distribution of Firms by ICT Capital and Value Added**

ICTCAP	*Vallue Added (× Rs 1,000)*											
	<50		*50–100*		*100–200*		*200–350*		*350+*		*Total*	
(× Rs 100,000)	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
<0.75	2	28.6	5	71.4							7	100
0.75–1.5	2	20.0	3	30.0	3	30.0	2	20.0			10	100
1.5–6.0	2	14.3	3	21.4	2	14.3	4	28.6	3	21.4	14	100
6.0–15	4	36.4			4	36.4	3	27.3			11	100
15+					3	33.3			6	66.7	9	100
Total	10	19.6	11	21.6	12	23.5	9	17.6	9	17.6	51	100

Note: % is the row percentage.
Source: Author's calculations.

It can also be seen from Tables 11.2 and 11.3 that not only is there a positive relationship between ICT capital and productivity of workers, but the distribution of firms also shows a similar trend. For instance, the labour productivity of 80 per cent of firms in the ICT capital category of Rs 75,000–150,000 is less than Rs 200,000. Controlling for the value-added category, this percentage of firms reduces to 33.3 per cent in the ICT capital category of more than Rs 1,500,000. Controlling for higher value-added categories, the percentage of firms, on the other hand, increases as the ICT capital increases.

It can be seen from Table 11.3 that the value added per worker is directly proportional to the investments in ICT capital. For instance, firms that have invested less than Rs 75,000 on ICTs experienced less labour productivity than others who invested more in ICTs. The average value added per worker in the former is Rs 57,656, whereas labour productivity of firms where investment in ICTs is more than Rs 1,500,000 is very high compared to others. The average productivity of a worker in such firms is Rs 332,625. In the other category of firms classified by ICT capital, the positive relationship between labour productivity and ICT capital holds true.

We can infer from Table 11.3 that the labour productivity of firms is influenced by the investment on ICTs that is an indicator of the

TABLE 11.3 ICT Capital and Value Added

ICTCAP	*Value Added (× Rs 1,000)*											
	<50		*50–100*		*100–200*		*200–350*		*350+*		*Total*	
(× Rs 100,000)	α	β	α	β	α	β	α	β	α	β	α	β
<0.75	40.62	0.60	64.47	0.54							57.66	0.56
0.75–1.5	46.15	1.00	64.62	0.88	151.02	0.93	230.53	1.00			120.12	0.93
1.5–6.0	42.79	3.5	84.17	2.5	178.00	3.50	251.21	2.50	581.34	3.7	245.93	3.05
6.0–15	41.75	8.88			171.00	9.13	299.77	10.23			159.12	9.36
15+					153.00	80.00			422.44	156.67	332.63	131.11
Total	42.61	4.57	69.88	1.16	162.74	23.88	262.81	4.74	475.41	105.69	191.99	26.25

Note: α → Average value added, and β → Average ICT capital.
Source: Author's calculations.

type of e-business technology used by them. It would have been more appropriate to differentiate expenditure on ICT application technologies and ICT infrastructure. This was not possible due to the fact that the sample firms were mostly SMEs. The firms of this study did not maintain the expenditure separately on two heads. Hence, we have no option except to use the total expenditure on ICTs.

Empirical Evidence

The hypotheses formulated earlier have been tested using the sample data, which have been analysed in a univariate framework before using regression analysis. The results of univariate and multivariate analyses are presented and discussed in this section.

Univariate Analysis

All the variables that were discussed in the previous section were analysed in a univariate framework. The mean value and standard deviation of these variables are presented in Table 11.4 along with the F-value and the level of significance.

TABLE 11.4 Univariate Analysis of Variables

	Mean and SD of Variables					
	Type of E-business					
Variable	*Offline*	*Online*	*Portal*	*F-Value*	*Prob.*	*Remarks*
ICTCAP	3.228 (5.461)	13.197 (31.160)	96.364 (153.212)	6.734	0.0026	ICT Capital (× Rs 100,000)
MDEDU	2.440 (0.917)	2.933 (0.884)	3.455 (0.934)	4.953	0.0111	Education of Managing Director
VAL	97.380 (72.163)	239.390 (178.275)	342.390 (145.405)	15.551	0.0000	Value added per worker (× Rs 1,000)

Note: Figures in parentheses are standard deviations.
Source: Author's calculations.

It can be seen from Table 11.4 that standard errors of ICTCAP are very high, particularly in firms using online and portal technologies. This is because the sample contains few IT firms that have made large investments in ICTs. In fact, a substantial portion of the firms' total investment is on ICTs alone.

The sample firms were operating in three different e-business technological paradigms. A low level of e-business technologies characterizes the first paradigm; the second one is represented by URL-based e-business technologies, while portal-based technologies constitute the third paradigm. The last paradigm includes IT-enabled management techniques, such as ERP, CRM and SCM. Therefore, we first test the hypothesis that the variables such as ICTCAP and MDEDU differ significantly in the three paradigms.

It can also be seen from Table 11.4 that ICT capital differs significantly in the three types of firms. Investment in ICTs by firms using e-mail is expected to be the lowest among the other types of firms because many of these firms had a single personal computer (PC) in their premises. They were using the PC for other activities as well, such as accounts and word processing. Several of these firms had more than one PC, but they were stand-alone computers. However, they were sharing output devices. Firms using URLs, on the other hand, had several PCs and in many cases were connected through local area network (LAN). However, most of these firms integrated activities other than manufacturing. In addition to sharing the output devices, they were sharing other resources such as storage, documents and messaging systems. These firms invested not only in network technologies, but also in costs for hosting their URLs on the ISPs' server. Hence, the ICT capital of firms using online e-business technology is expected to be higher than offline ones. It was found during the survey that several firms using portal had integrated their back office and front office activities through LAN. Moreover, many of them were using the ISDN mode of communication for ICT-enabled services. Therefore, the ICT capital of the last category of firms is expected to be highest.

The emergence of significant difference in the qualification and knowledge base of entrepreneurs in the three types of firms is in accordance with our expectations. Neo-Schumpeterian literature (Nelson and Winter 1982; Pavitt 1984; Soete and Dosi 1983) recognizes that technology is neither freely available nor does it come without 'search' costs. Large firms, where the entrepreneurial abilities of the individuals are not as important as in SMEs, can bear such costs, whereas in the case of SMEs, the entrepreneurial characteristics of MDs are very important in searching for new technologies. The choice of technology is therefore guided by the knowledge of the entrepreneur and other firm-specific factors.

In the context of e-business technologies, such as ERP, SCM and CRM, the role of the entrepreneur becomes more important because firms that can visualize all the enterprises in their supply chain as being their extension will gain a significant competitive advantage, which will increase sales opportunities and substantially reduce supply chain costs. These technologies help enterprises in reducing inventory and operational costs, while increasing the satisfaction of its customers. Firms can increase sales turnover and retain the customers by: (*a*) monitoring and analysing customer data and transactions; (*b*) detecting significant changes in customer behaviour; and (*c*) responding with customized offers. In the fast-changing and ever-evolving world of e-business, the leaders of the future will be those companies who are in tune with their customers and make the best use of their customer knowledge. To derive maximum benefits from e-business technologies, the entrepreneur must be appreciative as well as appropriately informed about these technologies.

Regression Analysis

The parameters of the two models represented by equation 1 have been estimated and the results are presented in Table 11.5. Two measures of e-business technologies have been used. First, the type of e-business technology used by sample firms, and second, the investment on ICTs, which has been used as a proxy of e-business technologies. The results with second measure of e-business technologies are presented in Table 11.5. As mentioned earlier, the degree of adoption of e-business technologies has been used as a proxy of entrepreneurial characteristics in this study. With regard to variables that represent organizational restructuring, we have used two indicators, namely, duration of ICT adoption; and skill enhancement of workers.

The duration of ICT use has been used as a proxy of organizational change because it measures the period between the adoption of ICTs and assessment of its impact on firms' performance. This gap between adoption and assessment is crucial because the firm might require changes in production processes. It often takes several years to complete the process of making appropriate changes in the plant (Lal 1998). This gap is also important for those who did not have to make many changes in their plants but had to wait until all the business partners made appropriate modification in their business activities. Therefore, we have considered the duration between adoption and assessment as one that is representative of organizational change.

The second variable, enhancement of skills, has been used as representative of organizational restructuring. This is a binary variable: 1 for those who regularly organize training programmes for skill enhancement of their workers, and 0 for others. The skill enhancement is not limited to those who are directly related to e-business activities but for those who require new skills as a result of adoption of ICT in production processes. Many firms reported that regular training is very essential in IT-based production processes because of the modifications in the processes due to technological evolution. The skill enhancement for some firms was found to be imperative for the efficient and successful use of new technologies.

TABLE 11.5 Results from OLS Regression: VAL as Dependent Variable

	Dependent Variable: Value Added per Worker		
Independent Variables	*Equation I*	*Equation II*	*Equation III*
Constant	–72.163 (–1.216)	–25.896 (–0.419)	39.015 (0.637)
Type of E-business (EB-TYPE)	82.606 (2.974)*		
Managing Director's Education (MDEDU)	18.163 (0.924)	34.576 (1.696)***	47.567 (2.243)**
Skill Enhancement (SKILL)	65.691 (1.090)	115.460 (1.847)***	166.630 (2.609)**
Duration of IT Adoption (ITYEAR)	15.365 (1.632)	26.198 (2.793)**	

Note: Figures in parentheses are t-values of the coefficients. * Significant at 1 per cent; ** significant at 5 per cent; and *** significant at 10 per cent.

Source: Author's calculations.

The results of the three equations are presented in Table 11.5. In the first equation, we considered all the variables. It can be seen from Table 11.5 that EB-TYPE has emerged as very significant, while other variables are insignificant in explaining the labour productivity. This is because EB-TYPE is highly correlated with other variables. In the second equation, EB-TYPE was dropped. The results show that other three variables, that is, MDEDU, SKILL, and ITYEAR become significant. However, MDEDU and SKILL are significant at 10 per cent. In the third equation, we dropped ITYEAR which was correlated with MDEDU and SKILL and found that the variables MDEDU and SKILL have also emerged as very significant factors that play an important role in influencing the performance of firms.

The productivity gains of ICTs have been unclear in the early years of their adoption. In the 1990s, however, several studies (Kraemer and Dedrick 1994; Lal 1999) have found significant labour productivity gains consequent to the adoption of ICTs. One of the major reasons for significant productivity gains is the development of process- and function-specific and customized ICT tools. The latter half of the 1990s has witnessed the development of industry- and firm-specific business solutions. Moreover, the recent development of ERP and internet-based technologies has been successful in integrating various business activities, thereby contributing to labour productivity. The results of this study are in line with earlier studies.

Brynjolfsson and Hitt (2000) found through the case study method that organizational restructuring and investment in new technologies are equally important. The authors concluded that investment in organizational changes has a significant influence on the contributions of ICT investments. The results of the present study, which are based on an econometric analysis, support these findings. It is difficult to quantify the 'restructuring of organization' variable. However, proxies like investment on restructuring and duration of the use of technology that in turn require investment in skill enhancement for effective use of the new technology, can be used. Another variable associated with the restructuring, which is even more difficult to measure, is the changes to be made in the organizations of all the other business partners. This study captures the role of restructuring in influencing the performance of firms by including the variables of duration of use of ICTs and skill enhancement in the analysis.

Summary and Conclusions

The study aims at analysing the role of the adoption of e-business technologies, entrepreneurial characteristics and organizational restructuring on performance of firms in the era of liberalization. The data that have been used to test the hypotheses come from 51 manufacturing firms located in NOIDA. This is a well-planned industrial town located in close proximity to the national capital, New Delhi. Although a majority of firms were engaged in manufacturing of high-tech products such as computers, printed circuit boards, cable TVs and communications equipment, garments manufacturing firms that belong to a low-tech industry also represent the sample. The survey was conducted during December 2000 and February 2001. Data on technological and financial collaborations with multinational companies was also collected.

It was found during the survey that a few sample firms had made substantial investment in knowledge-based technologies such as enterprise resource planning, customer relation management and supply chain management.

A linear production function has been used to test the hypotheses. The study finds that intensity of the adoption of e-business technologies and organizational restructuring have played important roles in influencing the labour productivity. The study reveals that the knowledge base of entrepreneurs has been very crucial in selecting an appropriate e-business technology. The results also show that the acquisition of e-business technology is a necessary but not sufficient condition for productivity gains. Appropriate organizational restructuring, coupled with human capital, can strengthen the competitiveness of firms that is essential in the era of liberalization. The findings of the study are similar to the other studies (Bresnahan et al. 2002; Brynjolfsson and Hitt 2000; Nelson and Pack 1999) that stress entrepreneurship, organizational restructuring and learning.

Appendix

TABLE 11.1A Description of Variables

Variable	*Abbreviation*	*Description*
Duration of IT Year	ITYEAR	No. of years a firm has been using IT tools until 2001
Education of MDs	MDEDU	Qualitative Variable: 1 for Graduates, 2 for Postgraduates, 3 for Engineering Graduates, 4 for Professional Masters Degree Holders
ICT Capital	ICTCAP	ICT Capital per Worker (× Rs 100, 000) adjusted for depreciation at 66% per year
Labor Productivity	VAL	Value Added per Worker (× Rs 1,000)
Skill Enhancement	SKILL	Binary Variable: 1 for Those Who Organize Training Programmes for Skill Enhancement, and 0 for Others
Type of E-business Technology	EB-TYPE	Qualitative Variable: 1 for Offline, 2 for Online, and 3 for Portal-using firms

Note

1. It may be mentioned that workers refer to the total employees of the firm and not only persons working in production processes.

References

Bresnahan, T., E. Brynjolfsson and L. Hitt. 2002. 'Information Technology, Workplace Organisation and the Demand for Skilled Labour: Firm-Level Evidence', *Quarterly Journal of Economics*, 117(1): 339–76.

Brynjolfsson, Erik and Lorin M. Hitt. 1993. 'Is Information Systems Spending Productive? New Evidence and New Results', *Proceedings of the 14th International Conference on Information Systems*, Orlando, FL: 47–64.

———. 2000. 'Beyond Computation: Information Technology, Organisational Transformations and Business Performance', *Journal of Economic Perspectives*, 14(4): 23–48.

Doms, Mark, Timothy Dunne and Kenneth R. Troske. 1997. 'Workers, Wages, and Technology', *Quarterly Journal of Economics*, CXII(February): 253–90.

Gatignon, H. and T.S. Roberston. 1989. 'Technology Diffusion: An Empirical Test of Competitive Effects', *Journal of Marketing*, 53: 35–49.

Geipel, G.L. 1991. 'The Failure and Future of Information Technology Policies in Eastern Europe', *Technology in Society*, 13(1–2): 207–28.

Greenan, Nathalie, Jacques Mairesse and Agnes Topiol-Bensaid. 2001. 'Information Technology and Research and Development Impacts on Productivity and Skills: Looking for Correlations on French Firm-Level Data', in Matti Pohjola (ed.), *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*. New York: Oxford University Press, 119–48.

Heertje, Arnold. 1981. 'Schumpeter's Model of the Decay of Capitalism', in Helmur Frisch (ed.), *Schumpeterian Economics*. New York: Praeger, 84–94.

Kraemer, Kenneth L. and Jason Dedrick. 1994. 'Payoffs from Investment in Information Technology: Lessons from the Asia-Pacific Region', *World Development*, 22(12): 1921–31.

Lal, K. 1998. 'The Adoption of Information Technology and its Consequences: A Case Study of Indian TV Manufacturing Firms', *Science, Technology & Development*, 16(1): 81–100.

———. 1999. 'Determinants of the Adoption of Information Technology: A Case Study of Electrical and Electronic Goods Manufacturing Firms in India', *Research Policy*, 28: 667–80.

———. 2001. 'Institutional Environment and the Growth of Indian IT Industry', *The Information Society*, 17: 105–17.

Lefebvre, E. and L.A. Lefebvre. 1992. 'CEO Characteristics and Technology Adoption in Small Manufacturing Firms', *Journal of Engineering and Technology Management*, 9: 243–77.

Lefebvre, E. and L.A. Lefebvre. 1996. *Information and Telecommunication Technologies: The Impact of Their Adoption on Small and Medium-sized Enterprises*. Ottawa: International Development Research Center.

Lundvall, B.A. (ed.). 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

Mansell, Robin and Uta Wehn (eds). 1998. *Knowledge Societies: Information Technology for Sustainable Development*. Oxford, UK: Oxford University Press.

Nelson, R.R. and Howard Pack. 1999. 'The Asian Miracle and Modern Growth Theory', *Economic Journal*, 109 (July): 416–36.

Nelson, R.R. and S.G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge and London: Harvard University Press.

Pavitt, K. 1984. 'Sectoral Patterns of Technological Change: Towards a Taxonomy and a Theory', *Research Policy*, 13: 343–73.

Pennings, J.M. and A. Buitendam (eds). 1987. *New Technology as Organisational Innovation*. Cambridge: Ballinger.

Pohjola, Matti (ed.). 2001. *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*. New York: Oxford University Press.

———. 2001a. 'Information Technology and Economic Growth: A Cross-Country Analysis', in Matti Pohjola (ed.), *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*. New York: Oxford University Press, 242–56.

Schumpeter, Joseph A. 1943 (1980). *Capitalism, Socialism and Democracy*. Delhi: S. Chand and Co.

Soete, L. 1987. 'The Impact of Technological Innovation on International Trade Pattern: The Evidence Reconsidered', *Research Policy*, 16: 101–30.

Soete, L. and G. Dosi. 1983. *Technology and Employment in the Electronics Industry.* London: Frances Pinter.

12

ICTs and Transformation of Traditional Workplaces: The Case of the Automobile Industry in India*

M. Vijayabaskar

Introduction

This paper will examine how the use of information and communications technologies (ICTs) impact on labour in traditional manufacturing industries in low-income countries. The automobile industry in India is taken up for examination as a case. Policy makers in such countries face a dilemma as they try and take advantage of ICTs. Since ICTs are a new and rapidly growing economic sector, creating an ICT industry can generate vast employment opportunities. Further,

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since ICTs are enabling technologies, the growing share of knowledge-based production globally warrants that, from a macro-economic perspective, economies develop a degree of technological capability in this sector if they are to compete in international markets. From a micro-economic perspective, promoting ICT-based industrialization and deploying ICTs in existing industrial sectors can impart greater flexibility and efficiency to production systems in user industries.

