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THE INDIAN ELECTRONICS INDUSTRY: CURRENT STATUS, PERSPECTIVES AND POLICY OPTIONS

by

Ghayur Alam

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RÉSUMÉ

Priorité des années 80, l'industrie électronique indienne a bénéficié d'une ample protection. Du fait de techniques de production inefficaces, elle génère des produits obsolètes d'une qualité médiocre à des coûts élevés. Depuis 1983, diverses tentatives de "libéralisation" ont vu le jour. De ce fait, la croissance du secteur s'est accélérée, de nombreuses entreprises se sont installées sur le marché, la dépendance à l'égard des technologies étrangères et dans le domaine des composants s'est approfondie. Quatre études de cas -- ordinateurs personnels (PC), téléviseurs couleurs, commutateurs électroniques et circuits intégrés -- montrent les effets de la nouvelle politique du gouvernement en matière électronique sur les performances et la compétitivité internationale du secteur. De toute évidence, cette libéralisation a laminé l'assise technique de l'industrie électronique et creusé sa dépendance à l'égard des importations.

Dans le secteur des ordinateurs personnels, après une période d'expansion rapide, la croissance du marché s'est effondrée et la chute des prix a compromis la rentabilité des entreprises. Dans un contexte de concentration renforcée, les entreprises survivantes s'efforcent de vendre, autant que possible, des équipements complets -- ordinateurs et programmes -- pour accroître leurs marges. Quelques uns des plus grands fabriquants d'ordinateurs personnels se lancent dans l'adaptation de modèles importés. Mais si les entreprises importantes ont réussi à automatiser certaines opérations, les plus petites éprouvent des difficultés. Si l'on excepte les circuits intégrés, la plupart des autres composants sont produits à des coûts élevés, sur des bases locales. La probabilité de l'apparition prochaine d'ordinateurs personnels proprement indiens et compétitifs à l'échelle internationale reste faible.

En ce qui concerne les téléviseurs couleurs, la production a démarré au début des années 80 à l'aide de pièces importées. Les contraintes d'équilibre des échanges avec l'étranger ont été assouplies, et l'on s'attend à voir la demande diminuer de façon substantielle. Sur ce marché aussi, la concentration est d'actualité à cause de l'impossibilité, pour les petites entreprises, de réaliser des économies d'échelle sans lesquelles l'acquisition de toute compétitivité internationale devient très difficile.

De réels efforts d'"indianisation" se sont portés sur l'industrie des tubes cathodiques : trois sociétés indiennes (toutes liées à un fournisseur japonais de technologie) produisent ensemble 4 millions de tubes par an. Mais l'utilisation des capacités de production et sa qualité restent faibles. Quant à la conception de modèles de téléviseurs proprement locaux, elle n'existe pas : la plupart des appareils ont des lignes dépassées depuis au moins cinq ans. Les coûts de production interdisent toute compétitivité des téléviseurs couleurs indiens sur le marché des exportations.

Pour les commutateurs électroniques, l'Inde s'est engagée dans la production de centraux téléphoniques en 1985 à partir de technologies françaises. Mais le souci d'une indianisation excessive des composants a enchéri leur coût. Les pouvoirs publics ont poussé à la conception locale de commutateurs qui a abouti à la mise à l'essai de deux prototypes expérimentaux. Comme les pouvoirs publics misent sur la consolidation des

capacités de production de l'Inde en matière de commutateurs électroniques, la question du choix entre technologie française et technologie nationale reste posée. La même concurrence existe sur le marché des autocommutateurs téléphoniques privés dont la fabrication est ouverte aux entreprises privées, à la différence des centraux téléphoniques publics. La multiplication excessive des fabricants est à prévoir, la plupart des plus modestes d'entre eux étant sous licence technologique locale, plus facile à obtenir que les licences de technologies étrangères. Mais la conception des produits s'en ressent, ils sont moins séduisants de divers points de vue.