Even as development of the ICT sector promises to generate new employment, the deployment of these technologies in existing industries creates challenges by transforming the organization of production. At one level, automating production can displace labour. Importantly, rationalizing production by deploying ICTs is likely to render existing skills redundant, profoundly altering patterns of labour demand. Further, its all-pervasive nature may enable new forms of work organization, though studies debate upon the actual impact upon quality of work and employment. These seemingly contradictory tendencies highlight the importance of a clear understanding of how the production and use of ICTs will affect labour markets. In contrast to the extent of interest in these issues in advanced capitalist countries, the labour market impacts of ICTs have received little research attention in the context of low-income economies, even as they strive to simultaneously provide quality employment and improve productivity and efficiency. This study seeks to fill this gap by examining how ICTs influence the Indian labour market in the automobile and automobile components manufacturing industry, which is deploying these technologies extensively to reap productivity benefits. In this, I primarily confine my focus to the deployment of one kind of IT—enterprise resource planning (ERP) systems.

Empirical and Theoretical Background

Impacts of microelectronics, communication and information technologies on the organization of production and employment in industrialized, and to a limited extent, in less industrialized countries, have been extensively discussed (Brynjolfsson and Hitt 1998; Castells 1996; ILO 2001; Knights and Willmott 1988; Mitter and Rowbotham 1995). The relationship between technical change and work and employment is crucially mediated by organizational imperatives (Carnoy et al. 1993; Holfman and Novak 2002). At the same time, organizational forms—outcomes of a multiplicity of factors including technologies deployed—are also transformed as a result of adoption of new technologies. That firms derive productivity gains from new technologies only when their adoption is accompanied by appropriate organizational innovations is well documented (Murphy 2002). Nevertheless, the relationship between ICT diffusion and labour market changes can be mapped along the following three dimensions: impact on organizational structure, on quality of work and on labour market segmentation.[1] I examine each of these strands in the following subsections.

Impact on Organizational Structure and Firm Size

One stream of inquiry focuses on how ICTs transform organizational landscapes, and on inter- and intra-firm division of labour and its co-ordination through market or authority (Blau et al. 1976; Carley 2000; Gurbaxani and Whang 1991; Kling and Iacono 1984; Laudon 1974). If firms are essentially information-processing entities, to the extent that deployment of ICTs enhance either the availability of information or the ease of processing, the structures tend to transform. In principle, ICTs are available to all firms in an economy. However, its effective implementation towards economic gains requires organizational restructuring to ensure an optimal structure given the new technological regime. There are various propositions concerning how ICTs can change organizations. To begin with is the proposition that ICTs may alter firm size and lead to the rise of smaller firms through labour substitution and/or outsourcing (Brynjolfsson et al. 1993).

Increased automation leads to reduced need for labour as well as enhanced productivity. When capital investments in IT are cheaper compared to employment of labour, firms may substitute IT for labour. In labour markets with few barriers to exit, ICTs may displace labour. When displacement is not possible due to institutional factors, the effect of deployment of ICTs may be seen on work organization and the kind of work. The product market obviously conditions the nature of such change. The use of ICTs may improve labour productivities, lowering the cost per unit of output. If price elasticity of demand for that output is high, demand for that product increases, forcing firms to expand capacity, and therefore leading to increased firm size. Furthermore, studies of the relationship between IT and employment also indicate that IT may actually increase employment, and may in fact complement rather than substitute employment (Morrison and Berndt 1990).

Another important impact of ICTs, especially in the context of low-income economies, is their ability to reduce transaction and co-ordination costs, and consequently, the impact on firm size. Several works suggest the ways in which IT might affect firm size by reducing various kinds of co-ordination costs, depending upon which kinds of costs are most affected (Gurbaxani and Whang 1991). Brynjolfsson et al. (1993), deriving from a transaction cost-based understanding of the firm, suggests the following possibilities with regard to diffusion of ICTs and its impact on firm size and structure.[2]

If IT reduces the costs of internal co-ordination more than external co-ordination, firms would make more things internally. This means that firm size will increase with the use of ICTs. If ICT reduces the costs of external co-ordination more than internal co-ordination, then we would expect firms to rely more on outsourcing for their inputs. Use of ICTs make available better quality information to firms and thereby reduce the scope for opportunism that they may confront in the market (Brynjolfsson et al. 1988). The average size of firms will therefore decrease. For example, if it is easier and cheaper for a firm to find an external supplier for new parts than to make them internally, then the firm is more likely to buy the parts from external suppliers than to set up internal manufacturing capacity. This phenomenon is especially evident in the case of the automobile industry, which requires a large number of small component inputs for a single unit of output. Typically, 70 to 80 per cent of the industry's component inputs are sourced from external suppliers.

A related effect of IT is that it might reduce market co-ordination costs by changing the 'specificity' of assets themselves. Klein et al. (1978) and Grossman and Hart (1986) emphasize that when assets are specific to one another, market co-ordination will be inefficient and this may lead to common ownership of large, related sets of assets. However, if IT facilitates techniques like flexible manufacturing, it may decrease the specificity of assets, and thus transform internal production into production organized through smaller units co-ordinated by markets. When both kinds of co-ordination costs decline relative to production costs, it would still favour buying to producing in-house. Greater outsourcing leads to a decrease in firm size, in terms of both material assets and numbers employed. Unlike the labour substitution proposition based on automation, employment does not decline in this case, but gets divided among new independent firms with implications for career paths. There is limited evidence to suggest that ICTs do lead to a decline in firm size in certain industries, though there is also ample evidence of increase in global outsourcing of various activities in the last decade or so.

While this discussion pertains to the impact of ICT use on firm size, another related set of questions concerns the effect of use of computers on distribution of power within an organization, that is, its ability to increase centralized authority or to decentralize decision-making powers, with its attendant implications for labour autonomy and control over work. Such questions are also enmeshed in the larger debate over changing forms of work organization in a 'post-industrial, informational' economy. Empirical evidence is again divided on this. That the very nature of ICTs has changed over time with the rise of networked systems, however, needs mention here.

While these studies saw technology as the prime mover influencing the distribution of power within an organization, subsequent studies argued for a more complex explanation for organizational structure based on organizational strategies and constraints (George and King 1991). Also, labour process literature, rooted in Marxist theory, analysed distributional impacts such as outcomes of capital–labour struggle within the workplace (Knights and Willmott 1988; Wood 1989; Zimbalist 1979). Quite a few do see the importance of other organizational and product market imperatives in conditioning final outcomes. Once again, the discussion, rather than arguing for a specific kind of impact, highlights the importance of institutional factors in shaping outcomes, that includes the bargaining power of various categories of labour vis-à-vis management.

ICTs and Nature of Employment

Another strand of literature concerns changes in the spatial organization of production due to the introduction of ICTs (Zuboff 1984) and implications for the nature of employment generated. Since ICTs reduce co-ordination and communication costs, it is not necessary to bring workers together to a single workplace. Use of ICTs, especially advanced communication technologies, coupled with appropriate incentives can provide an opportunity to employees to undertake homework, or more broadly, 'telework' that is, distance working. Since the nature of work is primarily information processing and knowledge creation, employees with access to information processing and communication tools can carry out their work without considerations of location. Such possibilities, it is argued, may favour greater entry of women into paid employment.

On the flip side, it also weakens the traditional bases for organizing labour and collective representation of labour. ICTs, by facilitating firms to employ homeworkers on a contractual basis, are seen to promote insecure employment opportunities. In India, as well as in other low-income economies, this potential of ICTs is seen to push employment from the formal sector to small firms in the unorganized sector where employment is not protected by any legislation. Further, if this feature of ICTs encourages the formation of small firms that are narrowly specialized, it also implies that there is less room for employee mobility within firms, transforming the career paths of employees (Francis 1986: 154–58). Vertical mobility of employees will be ensured primarily through movement from one firm to another rather than through intra-firm mobility. Interestingly, it has been observed in the context of low-income economies that while outsourcing by MNCs does take place, it has not led to home-based teleworking but to the formation of new firms in metropolitan centres (Hafkin and Taggart 2001: 39). Nevertheless, the rise of information-based service sectors has led to increase in women's presence in paid employment, reproduction of gender-based discrimination within these segments notwithstanding. While the discussion in this subsection pertains to changes in the nature of employment due to adoption of ICTs, the latter are also expected to alter the content of work, shifts in skill demands and consequent impacts on labour market segmentation.

ICTs and Quality of Work Content

There are generally two contrasting theses about the conditioning of work quality by new technologies, including ICTs: the post-industrial theory, in which automation is seen to liberate workers from routine tasks and produce a skilled, well-paid, committed and autonomous labour force (Bell 1973); and the degradation of work theory, which posits that new technologies reduce skill requirements and transform work activities into repetitive routines, so that labour becomes cheap and easy to substitute (Aronowitz and DiFazio 1994; Braverman 1974).

The first proposition about the impact on work is partly related to earlier discussions on labour substituting ICTs. Degrading, monotonous labour which was seen as essential to societal progress, but inimical to those involved in it can now be left to ICT-driven machines, leaving human labour to take care of more creative and knowledge-based work. What cannot be automated are tasks that require exceptional processing, spatial or visual skills or those that require non-algorithmic reasoning (Bresnahan et al. 2002: 4). Apart from such impacts in traditional sectors, the growing knowledge and information content of the new sectors too would require a highly skilled workforce. Such skill-based technical change (SBTC) gets accentuated with greater diffusion of ICTs.[3] The argument, however, omits to factor in the growing complexity in division of labour as a society/economy progresses. Though ICTs may liberate a set of workers from drudgery, accompanied as they are by growing complexities of economies, it is quite possible that new tasks will be created that require labour of a very monotonous and unskilled kind that are not readily amenable to automation. In fact, the post-industrial thesis presupposes a movement towards dominance of the service economy in terms of both employment and production (Castells 1996: 203). Again, since substitution of labour by ICTs are driven by relative costs of labour, the extent to which substitution takes place may differ across economies, with a lot less incentive for labour surplus economies to substitute as compared to that witnessed in advanced capitalist economies. Moreover, others argue that enskilling or otherwise is dependent upon product specialization, with the former being associated with production of high-value goods only (Okada 2000: 31–32).

While the earlier perspective is essentially a technocentric one, the second thesis stems from the Marxist perspective on capitalist dynamics as driven by capital's need to exercise control over labour to ensure adequate extraction of surplus value. Deskilling or reduction of complex tasks like that of a craft worker into simple tasks is important to this end. When unskilled workers can undertake the broken-down tasks, the bargaining power of skilled labour is reduced, while simultaneously serving to expand the supply of labour from which capital can draw. However, critics have pointed to the absence of the possible role that labour struggles can play in modifying strategies in the workplace. Deskilling or degradation of work has less to do with technologies per se, but are only visible in the need for capital to control the pace and quality of work. ICTs, when used towards this purpose, may downgrade the quality of work.

At a theoretical level, since ICTs reduce co-ordination costs between different work processes, they facilitate/encourage firms to fragment tasks to enable them to improve labour productivity. At the same time, when routine tasks can be automated, ICTs reduce unskilled work. This has led to the argument that ICTs alter the distribution of employment among occupations and skill classes of workers (Braverman 1974; ILO 2001; Katz 2000). Evidence thrown by some studies do point to deskilling tendencies (Aronowitz and DiFazio 1994; Braverman 1974; Greenbaum 1976; Kraft 1979). Castells (1996: 206) too observes that just as information technologies have eliminated a number of routine jobs, they have also created a need for new unskilled tasks. On the other hand, studies do indicate the elimination of routine tasks like documentation and record-keeping, a tendency that questions the proposition that ICTs in general lead to a deskilled workforce (Bresnahan et al. 2000). Even within software programming, it has been argued that programming continues to retain its craft basis despite efforts to introduce various software engineering processes. Part of our uncertainty about the effect that information technology has had on the nature of work can be traced back to the considerable uncertainty about the conception of skill.

Also, if the workplace is a 'contested terrain', as argued by Edwards (1979), then the direction of change in the organization of work depends on the strength of and organization of labour as well. This proposition also finds empirical support in a few studies (Clement 1991; Ormos and Blameble 1989, cited in Ng and Yong 1995). Strong trade union demands, coupled with a more open government (as in Scandinavian countries), can provide channels for participation of labour in planning and the use of new technologies (Forester 1985; Michie and Sheehan 2003). Similarly, Carnoy et al. (1993) refer to a study by Edquist and Jacobsson (1988) that has found a greater use of automated technology in countries where labour has greater job security. Further, given other social bases of segmentation like gender and ethnicity, ICTs too may affect these categories differentially. For instance, while new technology skills are being polarized by gender, it is also evident that women are entering computer professions in both high- and low-income economies, leading to class polarization within the female labour force itself.

Studies in fact reveal that the nature of change depends on relative power of the workers. For example, clerks fared less well, on average, than professionals. Again, secretaries sometimes experience better work improvements than workers, primarily women, who were involved in back office processing transactions. Occupational power thus, plays an important role in shaping the way ICTs restructure work content (George and King 1991). Thus, when women are confined to jobs lower down in the hierarchy, diffusion of ICTs may have negative impact on their work, employment and career paths. Problems also stem from conceptualizing skills and associating them solely with educational attainment. The ILO (1988) also notes that the new jobs being created do not require higher skills, only different skills (cited in Carnoy et al. 1993).

Objectives of the Study

There are marked differences in the impact of new technologies on labour processes, even between countries at apparently similar stages of development. It has also been pointed out that the pace and form of utilization of available technologies are crucially dependent on the institutional background of a given economy (Freeman and Perez 1988). Given the lack of adequate understanding of the relationship between diffusion of ICTs and labour market impacts in India, a study focussing on this becomes important. In this context, I seek to answer the following questions in this paper:

1. If the evidence from the automobile and component industry in India suggests that the promotion of ICT-based industrialization in developing countries leads to:

   - *Skill polarization*: skilled workers with better knowledge of use of ICTs have better career and work opportunities leaving the rest of the workforce in dead-end, low-paying jobs.[4]
   - *Deskilling*: ICTs render traditional skills redundant and therefore tend to deskill the workforce.
   - *Disintermediation*: ICTs reduce transaction costs involved in information flows within an organization and therefore undermine the need for middle management.

- *Gender neutrality*: ICTs reduce the need for physical labour and create white-collar jobs. Women, therefore, would find better employment prospects due to diffusion of ICTs.
- *Flexibility*: ICTs reduce co-ordination costs, allowing firms to rely on external labour markets, and therefore, promote greater labour market flexibility.
- *Autonomy at work*: ICTs ensure greater access to information among employees, therefore, helping decentralized decision making and giving employees greater autonomy at work.

2. Has the introduction of information technology had any quantitative impact on the level of employment and, if so, on what job profiles?
3. What are the implications for policy intervention in labour markets?

Method

Though the objective is to discern the effect of ICT use on work and employment, the above discussion clearly reveals the 'over-determined' nature of labour market outcomes. To disentangle the effects of IT use from other factors like organizational restructuring and product market changes is difficult, if not impossible. More important, however, is that such an analysis would fail to recognize the manner in which the process of ICT diffusion is enmeshed in an organizational and institutional regime. Hence, here the objective is to capture the labour market changes as firms deploy ICTs under such regimes. The changes would have obviously been different if the latter conditions were to be different. But the fact that firms in many hitherto closed low-income economies are striving to compete for global markets where quality and time to market are key success factors, validates the importance of our exercise to other similar regions.

Why ERP?

Among the fastest-growing software segments in the Indian domestic market in the last few years are enterprise resource planning (ERP) systems. ERP systems have revolutionized global business practices in a wide range of industries and across different scales of operation by facilitating information flows across various functions within firms, thereby reducing time-to-market and promoting decentralized decision making. Second, it makes available a considerable amount of information on various business processes, apart from increasing their availability. It can make available such information to all levels in the organization, bringing transparency to the entire organization. At another level, such transaction reducing effects are supposed to have a 'power effect' as well, that is, they enable the management to take more creative and accurate decisions, help them to control processes better, and provide them with a powerful tool to enforce organizational changes. Tracking how ERP is used offers an excellent means of comprehending the impacts of ICT diffusion.

In India, since ERP implementation began around the mid-1990s, the manufacturing sector has accounted for nearly 75 per cent of ERP system purchases, with the automobile and automobile component industry being one of the largest consumers. Under India's liberal policy regime since the mid-1980s, the automobile industry has been among the fastest-growing manufacturing industries, accompanied by intensified competition and fast-changing market conditions. The industry has increasingly moved away from the mass production model, with growing emphasis on competition through intense product differentiation, rapid launch of new designs, and incorporation of innovative features. Competition also requires firms to accelerate the speed of procurement, production and time-to-market.[5]

I have confined my analyses largely to the implementation of ERP solutions and the use of computer numerically controlled (CNC) machine tools on the shopfloor. However, all the firms studied have implemented ERP only within the last two to three years. As a result, its impacts are difficult to discern. Therefore, through interviews with systems personnel, senior management and human resources personnel, the attempt is to delineate the possible organizational and labour market changes that may result in the future. However, it was also observed that all firms had relatively robust legacy systems in which ERP systems have been introduced. The legacy systems too have altered work content and job types considerably. These changes are examined in order to capture the impact of ICTs.

Data Sources

The study is based on primary fieldwork carried out by case studies of four leading automobile firms in India. User respondents were chosen from different levels in the organizational hierarchy and semi-structured interviews used to access information. The data was collected from 80 employees. Relevant firm-level data was also obtained from annual reports, websites and from production and human resource departments. Fieldwork was done over a period of four months between May and August 2002.

To get a better insight, the impact is traced across different functional areas like purchase, quality control, inventory and stores management, production and material planning, R&D, human resources and finance. The major source of information was through semi-structured interviews with employees long associated with the firm in different departments and at various levels of the organizational hierarchy. In fact, quite a few of the managerial staff had, through vertical mobility, moved up from lower positions. Given the low turnover, most employees had been employed in the same firm for over 25 to 30 years, rendering this approach quite valid.

The firms studied manufacture a diverse range of components and vehicles. Two of them are leading medium and heavy vehicle manufacturers, of which one also manufactures passenger cars. The third firm is one of the largest manufacturers of two-wheelers in India and the fourth, a subsidiary of a passenger car manufacturer, makes transmission gears of a wide range for various client firms. All these firms have implemented either home-grown or imported ERP solutions.

Evidence from the Indian Auto Industry

Impacts may be quantitative or qualitative. By the former, I refer to the reduction in certain types of jobs and/or an increase in certain job types. In this, the exact magnitudes were not captured, given the long periods of IT use in all the firms studied and the various organizational restructuring undertaken by all these firms independent of IT use. In fact, I would argue that institutions play an equally, if not more, important role in this regard. Also, because the implementation of ERP solutions is very recent, its impacts will be noticed only in the future. Hence, I shall develop an analytical narrative of the changes taking place in the labour market as a result of organizational restructuring facilitated by use of ICTs. My emphasis would however be more on the latter dimension, that is, on qualitative impacts like changes in skill profile, employment contracts, work conditions and scope for meaningful work.

Quantitative Impact on Jobs

There are two distinct processes, but related by deployment of ICTs. One is redundancy of blue-collar workers through automation. In all the four firms studied, there has been considerable reduction in the number of blue-collar workers over time. There are variations across firms, partly due to differing growth prospects and market conditions. The deployment of CNCs and robots has led to reduction in the number of operators required on the one hand, and a shift in job type from that of an operator to that of a machine tender. However, in older plants, ordinary machine tools continue to be used along with CNCs. The reduction in the number of operators is not due to the use of CNCs alone. Respondents relate it to work reorganizations, like cellular/modular manufacturing, that allow them to tend to five to six machines per person, unlike the earlier mode of one machine per person.

Given the security of employment enjoyed by the workforce in the Indian organized sector, this reduction has been achieved by a freeze in recruitment of operators (trained in industrial training institutes) and non-replacement of employees retiring or leaving the firm. Also, attractive voluntary retirement schemes (VRS) have been introduced in two of the firms studied. In one of these firms, over 1,000 employees of the 13,000-odd workforce opted for this scheme between 2000–01 and 2001–02. Interestingly, product markets for both these firms have maintained a rather sluggish growth in the recent past, rendering such schemes viable to management. On the other hand, in the firm catering to the vibrant two-wheeler market, the management has been able to redeploy some of its redundant workforce. As the vice-president of the firm says, 'There has been a shift from data processing to management and some jobs have become redundant, but the two-wheeler industry is growing so rapidly that it will be possible to redeploy all the people.'[6]

The decline in the requirements of skilled operators on the shopfloor is best exemplified in the firm that has a nearly 50-year-old medium and heavy vehicle manufacturing plant and a five-year-old car manufacturing plant. While the former relies heavily on manual labour, the latter engages a large number of robots for most shopfloor operations like assembly, painting, etc. Highly skilled technicians and engineers monitor the functioning of the robots. The HR manager opines that the labour productivity in the car plant has to be at least four times that of the other plant.

Among the white-collar workforce, use of ICTs in the automobile industry has led to reduced need for jobs in most areas like documentation, inter-departmental communication, data processing and similar clerical work, apart from losses due to automation in the shopfloor. In all firms, in most departments, there has been a reduction in the number of staff. In terms of levels, there has been a marginal decline in the middle management level, considerably more in lower management levels and maximum among clerical staff. It must be reiterated that in this case, the redundancy is primarily an outcome of the use of ICTs in the organization that have simplified processes relating to computation, recording and transmission of vertical and inter-departmental information. The managerial and clerical staff has declined by 10 to 15 per cent in the last five years in all the firms studied. Department-specific information in two of the firms studied proved to be difficult as they had undergone considerable restructuring of departments recently, rendering collation of such data difficult.

In the two other firms, respondents cited a number of changes. For instance, in one firm, in the goods received and despatched division (called GR&D), the number employed came down from 12 to 4 between 1997–98 and May 2002. The functions here essentially involve ensuring that the ordered quantities of components and supplies are sent, and that bought out components reaching the factory, as well as their movement to the stores to be taken out during production are documented. With the introduction of an online tracking system, this process has been considerably simplified.

Many such data entry and data communications jobs have witnessed reductions in all departments. As for categories, there is a set of employees called 'monthly rated' workers or 'chasers', who belong to the unionized segment, but are paid on a monthly basis unlike the rest who are paid on a shift basis. They are low-skilled workers employed in data entry, who follow up on movement of goods and documents from and to various sections, and also ensure the transmission of documents containing relevant information within the firm. Thus, they are essentially involved in ensuring proper transactions within the firm to co-ordinate production. ERP systems and even the earlier legacy systems have considerably undermined the need for these workers.

Similarly, a number of employees were engaged in the purchase department to liaise with suppliers, answer their queries, follow up on orders placed, ensure payments, etc. Now, with online networking of suppliers, quite a few of these jobs have been made redundant. One of the workers in the purchase division had this to say: 'Earlier, there used to be three of us here and all we did was answer calls from suppliers most of the day. But now, I am the only one here and I may attend just 5 to 10 calls a day.' In the entire division, there used to be 20 to 25 personnel earlier, whereas in 2002, there were only six employees. The same is true of the 'bill passing' function in the finance department. In one firm, respondents in this division reported a decline from 12 to 6 in the last four years, and they attribute this to the new software systems. However, this reduced need has not resulted in layoffs of employees due to strong institutional protection to employees in these firms. As a result, different firms, depending upon their growth, product market conditions and management, rely on different strategies to offset the changing labour requirements.

There are a few functional areas/departments where there has been increased employment in recent years, indicating a possible complementarity of employment with the use of ICTs. The systems department is obviously one: its strength in one firm increased from 11 to 20, and from 20 to nearly 50 in another between 1999 and 2002. Apart from direct employment, firms also get IT professionals from IT firms on a temporary basis for implementation or consultancy in IT-related areas. The other departments that have witnessed increased employment are quality, R&D and sales and marketing divisions. This phenomenon is a direct outcome of the imperatives of global competition and not due to the use of ICTs. As was seen, however, there has been a reduction in labour absorption, which is likely to continue in the years to come.

Changes in Skill Requirements

Here again, the technical and the administrative and managerial workforce have been differentiated. On the shopfloor, with the use of CNCs, there has been a shift away from operative skills to machine tending skills. There has thus been more emphasis on cognitive and problem-solving skills and less on technical skills at this level. Workers are now required to watch out for faulty work and fix them. While operators are trained to correct standard errors, machinery suppliers handle more complex ones. Interestingly, there are differences in the extent to which CNCs impart new cognitive skills to users. In one firm, the programming was done by a few of the trained operators themselves. With their knowledge of high school mathematics, English and basic understanding of computers, they were trained to programme these machines. This is definitely a case of users requiring a shift from technical to cognitive skills, as has been pointed out by others (for example, Katz 2000). In another firm, a professional from the supplier firm programmes the machines periodically. Here is a clear process of deskilling. Even in the former case, not all the erstwhile machine operators were trained in programming, indicating the tendency of ICTs to create polarization of skills.

Simultaneously, with the introduction of new management techniques, emphasis has been placed on multiskilling. Multitasking has happened in three of the firms studied, and though it is due to organizational changes rather than the use of ICTs, the latter has facilitated this process by reducing the effort required on specific tasks. Thus, the 'organizational imperative', rather than the 'technological imperative' has led to this skill bias. Workers are being encouraged through appropriate incentives, and in two firms, they have been compulsorily made to learn new skills other than their current specialization. There are variations across different segments of workers. Unskilled workers have been asked to take up unskilled tasks in other departments, which in effect means that there is no skill upgradation. As for skilled and semi-skilled workers, they have been encouraged to enhance their current skills as well as learn other tasks. For instance, a welder could be trained to operate a computerized welding machine as well as taught other skills like painting or machining. Emphasis is given on multiskilling, as it is not possible for firms to gain quick benefits from skill enhancement due to increased automation.

Multiskilling ensures functional flexibility among the workforce, critical to cater to flexible product market conditions. Workers participate in cost-saving and quality enhancement measures as well, once again due to competitive pressures. Efforts are also under way to delegate more supervisory functions to the senior operators themselves. The process of skill acquisition on the shopfloor, as we shall see later, is, however, not entirely a step towards greater control over work among the blue-collar workers.

Among the white-collar workforce, low-level skills like data entry and clerical skills like bill passing and document preparation have been made redundant. On the other hand, there has been an increase in the need for skilled professionals like IT workers and design staff. Managers are required to move across departments to develop a comprehensive understanding of business processes in two of the firms studied. Control functions of managers are made easier, while also requiring them to use greater cognitive skills to interpret and take decisions based on information generated through management information systems. Employees in higher levels of organizational hierarchy of the firms and those with formal educational qualifications are being retrained for such changes. In other cases, like in the systems department, new skill requirements are by and large being met through employment of a different set of people in most cases, with higher formal qualifications compared to those whose skills have been made redundant.

Changes in Work Content

I have pointed to the shifting emphasis on cognitive skills among technical workers on the shopfloor. Given the reduced time required for machine tending, senior operators have also been asked to take up a few supervisory functions. Input of data into the system requires a certain amount of data entry work from the operators at the shopfloor, which was not welcome initially. It required some negotiation before it could be ensured.

Among the administrative jobs, the most important change brought about by the use of ICTs has been the increased speed and hence the reduced time to carry out many tasks. Before the advent of computers, everything had to be tabulated and calculated manually to arrive at final requirements. Further, organizations needed personnel to go to each of the departments to get the required information. At the shop-floor too, chasers were employed to find out how much of material had been processed, how much had been pending, etc. These were noted down and then used to arrive at future requirements. With the advent of computers, the need for manual calculation has been eliminated, which reduces time enormously. However, inter-departmental co-ordination still means sending people with printouts. The data would then have to be collated and requirements planned accordingly. With the implementation of ERP systems, such work becomes redundant. Inter-departmental movement of documents has more or less ceased.

Inventory control has become easier, and data entry in this department is done much faster. A respondent employed in this job for a long time says:

> Earlier, we used to work as a group. Now I do this all by myself. The others, have either retired or have been moved to other departments. For me, there is not much difference in the kind of work that I do. Earlier, I used to do write or note down manually on paper, but now I enter it into the machine and the machine generates whatever documents are required. But now since work gets done faster, I can handle the entire stores. But I can't say that it has benefitted me personally though it is a big advantage for the firm.

Planning functions too are easier. This has enabled firm managers to engage in more complex planning than what was done earlier. To cite an example, in all firms except one, production planning has moved from a monthly to a weekly plan and then to a daily plan. In other words, the organization has been able to react to changes in demand much faster, compared to the past. As the manager of production planning in one firm reported: 'It used to take me 20 to 30 minutes to draw up a production plan for one vehicle. Now I can do it in 2 seconds!' The main function of the department is one of planning and control. Now, because of implementation of ERP, control functions have been taken out of its domain because ERP enables the department to co-ordinate with other departments without much effort. Similarly, in another firm, a manager in the material planning division said that while earlier it took an entire night to produce the requirements plan, later on in the legacy system, it would take four to six hours. 'Now it takes only two to three hours.' Obviously, such savings on time gain organizational significance only under flexible and uncertain demand conditions.

The bill of materials (BOM) forms the base document for material planning, costing and generation of purchase orders. Preparation of the BOM is a complex and critical task, and given the lack of accurate department-specific information, it was very difficult to come up with a figure that reflects actual costs across departments. ERP systems, when used effectively, can sort out this major plan process. In all the firms studied, respondents from the senior management opined that the BOM had become more accurate and easier to prepare, enabling them to work with correct information for better micro-level planning.

Changes in Mobility

Among the blue-collar workers, a traditional career path has been to move into supervisory levels through time-based mobility. Of late, the number of these positions has come down, as ERP systems reduce labour requirements for monitoring. As stated earlier, senior operators are trained to take on a supervisory role in addition to their existing operative responsibilities. This process has definitely led to the development of multiple skills, while at the same time curtailing career paths. Thus, what we witness here is a transformation of career paths. Increasingly, mobility is tied to the acquisition of new skills as opposed to the time-based paths earlier in vogue.

Among the white-collar workforce, time-based mobility continues to exist in addition to inter-departmental movement of managerial staff. None of the respondents in this category felt that there have been changes in this regard due to the use of ICTs, though all human resource heads agree upon the slight reduction in positions as well as increase in this tendency in the years to come. This is partly due to the rapid turnover among graduate engineers, who are employed at the lowest levels in the managerial category. This turnover is a result of the boom in the software sector and the attendant high salaries. Hence, employees continuing to work in a particular firm are able to move along traditional career paths. One change has been the movement of some staff to the systems department due to acquisition of IT-related skills as well as to provide domain knowledge to aid systems development.

The hollowing-out due to reduced need for middle management has not happened. Organizations will seek to reduce personpower employed, as ERP systems definitely allow the removal of many routine functions of management. The outcome, however, will also depend on the power of middle management to resist such hollowing-out. Employment contracts have not changed in any of the firms studied. The only change in this regard has been the reduction in absorption of trainees from industrial training institutes (ITIs) into permanent employment due to the declining need for a blue-collar workforce. There is also a shift to the use of temporary workers for unskilled maintenance jobs, which of course cannot be attributed to ICTs.

Impact on Work Autonomy

ICTs through provision of transparency and easy access to information can enable employees to participate in decision making and therefore reduce hierarchical authority. On the other hand, they provide management with a powerful tool to exercise greater control over employees' work. We find little evidence of the former possibility among the case firms. Though new management techniques encourage workers' participation in decision making, this has been confined to areas like cost reductions on the shopfloor or in quality control through the formation of quality circles. Empowering workers by enabling them to take decisions based on increased information availability has not happened, though once again, HR heads claimed that the firm would introduce such changes in the future.

ERP systems provide a powerful tool to control the pace of work even in the shopfloor as well as concentrate power and authority among the top management. In ERP systems, the work process control in the shopfloor is designed in such a way that in case of bottlenecks in the flow of production process, it is possible to identify a particular point or person where it has come to a halt. As one production manager said,

> Earlier, the shopfloor used to be a black box. It took us a day to find out why the scheduled output had not come out of the assembly line. As a result, we hardly ever bothered to find out unless there were excessive delays. But now, it is possible to even set a trigger to go off if a particular task is not carried out within a standard time frame. It definitely offers

> the scope to exercise control on the shopfloor, but we haven't tried it as it may not be welcome among the workers .... Ideally, it should be possible for us to fix an average time for a specific task and introduce disincentives to prevent workers from overshooting the time limit. But we are still in an era when trade unions can stop work if they want to.

Another important advantage suggested is the usefulness of ERP systems in effective decision making. Earlier, the manager had to rely on statements made by lower-level management staff to arrive at solutions to problems. At the time of the study, however, he felt that he was able to get the information required to troubleshoot from the information system itself. Moreover, his reduced dependence on subordinates for such information meant that he had greater control over allocation of tasks during his work-time. More importantly, ERP solutions have introduced transparency in the organization with more accurate information available to employees at all levels. The extent to which this transparency has improved the effectiveness of processes is yet to be realized.

Impact on Firm Size

In India, even before new market conditions and technologies can encourage greater outsourcing, the auto industry has been characterized by high levels of outsourcing due to the government policy of reservation of production of some of the components for the small-scale sector (SSI) (Humphrey 1998; Okada 2000). While this has reduced the ability of firms to benefit from vertical integration, firms have also been forced to integrate uneconomical segments of the production process due to lack of competence of supplier firms in India. The levels of sub-contracting in all the firms studied were as high as 60 to 70 per cent. Use of ICTs has really not led to changes in these levels. While this is partly attributed to lack of adequate diffusion of IT use among the supplier firms, especially those in tier 2 and below, the primary factor has been the growing requirements of quality, brought about by global competition and the need to comply with global standards. Since the firms were unsure of the reliability of quality levels of most of their suppliers, they prefered to retain such operations in-house. Thus, as can be seen, a purely transaction cost-based explanation is inadequate to understand the impact of ICTs on firm size and structure.

It must, however, be stated that management in all the firms studied were keen to outsource some of the components if quality suppliers were available. While the growing demands on quality has led to working with some of the first tier suppliers to ensure required standards, it has also forced some of the larger, established tier 1 suppliers to get global quality certifications. Again, the extent of co-operation from the workforce and the costs of retrenchment will also determine the extent of outsourcing.

Changes in Organizational Form

Though three of the firms studied have undertaken considerable business process re-engineering prior to implementation of ERP systems, no dramatic change in organizational structure has been reported so far. Changes have largely been by way of combining functions that were earlier done by separate staff, with less reliance on subordinates for access to decision making information. Given the lack of codification of business processes and procedures in all the firms studied, the possibility of disintermediation, that is, the removal or decline in size of middle management in the near future, is remote. Employees' resistance to such changes is partly cited as a factor, as any kind of resentment may lead to reduced effectiveness of the firm to take advantage of existing systems. Apart from reduction in the numbers employed in certain levels like supervisors and clerical staff, no change was reported by any of the firms. On the shopfloor, even redeployment of workers from one floor (like the one for vehicles) to another (for engines) was not too welcome in the initial phases. However, the management felt that it might be required in future if full benefits are to be reaped. Thus, it appears that the ability of ICTs to create flatter organizations has been nullified due to the power exercised by the white-collar workforce.

ICTs and Labour Institutions

While trade unions representing labour's interests exist in all the firms, their relationship with the management has transformed from a more confrontationist one to that of a collaborative one since the mid-1990s. Increasingly, trade unions (TUs) concede that the changed market environment makes tremendous demands, failure to respond to which will negatively impact labour as well. TU officials perceived the pervasive use of ICTs as an inevitability that would lead to job losses. However, since labour in the organized sector is well protected from layoffs due to any possible redundancies, TUs have invested their energies in getting better terms for employees opting for VRS that were offered by all the firms studied. Also, performance-based incentive schemes have been accepted by TUs to enable firms to cope with product market changes.

Our evidence undermines the general belief that trade unions are a hindrance to the effective use of new technologies. In fact, in many instances, the management had used TUs to enlist the co-operation of the workforce in their restructuring attempts. This seems to support the findings of the other studies that find a positive relationship between trade union presence and a firm's ability to adopt new technologies effectively. Interestingly, in one firm, installation of computers on the shopfloor had some positive externalities, according to a senior manager. In September 2001, when there was some unrest among the workers, there was no work for a few days. Usually under such circumstances workers would damage some machines, and when work resumed, maintenance staff would have considerable work to do. However, this time since they were keen to play games on the computers, the machines were hardly damaged! Also, questions about resistance to installation of computers met with similar answers relating to acquaintance with computers as a symbol of elite consumption. To cite one response, 'They are happy to have a computer in front of them. Their children learn computers at school and so they are proud to acknowledge that they too know how to use them'. ICTs, with their uses in terms of consumption, appear to have reduced resistance to any perceived negative effects in the realm of production.

Summary and Implications

By and large, firms are yet to take full advantage of ICTs in the Indian automobile industry and to that extent, the impacts are yet to be realized. This is partly due to the relatively late adoption of ICTs on the one hand, and the recent imperatives of global competition with its reduced time-to-market, flexibility and quality requirements on the other. However, tendencies can be observed that have important implications for labour market intervention in traditional manufacturing sectors. An important component of public policy in India with regard to the labour market has been the high employment security guaranteed to formal sector employees. It has been suggested that such protection and the presence of strong trade unions prevent firms from adopting new technologies and efficiently utilizing human resources.

Our observations contradict such positions and in fact indicate the facilitative role played by trade unions in the implementation of ICT-based technologies. Also, unlike other countries, imperatives of globalization and new technologies have not led to drastic reduction in employment. On the contrary, at least some firms appear to have leveraged their competencies, including labour skills, to compete effectively (Okada 2000). While there is a declining trend as far as employment absorption is concerned, it has not led to layoffs of employed personnel. Instead, it has forced firms to redeploy a segment of the labour force in jobs where complexities have increased, like quality and cost control, not to speak of design and domain support to information systems implementation. The extent to which this redeployment has taken place varies according to market conditions. It is more frequently observed in firms operating under buoyant market conditions. It also depends on the skill levels of employees, and more importantly, on the kind of skills they have acquired. Employees with IT-related skills are more likely to be redeployed.

As a result, there is a tendency towards skill polarization, as only those with an ability to acquire such skills have better growth prospects within a firm. The ability depends on a certain amount of formal education critical to acquire cognitive skills. Increasingly, firms will tend to recruit personnel with better managerial and research training than labour with just technical skills. At the macro level, it therefore appears that there may be a steady decline in skills provided by traditional vocational training institutions like ITIs. Further, with the reduced numbers required for monitoring work, mobility prospects are likely to be reduced as well. However, in most of the firms studied, appropriate incentive schemes are in place to enable employees to acquire the requisite skills.

The marginal presence of women employees in the auto industry implies that ICT diffusion in traditional manufacturing does not really affect them. Nonetheless, with the expansion in systems departments, a small but growing number of women professionals are employed in the firms. The growth in importance of sales and marketing functions has also contributed to this process. Differences in mobility prospects within these departments are not clear, though in none of the firms studied women professionals have been employed in top managerial positions. There are intra-gender differences as well in accessing IT-enabled jobs due to differences in skill levels and formal education.

Interestingly, ICTs have not led to greater outsourcing and hence smaller firm size in India. The growing emphasis on quality and the low competence in this regard among the vendor firms prevents firms from such practices. Thus, while cost-cutting pressures and the need for scope economies push firms to outsourcing, need for enhanced quality restricts firms from such outsourcing, not to speak of the employment security available to labour.

ICTs do reduce the need for routinized work. They also invest enormous power in the top management to exercise control over activities of the firm at all levels. Easier access to information at all levels also offers the potential to decentralize decision-making power, thereby enhancing the autonomy of labour. At this stage, it appears that the former effect is likely to increase, as ICT diffusion has essentially been a top–down effort. Even if the latter possibility were to be realized, whether it would mean scope for more meaningful work is not clear, when we bear in mind the increased pressures on time-to-market and the need to adapt rapidly to changing market conditions. Such work conditions are only beginning to creep into the Indian manufacturing sector. The impacts on work and employment appear, therefore, to be crucially determined by product market imperatives. ICTs do enable such changes, but also provide scope for labour to negotiate changes in ways that may be beneficial to them.

Notes

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1. K.C. Laudon and K.L. Marr, 'Information Technology and Occupational Structure', http://hsb.baylor.edu/ramsower/acis/papers/laudon.htm.
2. The following discussion is largely based on Brynjolfsson et al. (1993).
3. '… in-firm training still requires a base of educated manpower to work with, which can be provided only by general schooling' (Okada 2000: 30–31).
4. To avoid problems associated with conceptualizing skill, we use a rather broad definition suggested by Okada (2000: 10): 'Skills refer to the range of capabilities to apply and transfer knowledge into action in production processes in manufacturing, including managerial, organizational, and technical skills that individuals acquire through either schooling or on-the-job training'.
5. www.karkhanisgroup.com/indusol/autosol.htm.
6. www.tvsmotor.co.in/prdetail.asp?pressid=6.

References

Aronowitz, S. and W. DiFazio. 1994. *The Jobless Future: Sci-Tech and the Dogma of Work*. Minneapolis: University of Minnesota Press.

Bell, D. 1973. *The Coming of Post-Industrial Society: A Venture In Social Forecasting*. New York: Basic Books.

Blau, P.M., C.M. Falbe, W. McKinley and P.K. Tracy. 1976. 'Technology and Organization in Manufacturing', *Administrative Science Quarterly*, 21(1): 20–81.

Braverman, H. 1974. *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century*. New York: Monthly Review Press.

Bresnahan, T., Brynjolfsson, E. and L. Hitt. 2002. 'Information Technology, Workplace Organisation and the Demand for Skilled Labour: Firm-Level Evidence', *Quarterly Journal of Economics*, 117(1): 339–76.

Brynjolfsson, E. and L.M. Hitt. 1998. 'Information Technology and Organizational Design: Evidence from Micro Data', Working Paper. Cambridge, MA: Sloan School of Management, MIT.

Brynjolfsson, E., T.W. Malone and V. Gurbaxani. 1988. 'The Impact of Information Technology on Markets and Hierarchies', Working Paper No. 2113–88, Center for Coordination Science, Sloan School of Management, MIT, Cambridge, MA.

Brynjolfsson, E., T.W. Malone, V. Gurbaxani and A. Kambil. 1993. 'An Empirical Analysis of the Relationship between Information Technology and Firm Size', CCS-TR#123, Center for Coordination Science, Sloan School of Management, MIT, Cambridge, MA.

Carley, K.M. 2000. 'Occupational Change and the Digital Economy: A Computational Organization Science Perspective', in E. Brynjolfsson and B. Kahin (eds), *Understanding the Digital Economy: Data, Tools, and Research*. Cambridge, MA: MIT Press, 325–51.

Carnoy, M., P. S. Pollack and P.L. Wong. 1993. 'Labour Institutions and Technological Change: A Framework for Analysis and a Review of the Literature', Discussion Paper No. 61, International Institute for Labour Studies, Labour Institutions and Economic Development Programme. Geneva: ILO.

Castells, M. 1996. *The Rise of the Network Society*. Malden, MA: Blackwell.

Clement, A. 1991. 'Designing without Designers: More Hidden Skills in Office Computerization?' (paper presented at the fourth conference on *Women, Work and Computerization*), 30 June–2 July, Helsinki, Finland.

Edquist, C. and S. Jacobsson. 1988. *Flexible Automation: The Global Diffusion of New Technology in the Engineering Industry.* London: Basil Blackwell.

Edwards, R. 1979. *Contested Terrain: The Transformation of the Workplace in the Twentieth Century*. London: Heinemann.

Forester, T. (ed.). 1985. *The Information Technology Revolution*. Cambridge, MA: MIT Press.

Francis, A. 1986. *New Technology at Work*. Oxford: Clarendon Press.

Freeman, C. and C. Perez. 1988. 'Structural Crises of Adjustment, Business Cycles and Investment Behaviour', in G. Dosi, Ch. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory*. London/New York: Pinter Publishers.

George, J.F. and J.L. King. 1991. 'Examining the Computing and Centralization Debate', *Communications of the ACM*, 34 (7): 62–72.

Greenbaum, J. 1976. 'Division of Labour in the Computer Field', *Monthly Review*, July/August: 40–55.

Grossman, S. and O. Hart. 1986. 'The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration', *Journal of Political Economy*, 24(4).

Gurbaxani, V. and S. Whang. 1991. 'The Impact of Information Systems on Organizations and Markets', *Communications of the ACM*, 34(1): 59–73.

Hafkin, N. and N. Taggart. 2001. *Gender, Information Technology and Developing Countries: An Analytic Study*, produced for the Office of Women in Development, Bureau for Global Programs, Field Support and Research. Washington, DC: USAID.

Holfman, D.L. and T.P. Novak. 2000. 'The Growing Digital Divide: Implications for an Open Research Agenda', in E. Brynjolfsson and B. Kahin (eds), *Understanding the Digital Economy: Data, Tools, and Research*. Cambridge, MA: MIT Press.

Humphrey, J. 1998. 'Globalisation and Supply Chain Networks: The Auto Industry in Brazil and India, http://www.ids.ac.uk/ids/global/pdfs/jhilo.pdf.

ILO (International Labour Organization). 1988. *Technological Change, Work Organization and Pay: Lessons From Asia*, ILO Labor-Management Relations Series, No. 68. Geneva: ILO, http://www.ilo.org/public/english/bureau/inst/papers/1993/dp61/index.htm.

———. 2001. *World Employment Report 2001: Life at Work in the Information Economy*. Geneva: ILO.

Katz, L. 2000. 'Technological Change, Computerization, and the Wage Structure', in E. Brynjolfsson and B. Kahin (eds), *Understanding the Digital Economy: Data, Tools, and Research*. Cambridge, MA: MIT Press, 217–44.

Klein, B., R. Crawford and A. Alchian. 1978. 'Vertical Integration, Appropriable Rents and the Competitive Contracting Process', *Journal of Law and Economics*, 21 (October): 297–326.

Kling , R. and S. Iacono. 1984. Computing as an Occasion for Social Control, *Journal of Social Issues*, 40(3): 77–96.

Knights, D. and H. Willmott (eds). 1988. *New Technology and the Labour Process*. London: Macmillan.

Kraft, P. 1979. 'The Industrialization of Computer Programming', in A. Zimbalist (ed.), *Case Studies on the Labor Process*. New York: Monthly Review Press, 1–17.

Laudon, K.C. 1974. *Computers and Bureaucratic Reform*. New York: Wiley.

Michie, J. and M. Sheehan. 2003. 'Labour Market Deregulation', "Flexibility" and Innovation, *Cambridge Journal of Economics*, 27: 123–43.

Mitter, S. and S. Rowbotham (eds), 1995, *Women Encounter Technology: Changing Patterns of Employment in the Third World*. Routledge: London and New York.

Morrison, C.J. and E.R. Berndt. 1990. 'Assessing the Productivity of Information Technology Equipment in the U.S. Manufacturing Industries', Working Paper No. 3582. Cambridge, MA: National Bureau of Economic Research.

Murphy, M. 2002. 'Organisational Change and Firm Performance', STI Working Paper No. 2002/14, Paris: OECD.

Ng, C.C.S. and C. Yong. 1995. 'Information Technology, Gender and Employment: A Case Study of the Telecommunication Industry in Malaysia', in S. Mitter and S. Rowbotham (eds), *Women Encounter Technology: Changing Patterns of Employment in the Third World*. Routledge: London and New York, 177–204.

Okada, A. 2000. 'Workers' Learning through Inter-firm Linkages in the Process of Globalization: Lessons from the Indian Automobile Industry', Ph.D. Dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Ormos, M. and M. Blameble. 1989. 'Strategies of Introduction of Office Automation in Mixed and Traditionally Female Jobs within Two Work Units of the French Electricity and Gas Public Utility Companies', in K. Tijdens, M. Jennings, I. Wagner and M. Weggelaar (eds), *Women Work and Computerization: Forming New Alliances*, Amsterdam, North-Holland.

Wood, S. 1989. 'The Transformation of Work', in S. Wood (ed.), *The Transformation of Work: Skill, Flexibility and the Labour Process.* London: Unwin Hyman.

Zimbalist, A. (ed.). 1979. *Case Studies on the Labor Process*. New York: Monthly Review Press.

Zuboff, S. 1984. *In the Age of the Smart Machine*. New York: Basic Books.

13

The Digital Divide, ICT Development and Telecommunication Reform in China

Wensheng Wang

Introduction

As China is undergoing rapid political, economic and social change, its telecommunication sector has been continually growing at annual rates of 30–50 per cent. By the end of 2002, China had the second largest public telephone network and the largest mobile phone market in the world. The number of telephone subscribers had reached 420 million. This paper seeks to address the uniqueness of information and communication technology (ICT) development in China, which includes telecom policy reform and regulation, and the pace and pattern of diffusion of ICTs. The fast pace of development of the telecommunications sector largely relies on the so-called 'competition without privatization' policy, which is deeply rooted in the integrated strategy of national economic reform, encapsulated by the term 'socialist market economy'. This means using market forces to improve the efficiency of production while retaining a managed, predominantly state-owned economy and authoritarian control over political activities (Mueller 1998).

However, despite the rapid diffusion of telephony and the internet, China is facing a severe problem of a digital divide that exists not only between China and developed countries but also among its own regions and social groups. The issue of applying appropriate telecommunication policies and Digital Opportunity Task Force (DOT-Force) strategy to bridge the digital divide is yet to be addressed adequately. This is a big challenge to the Chinese government because the digital divide seems likely to undermine its efforts to catch up with the developed world, to worsen the existing domestic imbalance of social and economic development, and to generally hinder the national benefits from ICT application.

This paper first of all introduces the current development of China's telecommunication sector and focuses on the difficult and complex process of China's telecommunication reform. Second, China's DOT-Force policy that addresses the digital divide and identifies ways of bridging the digital divide is especially mentioned. Finally, several conclusions are presented based on the previous discussion.

The Current Development of ICTs in China

As the largest developing country in the world, China has recognized the role of ICTs:

> Developing countries have great potential to compete successfully in the new global market, but unless they embrace the ICT revolution promptly and actively, they will face new barriers and the risk of not just being marginalized but completely bypassed. These countries, by extensively and innovatively using ICT for their development, were able to extract value from globalization, rather than watching globalization extract value from them (STOA 2001: 9).

The government of China is committed to building the information infrastructure and connecting all citizens. China focused its industrial policy on infrastructure and high technology. This policy led to dramatic expansion of the telecommunications infrastructure, personal computer (PC) manufacturing and adoption, led to an awareness of the internet and information technology (IT) applications, and created a pool of trained demanding users and the managers and technicians to serve them.

From the mid-1990s, the fast growth of ICTs highlights the characteristics of China's telecommunication development. By the end of 2002, the capacity of national telecommunication had increased by 28 per cent over 1997. In only five years, 1997–2002, China connected more than 15.8 million mobile lines with a 60 per cent annual increase and 17 million main telephone lines with a 42 per cent increase. The use of long-distance optical cable increased by 22,000 km (Table 13.1).

TABLE 13.1 **Telecommunication Development in China (1997–2002)**

	1997	*2002*	*Growth (%)*
Local Exchangers (million sets)	112.7	134.9	19.7
Long-distance Exchangers (million sets)	4.4	4.8	10.5
Mobile Exchangers (million sets)	25.9	41.6	60
Long-distance Circuits (million lines)	1.1	1.6	42.3
Long-distance Optical Cables (thousand km)	151	173	15
Telephone Lines (million)	70.3	87.4	24.2
Telephone Sets (million)	101.1	131.4	30

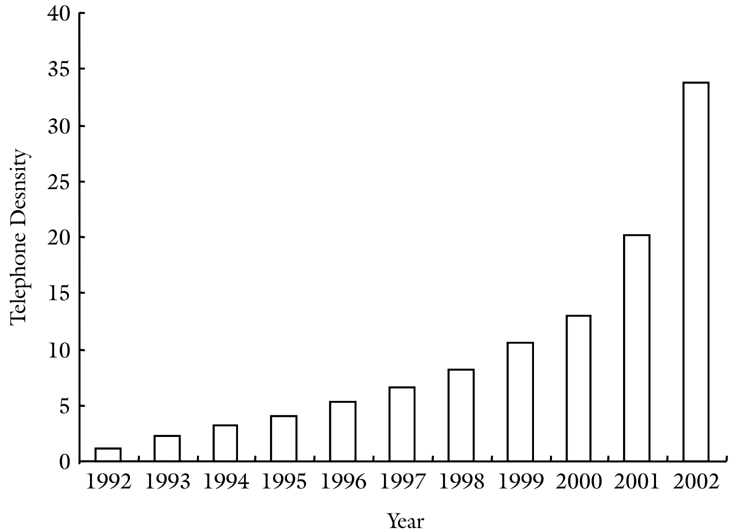
Source: MII 2003.

Figure 13.1 illustrates the development trend of China's telephone density between 1992 and 2002. By the end of 2002, the national telephone density rate had reached 33.7 per cent.

Compared to the growth of telephone penetration, the development of the internet has been even faster. Because the Chinese government heavily invested in a dozen backbone networks and in the PC-manufacturing industry for an entire decade, networked computer and internet application has spread at an unprecedented pace nationwide. By June of 2003, the number of networked computer and internet users[1] reached 25.7 million and 68 million respectively (Figure 13.2).

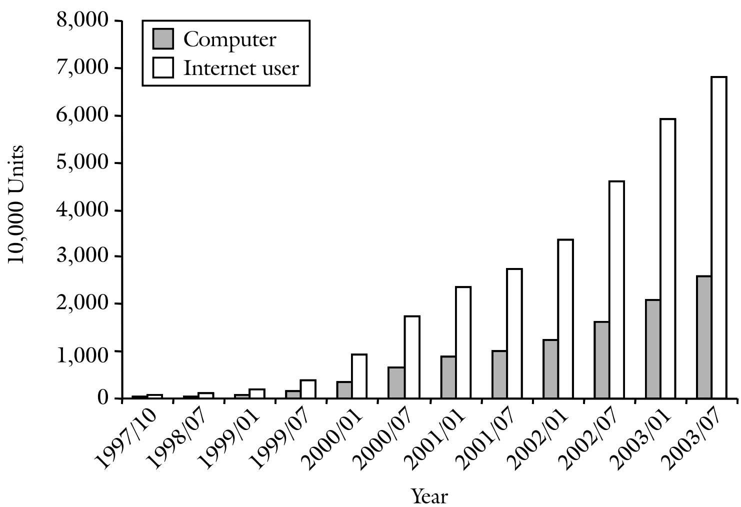
However, despite the fast growth of telephony and the internet, the national telephone density and the internet user rate remain relatively low. Furthermore, considering that the concentration of internet users is largely in urban areas, the rural internet user rate is lower still. The situation in telephone application seems much better, but is still similar to the internet situation. Indeed, two striking characteristics demand notice in China's telecommunication development: the fast pace of development and the severe problem of a digital divide.

FIGURE 13.1 Telephone Density in China



Source: MII 2003.

FIGURE 13.2 Development of Networked Computer and Internet Use in China



Source: CNNIC 2000.

China's Telecommunication Reform and Policy

The evidence of China's impressive and unique economic reform is in the telecommunications sector. While the opening up of the telecommunications market and privatization of telecommunications services have become a worldwide trend, China's telecommunications sector remains state owned in major service areas. Despite all the apparent shortcomings of state-owned monopoly, the sector has been growing at annual rates of between 30 and 50 per cent since the 1990s. The Chinese government wants to achieve

> an economic system that integrates the basic system of socialism with the market economy in an organic way whereby, under macro-regulation and control by the state, the market mechanism plays a fundamental role in the disposition of resources and [the state achieves] a high degree of balance between efficiency and fairness (Mueller 1998).

The Ministry of Posts and Telecommunications (MPT) of China has monopolized telecommunications operations for more than four decades. Recognizing its incapability to monopolize the huge market and to meet increasing demands, the Chinese government launched a telecommunications reform programme that was aimed at creating a competitive market. Although privatization and free market in the telecommunications sector would attract more investment, improve efficiency and stimulate development, it would also undermine the government's powers of controlling information flow, surveillance and censorship. Therefore, the Chinese government does not simply follow a private, liberalized telecommunications order, but carefully manages the introduction of market forces and balances development goals with its need for control. As a result, while telecommunication operators remain state owned, the basic telecommunication market has advanced from a monopoly to a duopoly, and it is now being extended to pluralistic competition.

Telecommunications Operation Reform

Prior to 1978, the Chinese telecommunications industry was under the monopoly of the state and specifically controlled by the Ministry of Post and Telecommunications. The telecommunications sector was seen purely as a tool for administrative needs. Telecommunications expenses were classified as 'non-productive' and were often subjected to cuts in hard times. By 1978, China had a telephone switching capacity of 1.75 million sets and the telephone density rate was a mere 0.18 per cent (Ding 2000). In fact, China's telecommunications sector was one of the least developed in the economy when the reforms were launched.

The programmes of reform began with decentralization of decision making and profit, via the contractual responsibility system (CRS). The CRS was supplemented by a new nationwide accounting system in 1985. Under the CRS, the telecommunications enterprises have gained greater autonomy in management and have developed an incentive structure that strongly encourages business expansion. Further structural reforms, separating postal and telecommunications operations from each other and from governmental oversight functions, were implemented in 1988–91.

In the 1990s, the Chinese government undertook a series of reform measures of strategic significance in the telecommunications industry. Within less than three years (1998–2000), the Chinese government accomplished the tasks of reorganizing industry sectors, dismantling monopoly and introducing competition in all the service sectors, including basic and value-added telecommunications and information services. In 1994, China Unicom was formed and allowed to build and operate nationwide cellular networks. To promote fair competition in the paging service, the paging sector of China Telecom was turned into a separate company called Guoxin Paging Ltd.

Aiming at deep reform, a new round of policies were launched in 1998. The basic idea was to form a fair market by breaking up China Telecom and at the same time to strengthen Unicom through market restructuring. China Telecom, Hong Kong, China Mobile Group, Jitong, and China Net Communication were also formed. Competition has now been introduced among state-owned institutions (Gao and Lyytinnen 2000).

At the beginning of the new century, competition in the domestic telecommunications market became fierce, with each of the seven telecommunications companies having their own advantages. China Telecom has more than 100 million telephone customers, holds 99.9 per cent of market shares, and has 70 to 80 per cent of the country's long-distance telephone network. It has linkages with more than 2,000 counties and cities and controls urban domain networks. China Mobile holds an 80 per cent share of the mobile telephone market and its position is unchallenged. China Unicom Mobile Telephone and IP Telephone developed side-by-side, with their long-distance optical fibre communications networks covering 250 counties and cities, and the leased long-distance telecom network connecting over 100 cities. With wide-band telecommunication network as its core, China Netcom is the epitome of the use of sophisticated technology. China Railcom relies on its own advantages and has 1 million fixed telephone users. Jitong Telecommunication's advantage is in IP telephones, and China Guangdian's (Broadcast and Television) in cable television transmission networks. The State Power Corporation is also preparing to enter the telecommunications market. The country will then have the eighth telecommunication operator, including China Powercom.

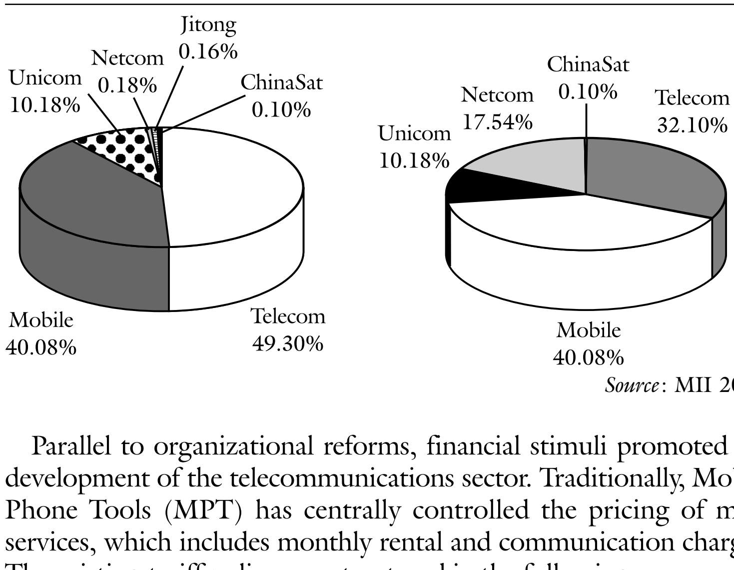
In recent years, it has become widely recognized that the obsolete and strict monopoly model meets neither the needs of the public nor the national policy objectives. The ITU's (International Telecommunications Union) Advisory Group on Telecommunications Policy recommends an adjustment of current policies and structures in order to increase private participation in the sector, to develop competition, and to shift the government's role from ownership and operation to policy management and regulation. China needs to further break up monopolies in its telecommunication sector to promote competition. The move is seen as one of the most important steps planned for the successful transformation from the planned economy to a market economy in the telecommunications sector.

The solution for breaking up China Telecom was finally settled by the Chinese government in 2001, which divided the company into southern and northern parts. The convergence of the branch companies of China Telecom in 10 northern provinces, China Netcom and Jitong, created China Netcom Corporation. The other branch companies of China Telecom in 21 southern provinces were grouped as China Telecommunications Corporation. These two reorganized corporations maintain the existing businesses of China Telecom and have been allowed to establish local telephone networks and operate local fixed line services in each other's service areas. Both companies offer reciprocal services such as equitable access. The southern and northern parts own 70 and 30 per cent, respectively, of the national transmission network as they control all local telephone networks in their service areas. After this reorganization, the telecom market in China will present a new competition pattern with China Telecom, China Mobile, China Netcom, China Unicom, ChinaSat and China

Railcom as the main operators, namely, the pattern of '5+1' (Deng 2002). In this new pattern, China Mobile tops the market in terms of revenue, and China Telecom and China Netcom are the second and third contenders. Figure 13.3 shows the change in the revenue share of the main telecommunication operators after the breaking up of China Telecom.

It is important to be aware of the fact that despite the competition in China's telecommunication market being severe, there is still no real competition because all the competitors are state-owned enterprises and licences separate and limit the competitor's scope of service. For instance, China Telecom does not have a licence to carry out mobile telecommunication services. Moreover, laws and regulations that are essential for fair competition need to be improved.

FIGURE 13.3 **Change in Share of Total Revenue after Reorganization of the Telecom Sector**



Source: MII 2003.

Parallel to organizational reforms, financial stimuli promoted the development of the telecommunications sector. Traditionally, Mobile Phone Tools (MPT) has centrally controlled the pricing of most services, which includes monthly rental and communication charges. The existing tariff policy was structured in the following manner: the rate of return was lower for local (intra-city) services and higher for long-distance and international services. At the end of 1990, the ministry set a price cap according to local telephone companies' average costs with a mark-up for profit. Local telecommunications companies were authorized to set their own intra-city rates not exceeding the cap, subject to the approval of the local government's price control authorities (Ding 2000). In addition, the Chinese government also gave high priority to the legislature work and industrial supervision of telecommunications. In 2000, the Regulations of Telecommunications of the People's Republic of China and the Administrative Methods of Internet Services were promulgated, a centralized telecommunication regulatory body was created, and the development of China's telecommunications and industrial administration were put on the track of the rule of law. (Lin 2001).

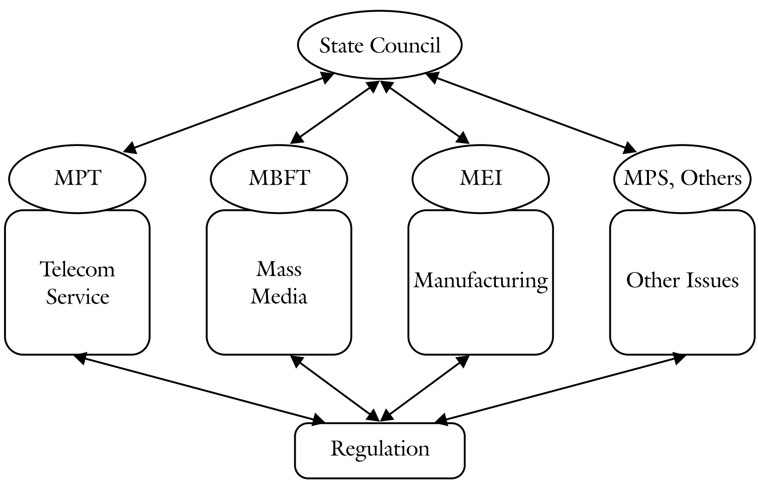
The new telecom regulation has 81 articles, which define basic and value-added services, in order to be fast, accurate, safe, convenient and affordable. Licences for all basic and value-added services that cover more than two provinces will be issued by the State Council. Basic services have government-set (or guided) prices and market-based prices, while value-added services would use market-based prices or government-guided prices. The responsibilities, including universal access obligations, have been detailed in the regulation for service providers. Restricting users to select other providers, using unreasonable cross subsidies, or charging below-cost prices to drive out competition, are considered illegal. Telecom infrastructure (facility construction and network access) will still be planned and highly regulated by the central and local governments, and no organization or individual will be permitted to engage in creating, duplicating and disseminating content that conflicts with constitutional principles, harms national security, interests and unity, damages religious policy, promotes superstition, destructs social discipline and stability, or impairs lawful rights of any other individual. Penalties for violating the articles on telecom security are quantified in the last chapter of the regulation.

Management Reform

For most countries during the monopoly period, the MPT has been the sole regulator and public operator. But in China, the situation was more complex due to influence from a planned economy that had employed a centralized, fragmented administrative system. Before 1994, the regulatory regimen had been fragmented, dominated by the MPT and other ministries (Figure 13.4). China's State Council was the official top decision maker of the regulations. However, the Council often relied on subordinate agencies to formulate and carry out policies.

As part of the nationwide reform initialized by the central government, the aim of the regimen of regulatory reform is to separate enterprise management functions from government branches. The Ministry of Information Industry (MII) was established in 1998 with the goal of completely separating government and enterprise functions, eliminating monopoly and establishing competition. The MII became a neutral regulator by taking over the regulatory functions of MPT, while ceding the functions of enterprise. MII was organized into departments responsible for policy making, administration, market regulation and internal affairs. As a neutral regulator, MII began to execute the regulatory function by implementing a proper asymmetric regulation. It is necessary to note that although the MII is the supreme regulator of telecommunications policy, local policy makers, to some extent, can also create flexible and elastic investor policies to attract outside investment and to adapt to local conditions (Gao and Lyytinen 2000).

FIGURE 13.4 **The Past Regulatory Regime**



Source: Gao and Lyytinen 2000.

ICT Strategy, Policy and Regulation

China is a vast country with diverse geographies and local economies. Therefore, it seems extremely difficult to bring a telecommunication service to every region at the same time. Creating appropriate telecommunications policies to meet the demand of all areas is a great challenge for the Chinese government. Hence, a number of different policies and regulations will be required.

National Informatization In order to take advantage of the digital opportunities, the Chinese government has formulated the policy of national informatization construction to promote the upgrading and optimization of Chinese industries while realizing the goals of industrialization and modernization. In the Ninth (1996–2000) and Tenth (2001–05) Five-year Plans, the Chinese government gave priority attention to the important role of the information and communication industry. Meanwhile, a series of important application programmes represented by Golden Card, Golden Bridge and Golden Gate have been initiated one after another, which have strongly promoted informatization. Social informatization was drawn up as the strategic initiative underlying the whole modernization drive to achieve rapid social and economic development.

Universal Service By 2001–02, a national strategy had developed with emphasis on ICTs as stimuli for development in society, politics, culture, health, etc. China has put a strong emphasis on the importance of information technology within the context of China's Tenth Five-year Development Plan, covering 2001–05. According to the Plan, widespread usage of computers and the internet in all parts of China will be promoted. The strategies envisaged in the plan include the following elements:

- Development and utilization of information resources;
- Linkage of IT with cultural industry;
- For universities and schools at various levels to provide education through active utilization of computers and the internet;
- Popularization of the use of information technology among the general public;
- Construction of infrastructure for modern ICTs;
- Construction of users' connection network; and
- Combination of three networks, namely, telecommunications, TV and computers.

In its recent Telecommunication Regulations and Rules of P.R. China, the government stipulates that telecom service providers/operators must fulfill the obligation of 'universal service', which means that all citizens living anywhere in the country should be able to access telephone and other most basic communication services at a universally acceptable/affordable price.

WTO, Privatization and International Competition

China's entry to the World Trade Organization (WTO) is generally recognized as an external force deepening and accelerating telecommunication reform, because the domestic telecommunication market will gradually open up to foreign investors and competitors. According to the WTO agreement, China will have to eliminate restrictions in the imports of pagers and mobile phones as well as regional restrictions on landline telephones by 2007. Within 2002–06, China is required to allow foreign investors to own up to 49 per cent of the company stakes in all telecommunication fields, and up to 51 per cent shares of some fields. China's entry into WTO will further open up the telecommunications market and attract more domestic and foreign investors. The emergence of multiple markets will no doubt fuel strong competition, which will in turn improve quality, lower prices and stimulate demand. In this way, China will rapidly become an IT society.

After China's entry into the WTO, some researchers are calling for opening all telecom business, including basic telecom business, first to Chinese privately-run enterprises (*People's Daily* 2000). China has already promised to open its domestic market to foreign investors after its WTO entry, so it is natural that the market should be open to domestic investors (*China Daily* 2001). Many analysts also believe that opening telecommunication business first to the domestic private enterprises will help China meet the fiercer competition after its accession to the WTO. Moreover, the outstanding performances of Chinese private enterprises since the 1990s have demonstrated that they are an important new force of the telecom industry and have the ability to play a greater role in this sector. Participation of private enterprises will help speed up the reform and transformation of mechanism of China's telecom industry and will facilitate a faster development of the telecom industry and other key state-owned enterprises.

Foreign investment had played an important role in ICT diffusion in China even before China's accession to the WTO. Foreign investment in China's telecommunications market is mostly in the area of manufacturing equipment to supply to operating companies. There are about 170 foreign joint ventures producing a wide range of equipment. The world's five largest switching equipment manufacturers have large production facilities in China. Alcatel, for example, has invested about $420 mn in 21 ventures. Among wireless equipment suppliers, Motorola has invested over $1 bn in its China operations. Ericsson, Motorola and Nokia mobile phones are widely used throughout China. As foreign manufacturers previously excluded from supplying telecommunications network equipment attempt to gain market share, some analysts expect price wars across most market segments (Dahlman and Aubert 2001).

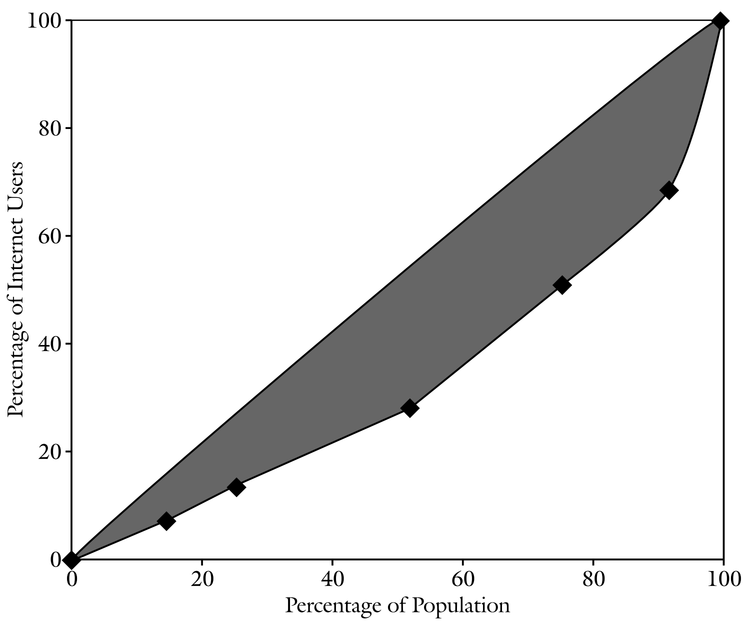
Analysts point out that with the involvement of foreign-run companies, real competition should be introduced in China to break the monopoly of state-owned telecom giants under the WTO regulation. China's telecommunications sector is taking steps to prepare for international competition brought by the country's impending entry into the WTO. 'With the participation of foreign investors, we strive to build a sound competitive environment in the domestic market and aim to achieve new growth after entering the world trade club', the Minister of the Information Industry, Wu Jichuan said.

Digital Divide in China and DOT-Force Policy

As mentioned earlier China is facing a severe problem of digital divide that exists not only between China and developed countries but also among its own regions and social groups. In the international context, the volume of statistics is impressive and persuasive: by the middle of 2000, America had 164 million computers, with a computer being shared by less than two persons on an average, and Germany had 30.6 million computers, with a computer being shared by less than three people on an average. The corresponding figures for China, on the other hand, were 15.9 million computers and 80 people per computer.

Figure 13.5 uses data on internet connectivity to plot a digital Lorenz curve for 30 provinces in China. The inequality is evident: 10 per cent of China's population constitutes more than 35 per cent of its national internet subscribers. The application of appropriate telecommunication policies and DOT-Force strategy to bridge the digital divide is a big challenge for the Chinese government, because this seems likely to undermine China's efforts to catch up to the developed world, to worsen the existing domestic imbalance of social and economic development, and to generally hinder the national benefits from ICT application.

FIGURE 13.5 **National Inequality in Internet Use in China (2002)**



Source: Based on CNNIC (2003) and author's calculations.

To investigate the digital divide in China, we discuss the current situation of ICT development, the extent of digital divide among regions, social groups and the remedial measures taken by the Chinese government in the form of new telecommunication policies.

Current Situation of Digital Divide in China

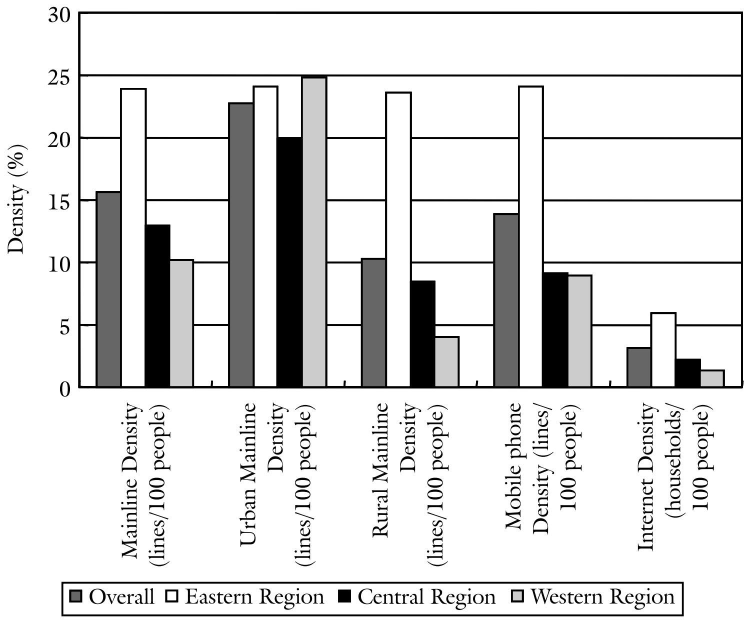
China is facing the problem of digital divide due to imbalance of diffusion of ICT infrastructure, high online charges, insufficient qualified staff, imperfect network legation and shortage of information resource in the Chinese language. Close attention should also be paid to the digital divide between regions, urban and rural areas, social segments with different income and education levels, and gender.

Digital Divide among Regions The current situation of telephone application and internet use indicates the severity of the digital divide among regions in China. Traditionally, China's regions have been divided into three categories according to their geographical location and administrative divisions: eastern, central and western. The eastern region possesses the largest segment of total internet users, and the central and western regions possess the smallest fractions, being less than half of the users in the eastern region.

Most researchers have found a close linkage between geographical features and telecommunication application; this linkage shows that geographical accessibility relates significantly to telecommunication access. The topographical feature of each region, from East to Central to West China, shows plains, hilly and mountainous areas, respectively. The second factor is demography: the population density of regions appears inversely proportionate to their geographical elevation: the Eastern region has the highest density, followed by the Central region, while the West, geographically the most elevated, has the lowest population density. The third factor is the level of economic development in these regions, which shows a similar picture: the level of economic development is closely related to internet access.

Figure 13.6 addresses the digital gap between eastern and western China and between rural and urban areas. The difference in mainlines between western rural and urban areas shows a last mile problem in ICT application.

FIGURE 13.6 **Comparison of Communication Development in China**



Source: MII 2002.

Digital Opportunities and Challenges of the Digital Divide

In recent decades, technological innovations in micro-electronic chips, microwaves, satellites, fibre optics and digitalization of information processors have been the motors of the information revolution and form the unique characteristics of ICTs. These inventions and applications of ICTs have brought about a drastic reduction in the cost of transmitting information, led to increase in the power of computing, created opportunities for leapfrogging over a traditional development period, and generated new ways of communicating in the social and economic spheres. Indeed, these powerful technologies bring about a great opportunity for all-round development, and at the same time, create a great challenge—digital divide—for all countries in the world.

Digital Opportunities As intermediaries and facilitators of efficient information, ICTs provide new communication channels that convey new resources of knowledge and information to society. Current evidence suggests that properly designed, adapted and implemented ICT solutions can offer multiple benefits in terms of economic and social development, which include enhancing productivity, extending the market, improving education and health-care facilities, and improving governmental efficiency. Access to ICT makes it possible for individuals or companies to obtain and distribute information about various production methods and to distribute, even to share, technologies to enhance their mutual productivity. Access to ICT also implies access to those channels and modes of communication through which new forms of productive organization and activities emerge. Commercial transactions are inherently information-intensive activities. Lack of, or outdated, information often causes market failure, and in the worst case scenario, transaction cannot be carried out at all. ICTs can reduce transaction costs in a whole range of commercial activities, and they can enable a whole range of commercial functions to be carried out quickly and easily.

ICT can be an economical means of investing in human capital, especially in education. Tele-education (or 'distance learning') techniques overcome geographical barriers and provide a whole range of education to people in rural remote areas at low cost, from primary school to university levels. Telemedicine is an active and expanding field of ICT application. Good quality data service capability is necessary so that medical readings, records and files can be transmitted reliably in rural and remote areas. Today, instead of having to move either the patient to the doctor or vice versa, it is possible to move only the relevant medical information (Barr 2000).

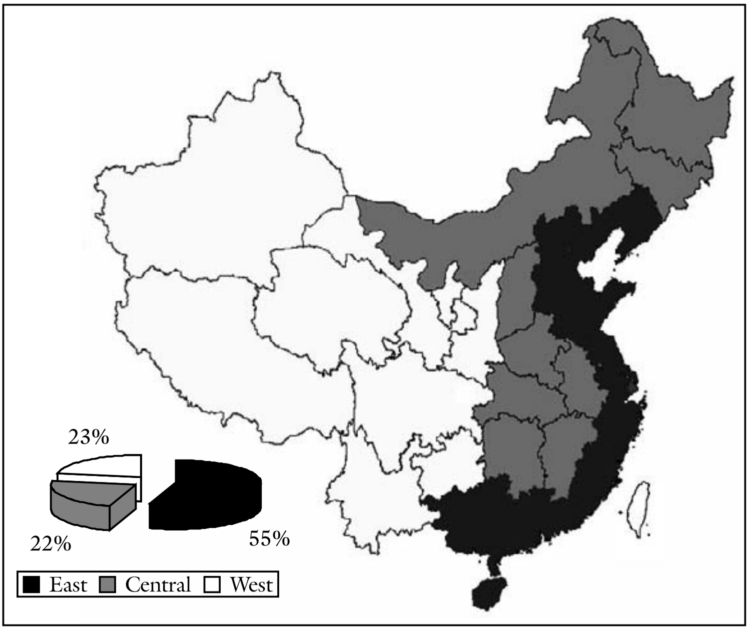
ICTs also provide an opportunity to extend government services and capabilities that were previously unavailable because of prohibitive costs. These technologies make it possible for developing countries to afford an improvement in the quality of governance. Establishing close links with the government, ICTs make the performance of governments more transparent and effective, especially in rural and remote areas (Wang 2001). However, it is important to be aware that ICTs do not offer a panacea for economic and social development and to recognize that their contribution alone cannot lead to sustained growth and development. As the prerequisites of ICT development, several factors need to be considered: human capital, physical infrastructure, integrated development policies and the concrete actions of all social stakeholders.

Challenges of the Digital Divide According to the United Nations Development Programme (UNDP), the digital divide is in effect a reflection of broader socio-economic inequalities that can be characterized by insufficient infrastructure, high cost of access, inappropriate or weak policy regimens, inefficiencies in the provision of telecommunication networks and services, lack of locally created content, and uneven ability to derive economic and social benefits from information-intensive activities.

It is generally believed that the digital divide will marginalize underdeveloping regions and groups because these regions and groups can neither afford the initial cost of telecommunication infrastructures nor use them efficiently and effectively when they are available. There are many reasons that the growing digital divide should be a cause of concern. First, the gap in the availability of ICTs is much larger than income disparities for some regions. In particular, the gap is growing in the availability of advanced ICT services, such as internet access. Second, there is a significant threat of less developed regions, particularly rural and remote areas, being forced into an ICT-related poverty trap. Regions that do not have sufficient access will be increasingly excluded from the regional or national trading system. Third, the gap in ICT access among social groups within a region aggravates social and economic inequalities. This will become even more serious as government and social service providers migrate online. The developmental impact and the risks of economic exclusion presented by the digital divide suggest that governments should implement an appropriate telecommunications policy that can fully seize the opportunity for the development of ICTs, and thereby reduce the threats posed by a digital divide.

Measurement of digital divide is the first task in dealing with the problem. OECD countries adopt computer availability—and potentially, the availability of alternative access through TVs or mobile phones—and internet access as important economic indicators in addition to communications infrastructures (OECD 2001). However, in most developing countries, computer and internet access are still not pervasive. Because fundamental telecommunication access paths are the basic symptoms of the digital divide, the most important indicator of measuring digital divide in developing countries is primary telecommunication availability, such as telephone access. Nevertheless, internet access became an important indicator when the internet rapidly, but unevenly, diffused into the developing world.

FIGURE 13.7 **Internet Users by Region**



Source: Based on CNNIC (2000) and author's calculations.

In particular, internet users concentrate largely in metropolitan areas. The latest statistics by the China Internet Center show that internet users in Beijing account for 6.6 per cent of the national total; Shanghai accounts for 7.1 per cent, while the corresponding figures for Tibet and Qinghai Province in north-western China are 0.1 per cent and 0.3 per cent, respectively (see Figure 13.7 for a region-wise break-up of internet users in China).

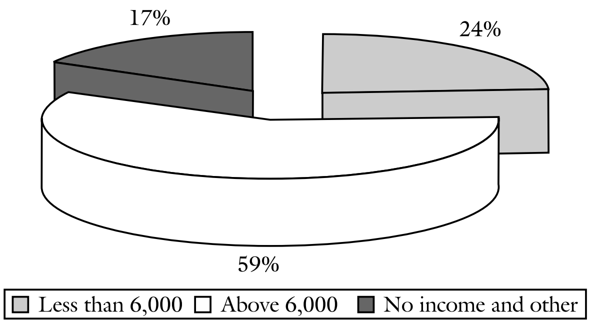
The Digital Divide between Urban and Rural Areas China's telecommunication development is severely imbalanced between its rural and urban areas. Due to low population density and geographical disadvantages, rural areas face extremely high costs of investment in ICT infrastructure. Nevertheless, the situation of ICT development in rural China has improved gradually, thanks to general economic development and to generous ICT investment in rural areas. In 1998, the number of new telephone subscribers reached 6.9 million in rural areas, a 38.7 per cent increase over 1997. The growth rate was two times that in urban areas. By the end of 1998, total telephone subscribers in rural areas had reached 24.8 million;[2] among them 20.6 million were rural household subscribers (Ke and Zhang 1999).

Compared to telephone development, the urban and rural gap of internet use is astounding: merely 1.7 per cent of all internet users live in the countryside. In fact, internet use is largely concentrated in urban areas. While commercial internet access is now available in over 200 metropolitan cities from every Chinese province (Press et al. 2002), most rural areas have not yet been networked. Where rural areas do have access, connection speeds are slower (employing earlier technology) than in the cities. This speed gap will grow even larger as new broadband technologies reach the cities. Access to new technologies such as broadband show pronounced divisions, especially between urban and rural areas.

The Digital Divide among Groups with Different Incomes According to the OECD, income is a key factor in computer and internet access. A CNNIC survey (Figure 13.8) indicates that 59 per cent of China's internet users earn an annual income of more than, 6,000 yuan,[3] in contrast, internet users who earn less than 6,000 yuan annually only share 24 per cent of total internet use. Although the non-earning users do share 17 per cent of internet use, this fact may not undermine the importance of income, because this percentage is more likely to represent students who usually receive a high subsidy from their parents. Studies on telephone subscription of farm households in rural China also show that farm households with higher annual incomes are more likely to subscribe to a telephone than are low-income farm households (Wang 2001).

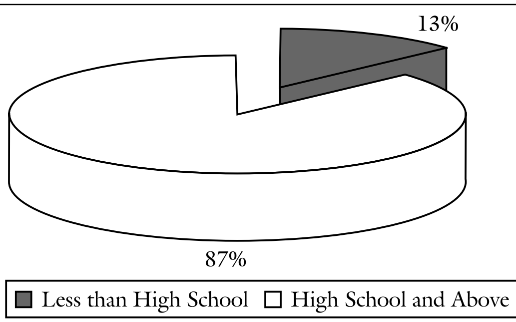
The Digital Divide among Groups with Different Education Levels Differences in education levels are also highly correlated to PC and internet access: those with higher levels of education are more likely to use ICTs at home and/or at work. Education is closely correlated to income, which obviously facilitates the purchase of ICTs and their inclusion in the work environment. Figure 13.9 illustrates that 87 per cent of Chinese internet users have a high school degree or a higher level of education. A ZEF (The Centre for Development Research, University of Bonn, Germany) study on telephone access in rural China shows that heads of farm households with a primary level of education were more likely to subscribe to telephones than those without any level of education (Wang 2001).

FIGURE 13.8 Internet Users by Income (2003)



Source: Based on CNNIC (2003) and author's calculations.

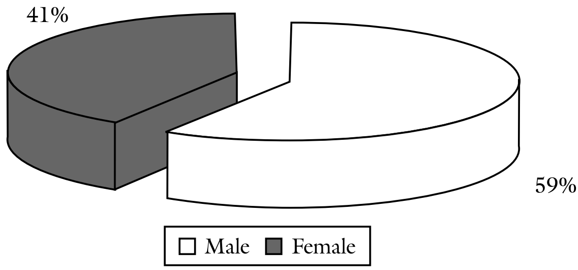
FIGURE 13.9 Internet Users by Education (2003)



Source: Based on CNNIC (2003) and author's calculations.

Digital Divide between Genders In China, gender-based digital divide appears to be much smaller than education- and income-based divides (Figure 13.10). According to a CNNIC report (2003), 41 per cent of Chinese internet users in January 2003 were women. Compared to the figure in July 2000, there was a 10 per cent increase in internet use among women.

FIGURE 13.10 **Internet Users by Gender (2003)**



Source: Based on CNNIC (2003) and author's calculations.

DOT-Force Strategy and Actions

In all countries around the world, especially in developing countries, policy makers are confronted with the following serious issues of telecommunication development: the promotion of the development of the ICT industry and services, satisfying the increasing demand for ICTs, and limiting the potentially harmful consequences of the digital divide. To bridge the digital divide in international and national contexts, an environment of regulation and competition within which the new technologies can spread to their citizens should be established by the government.

In July 2000, the G8 heads of state launched a project specifically addressing the digital divide: the DOT-Force. In a co-operative effort to identify ways in which the digital revolution can benefit all the world's people, especially its poorest and most marginalized groups, the DOT-Force project brought together 43 teams from various governments, the private sector, non-profit organizations and international organizations, collectively representing both developed and developing countries. It is clear that the main responsibility for the relevant digital divide policy action remains in the hands of developing countries (DOT-Force 2001).

According to the Okinawa Charter on the Global Information Society,[4] the DOT-Force looks into activities aimed at eliminating this threat to global development. Although China did not take a part in the G8 conference, it has certainly formed its own DOT-Force strategy and has been carrying out a series of decisive actions.

The first was the creation of national strategy of informatization. In order to grasp the digital opportunities, the Chinese government has formulated a policy of quickening national informatization construction to promote upgrading and optimization of Chinese industries, while realizing industrialization and modernization. Through the Ninth and Tenth Five-Year Plans, information and communication were prioritized in overall development. As mentioned earlier, the government introduced a series of important information application projects to promote informatization.

The second action was the online programmes of the government and enterprises that were initiated in the mid-1990s to mobilize the governments at all levels to facilitate information access for all citizens. The aim of the programmes was that 30, 60 and 80 per cent of all levels of government would be online by 1998, 1999 and 2000, respectively; 100 large conglomerates, 10,000 midsize firms and 1,000,000 small firms would be wired within 2000. These e-government programmes not only allow people to promptly obtain information on government policies, regulations, law and enterprise services, but are also a crucial driving force bridging the domestic digital divide between the information 'haves' and 'have nots' nationwide.

Third, a special expenditure was marked for bridging the digital divide among regions. It is clear that bridging the digital divide is impossible without additional expenditure from the national budget. In China, the government has not only invested heavily in the creation of telecommunications infrastructure, but also in the universal telecommunication access in rural and remote areas. To bridge the widening internet connection gap between rural and urban areas, the Chinese government has launched the 'Every Village has a Phone' (2004) and 'Gold Farm Engineering' (1994) projects, which promote telephone access and internet application in rural areas. As of 2000, 5,000 networked telephones had been installed in rural areas and more than 200 agricultural websites had been created.

In particular, great efforts have been made to accelerate the construction and improvement of information infrastructure to satisfy the socio-economic needs of the western regions of the country. The Chinese government has drawn up a series of favourable policies to encourage domestic and foreign investors to participate in the investment and building up of the information industry in the western regions. Moreover, special efforts have been made by the government to cultivate a number of promising information technology industries in the western regions.

Fourth, actions have been taken to narrow the digital divide caused by the difference in education and gender. The Chinese government encourages and supports colleges and universities to educate people how to use ICTs and how to benefit from ICT application. After networking almost all universities and important institutes, the Chinese government has taken great efforts to provide long-distance education facilities in less developed regions, in particular, the rural and western regions. For instance, with support from the Government of Australia and the World Bank, the Government of the Ningxia Hui Autonomous Region launched a distance learning centre (DLC) recently, which will help promote development and poverty reduction in this western province of China by introducing the use of ICTs to promote distance learning as well as information and knowledge dissemination. Using state-of-the-art distance learning technology, the DLC allows participants across China and other East Asian countries, and even other continents, to share information and learn without leaving their hometowns.

Fifth, the Chinese government allows the private sector to provide information services which do not have sensitive political content. This policy significantly has fostered internet diffusion and facilitated the spread of internet cafés throughout the country. Despite strong arguments on whether the private internet cafés are harmful to society and the political regime, the number of cafés has grown very rapidly. As a result, severe competition from the private sector undermines the monopoly of state-owned internet service providers, brings the cost of internet use down to an affordable level for a lot of people and leads to the rapid increase of the number of internet users.

Generally speaking, DOT-Force demands gigantic comprehensive systems engineering projects. All stakeholders, including the Chinese government, state-owned enterprises, private companies, research institutes and universities, should play active roles in bridging the national digital divide. There is urgent need for international co-operation to deal with this problem, because all countries are faced with digital divides. Advanced countries should take up the responsibility for offering more financial aid and technology transfers to developing nations. Faced with digital divide, developing nations should strengthen co-operation among themselves so as to create a favourable international environment for removing this divide (Ling 2001).

Conclusions

The fast development of the telecommunications sector in China largely relies on unique reform of the telecommunication sector, the so-called 'competition without privatization'. The Chinese government has played a pivotal role in telecommunications reform. The unique reform of China's telecommunications sector has been market oriented to some extent, with strong state initiatives and influence. Indeed, the Chinese government has successfully managed the introduction of market forces and balanced development goals with its need for control of information, at least in the short term.

Although competition in China's telecommunication market has been introduced, there is still no real competition because all competitors are state-owned enterprises. Moreover, limitation of licences hinders full competition. In addition, laws and regulations that are essential for fair competition still need to be improved.

As an external driving force, China's accession to the WTO will deepen and accelerate telecommunications reform. The domestic telecommunication market will gradually open up not only to foreign investors, but also domestic enterprises. The emergence of multiple markets will no doubt fuel strong competition, which will in turn improve quality, lower prices and stimulate demand. In this way, China will rapidly become an IT society. The dramatic development of ICTs offers historic opportunities for China to leapfrog and catch up with developed countries, if it wisely applies these technologies and uses the digital opportunity to the full. China is facing a severe digital divide among the regions, between the rural and urban areas, between genders and among the groups of people with different education and income levels.

To bridge the digital divide and to ensure the provision of digital services, the national DOT-Force requires large and comprehensive projects of implementation. While deepening telecommunication reform, the Chinese government should create an integrated strategy and mobilize all stakeholders: governmental organizations, ICT enterprises, universities and research institutes, and the private sector to participate in bridging the digital divide in national and international contexts.

Notes

1. According to the CNNIC (2000) an internet user refers to a residential Chinese citizen who owns his/her own computer or who shares a networked computer or account.
2. China's urban and rural population was 379.42 million and 868.68 million respectively in 1998.
3. Yuan is the unit of Chinese currency. 1 Yuan = 0.12 US$.
4. The heads of state of the G-8 countries, meeting at Okinawa, Japan in July 2000 for their annual summit, called for an international effort to eliminate the digital divide. They agreed on some principles which would promote the development of the internet and maximize its social and economic benefits. The Okinawa Charter was the outcome of the agreement of the G-8 summit.

References

Barr, David F. 2000. 'Integrated Rural Development through Telecommunications', in Don Richardson and Lynnita Paisley (eds), *The First Mile of Connectivity—Advancing Telecommunications for Rural Development through a Participatory Approach*. Rome: FAO.

China Daily. 2001. 'Telecom Monopolies Urged to be Curbed', 30 March.

CNNIC (China Internet Network Information Center). 2000. *Report on the Development of Internet in China*. Beijing: CNNIC.

———. 2003. *12th Statistical Survey on Internet Development in China*. Beijing: CNNIC.

Dahlman, Carl J. and Jean-Eric Aubert. 2001. *China and the Knowledge Economy Seizing the 21st Century*, Washington, DC: The World Bank.

Deng, Zhicheng. 2002. 'The New Pattern in the Operation of China's Telecommunications: "5+1"', *China Telecommunications Trade*, China Telecommunications Industry, 23–26.

DOT-Force (Digital Opportunity Task Force). 2001. *Digital Opportunity for All: Meeting the Challenges*, Report of the DOT-Force, 11 May 2001.

Ding, Lu. 2000. 'China's Telecommunications Infrastructure Buildup: On Its Own Way', in Takatoshi Ito and Anne O. Krueger (eds), *Competition Policy in the Asia-Pacific Region, East Asian Seminar on Economics*, vol. 8. Cambridge, MA: NBER-University of Chicago Press.

Gao, Ping and Kalle Lyytinen. 2000. 'Transformation of China's Telecommunications Sector: A Macro Perspective', *Telecommunication Policy*, 24: 719–30.

Ke, Bingsheng and Xiaohui Zhang. 1999. *The Development of ICT and Its Impact on Rural Economy in China*. RCRE.

Lin, Rong. 2001. 'Seizing the Opportunity to Cross Digital Divide' (text of a speech at Asia Society's annual session of the China Reform Forum), 13 March, Bangalore.

MII (Ministry of Information Industry). 2002. *P&T Monthly Statistics*, June. Beijing: MII.

MII (Ministry of Information Industry). 2003. *The Guidelines for China's Telecommunication Industry*. Beijing: MII.

Mueller, Milton. 1998. 'China's Telecommunication Sector and the WTO: Can China Conform to the Telecom Regulatory Principles?' (paper presented at the conference on *China as a Global Economic Power: Market Reforms in the New Millennium*), Cato Institute and Fudan University, Shanghai.

OECD (Organisation for Economic Co-operation and Development). 2001. *Understanding the Digital Divide*. Paris: OECD.

People's Daily. 2000. 'Deputies Call for Opening Telecom Business to Private Firms', 7 March.

Press, Larry, William A. Foster and Seymour E. Goodman. 2002. 'The Internet in India and China', *First Monday*, 7 (10).

Wang, Wensheng. 2001. *Impact of ICT on Farm Households in China*. Bonn: ZEF, University of Bonn.

STOA (Scientific and Technological Options Assessment). 2001. 'Developing Countries and the ICT Revolution: Final Study', Working Document for the STOA, March. Luxembourg: Directorate General for Research and STOA.

14

India–China: A Battle of Two New ICT Giants

Meine Pieter van Dijk

Introduction

Many governments are attracted by the buoyant success of Silicon Valley, a well-known concentration of ICT activities, and want to know how this success can be replicated. Consequently, a large number of cities have invested heavily in the information and communication technology (ICT) sector, developing existing ICT enterprises and attracting new ones. Researchers from different disciplinary backgrounds have only begun to discuss why developers of distance shrinking technologies often tend to cluster together.

The subject of this paper is the factors influencing the development of the ICT sector in two cities in Asia: Bangalore and Nanjing.[1] I shall describe the development of the clusters, analyse the policies these cities pursued to strengthen their local ICT clusters, and finally attempt to identify important differences between ICT clusters in the two cities.[2] This paper takes a comparative perspective of the composition of the ICT sector in the two cities. By taking two Asian cities and comparing them, this paper seeks to contribute to the understanding of the diversity of experiences in developing the ICT sector (van den Berg et al. 2001). The cities selected are greatly underrepresented in ICT cluster research.[3]

The next section reviews the relevant literature on ICT clustering and urban development, and elaborates on the methodology used. Then a brief description of the ICT clusters in Bangalore and Nanjing is provided and the urban policies, which these cities pursue to strengthen their ICT clusters, are discussed. Subsequently, the clusters are compared on the relevant dimensions derived from the literature. In the last section, conclusions are drawn and issues identified for further research. Bangalore and Nanjing have benefited from the growth of the ICT sector and to become strong ICT centres. Hence, some policy recommendations will also be formulated.

ICT Growth in Urban Regions: Theory and Methodology[4]

Growth figures for the ICT sector are often impressive. The total value of the European market amounts to 365 bn euro, 5 per cent of the European gross domestic product (GDP), and this percentage is rising rapidly (EITO 1998). A number of studies have appeared on the location behaviour of innovative industries, but also on the opportunities and constraints for cities to develop their ICT industries. A strong spatial clustering of innovative industries has been observed in most countries. To explain this, some authors stress the importance of inter-firm co-operation and regional knowledge transfer (Boekholt 1994; Cooke 1995; Lazonick 1992; Malmberg et al. 1996). The argument is that in fast-changing business environments, inter-firm knowledge and information exchange greatly benefits the development of the sector, because it stimulates and speeds up innovation processes and facilitates specialization. Knowledge can be transferred via people changing jobs within the region, via supplier relationships, or via joint product developments. Spatial proximity greatly enhances all these types of transfer. There are factors stimulating regional knowledge transfer, such as cultural proximity and the trust needed to share valuable information (Aydalot and Keeble 1988; Putnam 1993). Finally, the literature points to the importance of universities for the development of ICT clusters.[5]

A very relevant issue is the role of large, transnational companies (TNCs). They play a pivotal role in the way local innovative networks relate to global networks. Malmberg et al. (1996) and van den Berg et al. (2001) stress that if a TNC is rooted and integrated (fledged) in the region and engages in regional networks, it can act as an important disseminator of new knowledge, information and innovation from abroad into the region. This is particularly relevant for R&D activities. These knowledge flows are facilitated by personal relationships and mobility of employees, or through spin-offs from larger firms. Hall (1998) stresses the special advantage of (some) urban regions for ICT activity. He points at the fruitful marriages between ICT and typically urban sectors, such as cultural and entertainment industries. Cities with particularly good prospects are those with a thriving cultural life, rich history and high quality of life.[6] Finally, Porter (1998) stresses the importance of large and critical local demand as a condition for cluster development and a trigger for innovations. This demand may be important for ICT clusters as well: there is some evidence that ICT firms tend to be located near their main customers, in regions with high concentrations of financial and business services (Roost 1998).

The cities studied are centres of ICT industries. A number of factors determine the development of an ICT cluster. According to Sachs et al. (2002), high-tech services such as those provided by the information and communication-based industry are almost always reliant on a network of universities and urban labour markets. A high quality of life of the location is also important. These factors were important for the clusters studied, but there were some other relevant and some city-specific factors as well.

Bangalore and Nanjing have both developed policies to develop their ICT clusters. At the same time, the two cities are very different in their economic structure and position in their national urban systems. The framework for the analysis is based on the literature summarized earlier. The following research questions were formulated:

- What is the role of (local) demand in the urban cluster's development?
- What is the role of large firms in urban ICT cluster development?
- What is the role of R&D and the educational infrastructure?
- What is the importance of quality of life for ICT development?

For each city, the available literature on the ICT cluster was reviewed to identify key (public and private) actors in the cluster.[7] After this, in-depth interviews were conducted with key representatives.[8] In each case, surveys were also used.[9]

Bangalore and Nanjing

Bangalore

Some state or local governments in India provide substantial benefits to make investments attractive. The central government in New Delhi also very seriously promotes new investments in ICT companies in the different states. With over 925 software companies employing over 80,000 ICT professionals, Bangalore in Karnataka state is the undisputed ICT capital of India (Anand 2002). According to the same article, in 2000–01, at least one company with 100 per cent foreign equity participation set up shop every week in this city. Apart from ICT majors like Infosys, Wipro, Satyam, Tata Consultancy Services (TCS) and Microland, the world's leading ICT companies like GE, Texas Instruments, CISCO, Digital, IBM, HP, Compaq, Motorola, Lucent Technologies, Microsoft, Sun Micro Systems, Oracle, Novell and several others have made Bangalore their home.

India's first aircraft factory was founded in Bangalore during World War II and hence the city had one of the most technologically advanced industries and a well-trained workforce in India (Srinavas 1998). Bangalore is now known as a centre for outsourcing the development of software, an industry which came up in the 1970s. The improvement of satellite communications has been a catalyst to this outsourcing. In 2002, about two-thirds of Indian software exports went to the US, and in total more than 500,000 people were working in the ICT sector in the country. The real growth in Bangalore came in the 1980s, with a compound annual growth of production of almost 30 per cent between 1987 and 1991 (Renu 2000). Indian software expanded almost twice as fast as the leading US software industry in the same period. The major software companies in Bangalore are Wipro, Satyam and Infosys, but new activities are developing, particularly what is called business process outsourcing (BPO) industries, ranging from call centres to managing back office tasks. Many ICT companies selected Bangalore for setting up plants because of the availability of cheap specialized labour and because this was the first state in India to develop its own ICT policy.

In the years after Independence, the national government established some of the country's biggest public sector factories in Bangalore, notably, Indian Telephone Industries, Hindustan Machine Tools and Bharat Electronics and Bharat Earth Movers (Renu 2000). They have been the drivers of Bangalore's fast growth. Municipal and local governments are also very active in the city. Besides developing its own ICT policy, the governments have sought public–private partnerships for infrastructure development. This has led to policy-related incentives: for example, ICT companies settling in Bangalore usually get a number of tax incentives. The companies also benefit from the large number of education and training institutes in the city. Additionally, the Karnataka state government has actively promoted Bangalore as the capital of software in India and abroad. The Bangalore municipal government had begun to formulate positive economic policies, also with respect to small and medium ICT enterprises (SMEs) in the city, before economic liberalization started in India under Rajiv Gandhi in 1991.

In November 1971, the Government of Karnataka thought that it was necessary to disperse industries to backward areas in the state. For that purpose, the state was divided into four zones with a view to ensure dispersal. An incentive package and concessions were made available to industries installing themselves in areas around the city of Bangalore, which were identified as backward. Renu (2000) notes that originally no specific policy seems to have guided the location and development of industries in and around Bangalore. It was often convenient to set up units along or in the vicinity of high roads. Subsequently, a policy of discouraging new industries in the Bangalore city itself became effective. For instance, investment subsidies were not permissible in Zone 1 (covering the Bangalore urban agglomeration). However, interest subsidies on term loans were available and price preference for small-scale units for the first five years was also possible. The early industrialization of Bangalore was positively influenced by the availability of cheap water and electricity.

Looking at the factors derived from the theoretical framework, it is noted that in the case of Bangalore, local demand is not very important. The role of large firms has been important for the development of the cluster, as these make available a large number of experienced engineers for software companies, but these are not necessarily foreign firms. R&D is present and has been developed, although it is not the key to understanding the success of Bangalore. Finally, quality of life certainly contributed to making Bangalore an attractive city for a knowledge-intensive industry.

The tech meltdown in the US at the end of the 1990s had serious implications for the Indian information technology industry. However, US demand in 2001 was again 40 per cent higher than in the pre-crisis year 1999. Indian software exports totalled $ 1.9 bn during the last three months of 2001, a 25 per cent increase compared with the same period in 2000. This was a slower growth than in the previous 10 years, but it also revealed the resilience of the ICT industry. The crisis forced companies to become more practical and focus on solving real-world problems (Merchant 2002). It meant operating on leaner budgets and focusing on finding customers.

Nanjing

China's main cities have developed 'electronic roads', places where computer-related shops are concentrated. The best-known ones are in Beijing, Shanghai and Shenzhen.[10] For the ICT sector, five districts are particularly important. The inner city cluster studied can be placed in the larger context of the whole city, including the Gulou Science Park in the north-west, the Jiangning technical economic development zone in the south, the Nanjing economic technical zone in the Xixia district in the north-east of Nanjing and the Pukou high-tech development zone in the north-west of Nanjing. The city-wide cluster is potentially more diversified and hence more resilient to crisis, because of the complementary nature of the activities.

The study is based on a sample of 50 ICT enterprises on Zhujiang electronic road in Nanjing, which is the capital city of Jiangsu province (van Dijk 2003). The city counts more than 5 million inhabitants. It is an important business centre in the eastern part of China. In 1989, the municipality decided to start an 'electronic road.[11] The enterprises occupying plots along the Zhujiang road were notified that the street would be reserved for ICT companies and that they would have to move if ICT was not their core business. Alternative locations were offered and empty plots and buildings were allocated to ICT firms.

In due course, more than 1,000 enterprises (925 in 1999) found a place on Zhujiang road or along neighbouring streets. The local government reinforced this concentration process by reserving a number of buildings known as 'enterprise buildings' for ICT companies. Usually some common services are offered, such as accountancy and cleaning.[12] About two-thirds of the enterprises in the cluster are private enterprises, double the number compared to the figure in 1997.

The development of the Zhujiang road is strongly related to the promotion efforts of the local government, notably of the Xuanwu district authorities. This is the district where the electronic road is located. The total industrial product of the firms clustered along the road was about US$ 321 mn in 1998 and grew by 40 per cent in 1999 (Nanjing Science Committee 1999). The firms concentrated on the Zhujiang road are very diverse in nature. One can find the regular sellers of specific software and hardware, but specialized firms providing hospital information systems, software for system integration (including installation and adaptation) and companies repairing monitors or other parts of a computer system are also found here. ICT consultancy firms can be found side-by-side with firms recycling old computers.

Many of the companies on the Zhujiang road mainly sell hardware or software. Some also offer space and infrastructure in technology zones at the outskirts of Nanjing. In principle, that space is meant for factories.[13] Many entrepreneurs along the Zhujiang road are young and ambitious. Buying and selling of ICT products is still quite concentrated in the city. Usually, only some 10 to 20 per cent of the goods or services are sold outside Nanjing and some 10 to 20 per cent are bought elsewhere. The entrepreneurs usually set up free-standing firms and they do not hesitate to copy ideas or software to further the development of the firm. The majority of the firms is privately owned which is not what one would expect in China. Very few are collective, and only 6 per cent are state owned. The joint ventures are sometimes also between a private and public partner. Most firms are registered with the district or the municipality, which actively promote private firms to locate in their area. Investments are usually limited and only a few firms have a turnover of over 1 million RMB (7.4 per cent). There are a lot of similar ICT zones in China and the national government also tries to attract IT enterprises to the underdeveloped western part of the country.

The advantages and disadvantages of a cluster of ICT enterprises mentioned by the entrepreneurs interviewed are nearness, exchange of ideas, providing choice to customers, positive policies by local government and supporting services in business buildings. The major factors negatively affecting the competitiveness of this network of enterprises seem to be the inland location of Nanjing and the lack of an enterprise culture in the city. It is also difficult to find skilled labour in Nanjing and the impact of the universities and specialized research institutes is also not as positive in this case as they seem to be in the other Chinese cities.

The local government sometimes helps enterprises on the Zhujiang road to gain access to bank loans and to prepare their tax forms. Not only do the municipal authorities play an important role, district authorities (for example, the Xuanwu district in Nanjing in which the cluster is located) play a role in developing the cluster as well. For example, the eight business/enterprise buildings provided by the district authorities are very important for the development of the sector. The Xuanwu district government also established the Zhujiang Electronic Road Administrative Office, which collects data on the cluster and has developed plans for its future development.

Compared to similar concentrations of ICT firms in Beijing, Shanghai and Shenzhen, Nanjing is not considered very competitive. The other cities tend to be bigger and have even larger clusters of IT firms. The problem mentioned by most of the entrepreneurs interviewed is that Nanjing is not considered to be as attractive as Beijing, Shanghai and Shenzhen because it is a smaller city, located away from the coast and its business sector is less developed than in the other three cities. The lack of competitiveness at the regional, city, cluster and enterprise level are evident in the case of Nanjing and the lack of competitiveness at the regional and city level may be compensated only to some extent by the advantages provided by working in the ICT cluster on Zhujiang road.

This lack of competitiveness is a real problem according to a large number of the people interviewed. It becomes difficult to hire efficient personnel at the current wage rate and many employees consider Beijing, Shenzhen or Shanghai more attractive cities to work in. Second, many companies feel the need to develop a marketing strategy, but are not capable of doing so. The owners tend to be technicians, who have limited skills as far as marketing or management in general are concerned. A third problem is the relation with the supporting institutions in the city, like the universities and research institutes. There is a trend to involve them for research and to supply good employees, but to keep them at a distance at a later stage because the business culture of the two types of organizations is very different.

Finally, paying taxes is a hot issue, although they still seem to be relatively low in this sector. The accounting services provided in some of the business buildings may actually include advice on how to deal with tax issues.

To find out to what extent the Zhujiang cluster is more than a market cluster (a concentration of sellers), we looked at inter-firm relationships. Normal economic relations (buying and selling) between companies in the cluster are not very well developed. Other types of co-operation (exchange of ideas, carrying out of projects together, etc.) seem to be quite important, however. Many IT firms have well-developed relations with other companies, the government or universities, but these do not seem to lead to an advanced labour division, nor to innovation. Some innovation is certainly taking place in the cluster and many companies have invested a substantial part of their profit for this purpose. Non-innovative firms tend to be subsidiaries of larger firms. Some firms consider innovation to be the result of carrying out jobs for others. Indeed, sub-contracting can stimulate innovation. The overall evidence suggests that this is not yet a fully developed innovative cluster (van Dijk 2003).

Comparable Factors for the Two ICT Clusters

Reliance on a Network of Universities and Research Centres

The R&D infrastructure and the educational system (including universities and polytechnics) are an important part of most ICT clusters. They serve as sources of staff for the urban ICT industry, as generator of new knowledge, and provide incentives for start-ups. Both cities in this investigation stress the quality (and quantity) of their universities in their promotion activities to attract foreign ICT firms. Many surveys have shown that ICT companies attach great importance to infrastructure in their location decisions.

An important issue is the degree of co-operation between universities and the local ICT industry. Greater co-operation and interaction is better for cluster development: companies can benefit from the human resources of the local universities, such as staff, trainees, but also in terms of preparing their research results. For the university, co-operation generates financial resources, helps to focus research activities on matters that are relevant for business or society, and thus entails a more efficient spending of (public) money. It may also increase the quality of the research, since the demands of the market are generally high. In both cities in this study, we found co-operation projects ranging from contract research to specific education for ICT entrepreneurs and ICT adoption for SMEs. However, incentives may work negatively too: for universities, what counts most is the volume and level of publications, and applied research for industry has a lower esteem in university research programmes.

Quite a few educational institutes and research centres are located in Bangalore, but there are not enough relations between existing R&D institutions, universities and the ICT sector. Although the presence of six major science and technology institutions and four major centres of higher education was not the main reason to situate the ICT cluster in Bangalore, the companies located there do benefit from the substantial number of education and training institutes in the city. This helps in providing the large number of skilled labour necessary for such a kind of industry.

In Nanjing, there are many educational institutions, but again, according to my survey there is not enough co-operation among the existing R&D institutions, the universities and the ICT sector. The local governments have announced that they will take the initiative by setting up a software park and an incubation centre where the academia and ICT industries will be invited to undertake joint projects.

Specialized Urban Labour Markets

We have mentioned the importance of specialized labour markets for ICT firms. Labour shortages and rapid business expansion imply that there is increasing global competition for ICT talent. This group of professionals also shows high rates of job rotation. However, job-hopping is also one of the positive knowledge spillovers of a cluster. Linked to the presence of specialized labour markets is the quality of life in the cities, a point that will be discussed here.

The low wages, high number of skilled workers in the city due to the existing industries and the number of educational institutes worked to the benefit of Bangalore. This labour force is English speaking and has received a solid technical education. This is certainly not the case in Nanjing, where English is often a problem and employers prefer on-the-job training over investing in someone through financing a university education.

A High Quality of Life in the Cities

The quality of life in the urban region—availability of comfortable housing, metropolitan ambiance, cultural conditions, green spaces, but also the climate—is a great attraction for aspiring ICT professionals, and is thus an important condition for the development of a cluster. Mitchell's (1999) statement that in the end, the 'pleasant places' on earth will be the main ICT centres might be somewhat extreme, but there is much truth in it. Most policy makers in the cities studied realize the importance of quality of life as a general condition for knowledge-intensive activities, as in the ICT sector.

Bangalore seeks to improve the quality of its urban environment by restructuring the inner city and stimulating expensive housing areas. The city is also cooler than most Indian cities because of its altitude. It is considered a green city and has started a long time ago to improve its living conditions. This certainly contributed to its attractiveness for the ICT sector.

Although Nanjing is known for its pleasant environment, it faces heavy competition for talent with Beijing and Shanghai. Nanjing is generally considered more attractive in terms of green spots and the pace of life than cities like Beijing and Shanghai, according to the people interviewed. The capital acts as a magnet for talented people in any sector, including the ICT sector. Many young people are attracted by these modern and fast-developing cities and are willing to leave if they can get a job in Beijing or Shanghai.

Special and City-Specific Factors

I would now like to point to some factors that are also important for the development of urban ICT clusters, but are different for the two cities. I shall start with the importance of specific products produced, then look at the role of different demand conditions and of large firms, and finally point to the importance of different policies pursued in each of the cities.

Specific Products

In Bangalore, software development and outsourcing of information and communication-related activities, such as call centres, for Europe and the US are the main features. In Nanjing, the development started with electronic products like televisions and CD players, but the hardware sector expanded gradually, and a software sector is now developing, producing software for security systems, power generation, telecom and other spheres mainly for the Chinese market. Bangalore is not at the end of the chain, supplying to other producers who use the developed software in their production or products. In Nanjing consequently local innovation capacity is less important, while in Bangalore it is important to remain competitive.

Although the specific products have some influence on the eventual development of the ICT clusters, they are not as crucial as is sometimes suggested. In fact, as long as there is a good sub-contracting system and if complementary services are available, ICT companies can develop everywhere.

Different Demand Conditions

In line with Porter's (1990, 1998) argument in his work on clusters and competitive advantage, we found indications that the development direction of an ICT cluster is strongly related to the economic structure in the urban region. The most 'heavy' users of ICTs are corporate headquarters, financial institutions and the media industry (Hall 1998; Saxenian 1994). The rapid development of online banking and new media (online publishing, web-TV and radio) and entertainment services provides a combination of different ICT activities.

Interestingly, local demand in Bangalore is not an issue, because of the export of its products to the US. During the recent crisis in the US market, local software companies managed to diversify their exports to Europe.

In Nanjing, local demand is the determining factor for the ICT cluster. However, the market is very big, and given the economic growth of the region, the ICT sector can still continue to increase each year.

Different Roles of Large Firms

The presence in the urban area of a dominant, strong ICT firm may have a strong positive effect on the cluster's development in a number of respects. First, it might give the host city an internationally known 'ICT-image'. Second, it would create a pool of qualified labour, which would make the city attractive for competitors who might 'buy' staff; third, if a firm has an open culture, it serves as an important client for other ICT-related firms (suppliers). As they are active in international partnerships, they have access to global sources of knowledge and technology, some of which are transferred in the local economy. Also, a large firm often faces spin-offs, which lead to new companies being created by its staff.

Bangalore also has some large enterprises, which have certainly contributed to making the city known as a centre for software production. However, these were not multinational companies bringing in new ideas or fresh capital. A more important factor for its success was the better climate and the already established Indian high-tech industries, which contributed to the presence of a pool of specialized labour in this city.

Finally, in Nanjing, some large Chinese firms and joint ventures have played an important role in creating the conditions for the development of the cluster. A crucial role was also played by government policies that favoured this development. In the 1990s, the subsidiaries of Hong Kong enterprises and local small private companies became more important, using the Zhujiang road to sell their products. Given the emphasis on selling computers and software in this cluster, the units located there tend to be small, although they may be linked to larger ones located elsewhere.

Policies

Both cities have benefited from the rapid general growth of the ICT sector, and actively seek to expand it with various policies. Both cities run programmes to enhance ICT adoption by firms in their city. In this way, they not only seek to improve the competitiveness of 'old economy' firms (mostly SMEs), but also indirectly stimulate the ICT sector. Some ICT-related policies cannot be influenced directly by urban policy makers but depend on higher levels of government.[14] Policies differ between European and Asian clusters. In Europe, urban managers can formulate cluster-specific policies: starters' policies, infrastructure policies, ICT adoption policies, inward investment policies and activities for the development of business locations in the new economy. I have deliberately left out the internal ICT policies of the cities (such as introduction of local e-government, e-democracy and service provision), because the impact of these policies on the development of the urban ICT business clusters is negligible. In Asia, the advantages are usually tax incentives, the availability of cheap and serviced land, and sometimes, links with existing R&D centres.

In India and China, the policies focused on creating an enterprise-friendly environment and on attracting foreign capital. They did use locally available knowledge resources. In Bangalore, the municipal government developed its own technology policy, particularly policies for ICT SMEs, and looked for public–private partnerships in infrastructure development.

The cities studied all seek to expand their local ICT sector with marketing efforts directed towards foreign ICT companies. In Nanjing, the municipal investment agency has designated ICTs as the spearhead sector. It offers US- and Canada-based firms general information on the region, supports them to find a good location, and provides them with staff and tax reduction and subsidy possibilities. The organization works at the regional level. In Nanjing, different policies are pursued at different levels of government to promote the city as an ICT hub. The city has several policies to attract investment in the ICT sector. Suning (2002) describes the positive role of technological enterprise incubators in Nanjing, defined as service centres or innovation centres, for starting up businesses.

Secondary Factors in the Success of ICT Clusters

Place in Urban Hierarchy

I have studied two very specific cases, which do not really allow a conclusion about the importance of the placement of clusters in the hierarchy of cities. The impression is that this factor does not contribute significantly to the success of the ICT sector in these cities.

Bangalore is only a state capital and is not the most important nor the biggest city in India. It rather happens to be the first technology centre in India and is located in the southern mountains. Nanjing is a provincial capital and an administrative city, but not one of the most important cities in China as far as the size and the competitiveness of the ICT sector is concerned. Therefore, the importance of the cluster in the urban hierarchy is difficult to prove.

Economic Cycle

The economic cycle is important in the urban economy. However, it tends to hit different sectors at different moments of time and can hardly be considered a variable explaining the success of the four ICT clusters.

In Bangalore, the year 2001 was when the ICT sector underwent its first recession period. The city has weathered the recession quite well and even achieved some growth in production (Merchant 2002). Indian software exports totalled Rs 1.9 bn during the last three months of 2001, a 25 per cent rise compared with the same period in 2000. Growth was slower than in the past 10 years, but the feeling was that the industry is resilient to recession. Two-thirds of the orders still come from the US.

In Nanjing, too, the worldwide recession at the end of the millenium has not been an issue. Local demand seems to be strong enough to compensate for the lack of international demand. The conclusion is that a recession hits different products at different moments of time. In India, for example, the software sector grew at a slower rate than the BPO sector, which started to take off after 2001. It is important to determine where they are in their product life cycle. In the later phases, products tend to be more sensitive to competition.

Conclusions

The ICT sector's growth is high, but the way different types of cities benefit differs widely. The clusters in our case cities differ in character in many respects. An average cluster is diversified, with a varied mix of ICT business. With some exceptions, most firms in the cluster serve the regional market, as service provider or sale outlet, with a small proportion also linked to infrastructure provisions. Different trajectories of ICT sector development in cities may be traced back to national circumstances and chance factors.

It may also be concluded that for the future, a high quality of the urban living environment will more than ever be a precondition for cluster development: because of increased mobility (and scarcity) of ICT professionals, cities need to be attractive to talented professionals, the basic resource of the ICT sector. This also means that investments in, for example, the environment and cultural provisions, may have a high return in the long run.

What more can cities do to strengthen their ICT cluster? A first thing could be to exploit local knowledge resources embedded in universities by stimulating industry–university co-operation. Furthermore, rather than attracting just any type of ICT companies, cities should make well-considered efforts to attract ICT companies that fit their economic structure. Another frequent mistake is to focus only on the construction of ICT infrastructure and facilities, in the belief that once the infrastructure is present, economic activities will follow as a matter of course. There is a risk that optimistic growth expectations will lead to ill-considered policies. Many regions seek to replicate the success of Silicon Valley by attracting high-tech industries, without arranging for the ingredients of real success (Salomon 1998). An example from the 1980s and early 1990s is the investment by many cities in teleports, assuming that in the twenty-first century teleports would have an economic relevance comparable to airports and seaports. However, the one-sided emphasis on providing infrastructure and technology and the lack of integration and economic judgement have caused many a teleport project to fall through.

A more promising strategy is the co-ordinated investment in infrastructure, technology and human capital. That is the strategy pursued in Singapore (Corey 1991; Warf 1995). That city-state has, in close co-operation with the private sector, invested on a massive scale in ICT infrastructure, as well as in training courses. The efforts were directed not only towards stimulating ICTs as an independent growth sector, but also, explicitly and consistently, towards making capital of ICTs' potential for enhancing the existing strengths of the economy: the trade function, the port and the financial sector. Integrality is yet another strong point: much money is invested not only in infrastructure but also in education, on the assumption that the presence of human capital can tip the scales in investment decisions.

Initiating an ICT policy oriented towards new entrepreneurs is another way for towns to strengthen the local ICT sector. The local government can act as provider of generic support, such as (cheap) accommodation and venture capital, but also as purchaser of the products of new companies, or as broker and connecting factor between starters and both the existing private sector and the knowledge institutions.

It can be concluded that public–private co-operation is a prerequisite to develop effective and efficient cluster policies. 'Interactive policy-making' is needed in the marketing of the cluster, in attracting new firms, in helping start-ups and in all other aspects of cluster policies, to make optimum use of the knowledge and resources of existing actors in the cluster. This also implies that civil servants involved in cluster policies need to be well educated and committed to its development.

Notes

1. The research project has been financed by the Netherlands government and carried out by the Sino-Dutch International Business Center (SD-IBC) at the Nanjing University by its Business School and a consortium of IHS, ISS and MSM, the leading partner. Data were collected in July 2000 by me (at IHS) together with He Jian and Wang Quansheng of the Business School.
2. Geographers typically focus on large regions, such as Silicon Valley and Route 128 (Saxenian 1990, 1994; Scott 1995), which implies that the urban dimension is under-emphasized.
3. A large number of studies focus on world cities such as New York, London and Tokyo, or on well-known high-tech cities, such as Cambridge (UK), Boston and Seattle.
4. Based on joint research with Willem van Winden.
5. An outstanding example is the role of Stanford University in the development of Silicon Valley (Malone 1985). Van den Berg et al. (2001) discern several roles of universities: as source of spin-out companies (founded by students or staff), as supplier of new employees for the cluster, or as partner for the local industry in research projects.
6. Mitchell (1999) sees a bright future for cities with a rich cultural life, thriving urban scene and good climate, as these places will be able to attract the (increasingly mobile) most talented professionals.
7. In the analysis, there were severe data problems, seriously hampering a comparative analysis on the basis of data only. To start with, each city uses its own definition of what its ICT cluster consists of. Also, the regional scale to which the data applies is variable.

8. In open interviews, the interviewees were asked to express their views on local cluster development, the relation between the ICT sector and the local economy, the role of the research and electronic infrastructure, as well as local ambitions and policies with regard to the ICT sector.
9. For Nanjing, a survey of 50 entrepreneurs was conducted with a standard questionnaire (van Dijk 2003), while for Bangalore, use was made of an available survey of 120 enterprises (Renu 2000).
10. The fact that by now almost every Chinese city is trying to build an IT centre in the city or the region means it may be more interesting for start-ups to benefit from the incentives provided elsewhere in the country. Some provincial or local governments provide substantial benefits to make investments attractive. For example, the national government and the provinces concerned very seriously promote new investments in IT companies in West China.
11. The Nanjing government gained more autonomy after 1992 and in 1993 started to formulate positive economic policies, also with respect to SMEs.
12. The quality of the buildings varies a lot and depends on the location, services offered and attractiveness for consumers (for details, see He Jian 2000).
13. A restructuring exercise has been undertaken by the local government, where companies can only move in if they are involved in software development and at least 50 per cent of their activity is actual production, rather than sales of computers or computer-related products.
14. Examples are telecom market regulation, competition policy, tax policies and research and education policies.

References

Anand, Latha. 2002. 'Industry on a Blazing Trail', *The Hindu*, 28 February.

Aydalot, P. and D. Keeble. 1988. 'High Technology Industry and Innovative Environments in Europe: An Overview', in P. Aydalot and D. Keeble (eds), *High Technology Industry and Innovative Environments: The European Experience*. London: Routledge, 1–21.

Boekholt, P. 1994. 'Methodology to Identify Regional Clusters of Firms and Their Needs' (paper for Sprint-RITTS workshop), Luxembourg.

Corey, K. 1991. 'The Role of Information Technology in the Planning and Development of Singapore', in S. Brunn and T. Leinbach (eds), *Collapsing Space and Time: Geographic Aspects of Communications and Information*, New York: Harper Collins Academic, 217–31.

Cooke, P. 1995. 'Regions, Clusters and Innovation Networks', in P. Cooke (ed.), *The Rise of the Rustbelt*, London: UCL.

EITO (European Information Technology Observatory). 1998. *EITO '99*. Brussels: European Union.

Hall, P. 1998. *Cities in Civilization*. New York: Pantheon Books.

He Jian. 2000. 'SME Competitiveness: The Relevance of Enterprise Clusters for Local Economic Development in Nanjing', M.A. thesis. Rotterdam: Urban Management Centre.

Lazonick, W. 1992. *Industry Clusters versus Global Webs*. New York: Department of Economics, Columbia University.
Malmberg, A., O. Sölvell and I. Zander. 1996. 'Spatial Clustering, Local Accumulation of Knowledge and Firm Competitiveness', *Geografiska Annaler*, 78 (2).
Malone, M.S. 1985. The Big Score: The Billion Dollar Story of Silicon Valley. Garden City, NY: Doubleday.
Media Studio. 1997. *The Finnish New Media Industry*.
Merchant, Khozem. 2002. 'Indian Software Weathers Global Recession', 6 February.
Mitchell, W.J. 1999. *E-Topia : Urban Life, Jim—But Not As We Know It*. Boston. MA: MIT Press.
Nanjing Science Committee. 1999. *Annual Report*. Nanjing: Science
Porter, M.E. 1990. *The Competitive Advantage of Nations*, London: Collier Macmillan.
———. 1998. 'Clusters and the New Economic of Competition', *Harvard Business Review*, 6 (November/December).
Putnam, R.D. 1993. *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton, NJ: Princeton University Press.
Renu, R. 2000. 'Autonomous IT Firms in Bangalore City: Location Rationale', Thesis for the Postgraduate Diploma in Planning at the School of Planning, Ahmedabad.
Roost, F. 1998. 'Recreating the City as Entertainment Center: The Media Industry's Role in Transforming Potzdamer Platz and Times Square', *Journal of Urban Technology*, 5: 111–132.
Sachs, J.D., N. Bajpai and A. Ramiah. 2002. 'Geography and Regional Growth', *The Hindu*, 25 February.
Salomon, I. 1998. *Telecommunications, Cities and Technological Opportunism*. Leeds: Regional Science Association.
Saxenian, A. 1990. 'The Origins and Dynamics of Production Networks in Silicon Valley', Working Paper No. 516, Institute of Urban and Regional Development, University of California, Berkeley.
———. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press
Scott, A.J. 1995. 'From Silicon Valley to Hollywood: Growth and Development of the Multimedia Industry in California', *Working Paper No. 13*, Lewis Centre for Regional Policy Studies, University of California, Los Angeles.
Srinavas, S. 1998. 'The Information Technology Industry in Bangalore, A Case of Urban Competitiveness', DPU *Working Paper No. 89*, April, London.
Suning, B. 2002. 'Research on the Development of Technological Enterprise Indicators in Jiangsu Province', MBA thesis, Nanjing Business School, Nanjing.
van den Berg, L., E. Braun and W. van Winden. 2001. 'Growth Clusters in European Cities: An Integral Approach', *Urban Studies*. 38 (1): 185–205.
van Dijk, M.P. 2003. 'Is Nanjing's Concentration of IT Companies an Innovative Cluster?' in D. Fornahl and T. Brenner (eds), *Co-operation, Networks and Institutions in Regional Innovation Systems*. Cheltenham: Edward Elgar, 173–94.
Wang, Quansheng. 2000. 'Gaining and Sustaining Urban Competitiveness in Nanjing through Information Technology', M.A. thesis, Urban Management Centre, Rotterdam.
Warf, B. 1995. 'Telecommunications and the Changing Geography of Knowledge Transmission in the Late 20th Century', *Urban Studies*, 32(2): 361–78.

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