Sur le plan des circuits intégrés, l'Inde se trouve reléguée bien loin des technologies de pointe. Le seul fabriquant de produits élaborés souffre de sa basse productivité et de ses coûts de production élevés, en majeure partie des circuits intégrés pour les postes de radio et les téléviseurs en noir et blanc. Mais l'entreprise a également réalisé nombre de circuits intégrés de télécommunication en copiant des modèles existants. La production des circuits plus sophistiqués se caractérise par sa grande inefficacité, avec des exportations à peine suffisantes au maintien de l'activité et incapables de dégager des profits. Tous les efforts déployés dans l'espoir de créer des modèles de circuits plus originaux ont buté sur l'impossibilité d'importer les logiciels indispensables jusqu'à la récente levée des restrictions imposées par le Cocom. La profonde dépendance à l'égard des éléments importés limite beaucoup la demande de circuits intégrés de conception nationale. Des centres de conception de circuits d'application spécifique (application specific integrated circuits, ASIC) pour l'exportation ont récemment bénéficié de quelques investissements, avec une collaboration étrangère.

SUMMARY

Prior to the 1980s, India's electronics industry was heavily protected. The industry used inefficient production methods to produce obsolete products of low quality at high cost. Since 1983, various attempts were made to "liberalize" the industry. The overall effects have been accelerated growth, the entry of many new firms in the market place and an increased reliance on foreign technology and components. Four case studies, covering personal computers (PCs), colour TVs (CTVs), electronic switching equipment, and integrated circuits (ICs), demonstrate the impact which the government's new electronics policy has had on the industry's technological capabilities and international competitiveness. There is growing concern that liberalization has eroded the industry's technological base and made it far too dependent on imports. A policy shift is likely to occur in the near future to promote greater localisation of component production as well as local research and development.

In the PC sector, after a period of rapid expansion, market growth has drastically declined and price cutting has squeezed firms' profitability. Concentration is likely to increase, and the remaining firms will try to sell more PCs as part of systems -- packaged with software -- in an effort to boost their margins. Some of the larger PC manufacturers have begun to make improvements in imported designs. While large firms have been

able to automate some operations, small firms have had difficulty. Except for ICs, indigenisation has occurred for most components of PCs but at high cost. The likelihood of Indian-made PCs becoming internationally competitive in the near future is very small.

Colour TV production began in the early 1980s based on imported kits. Foreign equity limitations were relaxed on firms in this field. Demand is expected to slow down quite substantially. Concentration is also likely to occur in this market, as small firms unable to reap economies of scale find it increasingly difficult to compete. Strong indigenisation efforts have been made in picture tubes, with three local firms (each linked to a Japanese technology supplier) having combined capacity of 4 million tubes a year. Capacity utilisation and quality are both low. Local design of colour TVs is nonexistent and most sets assembled are based on designs at least five years old. High production costs also render Indian colour TVs uncompetitive in export markets.

In electronic switching systems India set up production of digital exchanges in 1985, based on French technology. Excessive component localisation has inflated costs. The government has also pursued development of an indigenous switch design, two experimental versions of which have been installed for trial use. As the government plans to expand production capacity for switching equipment, the choice has yet to be made between the French design and the indigenous one. Similar competition between foreign and local designs exists in the market for electronic private automatic branch exchanges (EPABXs). In contrast to public switching systems, private firms are now permitted to make EPABXs. Excessive entry appears to have occurred, with most of the smaller firms licensing the local technology. The terms of the licensing agreement are more generous than in the case of the foreign technologies, but the design appears to be less attractive in several respects.

India is perhaps farthest behind the world frontier in IC technology. In the case of more mature products, India's sole producer suffers from low production yields and high production costs. Most of these ICs are for black-and-white TVs and radios. The firm has also been able to make a number of telecommunications ICs using copied designs. Production of more sophisticated ICs is also highly inefficient. Exports are necessary just to keep the process running but they are not profitable. Efforts at greater local IC design have been hampered by inability to import the necessary software until recently (due to Cocom restrictions). Demand for locally designed ICs remains very limited due to heavy reliance on imported kits. A few investments have been made recently in export-oriented ASIC (application specific IC) design centres, with foreign collaboration.

PREFACE

This investigation of India's electronics industry provides a thorough assessment of government initiatives to increase the sector's technological capabilities and competitiveness in the international marketplace. Its usefulness goes beyond the particularities of an individual country study, since the Indian experience has relevance for other developing countries where decision makers are tempted to pursue policies promoting local self reliance on the one hand, while on the other, often encountering pressure to liberalize various industrial sectors.

Alam's study helps to understand better some of the underlying forces at work when policies tending towards "self-reliance" or "liberalization" are implemented. "Self-reliance" condemned India to using outmoded production techniques to turn out low quality goods at high cost. Yet, it did foster considerable technological learning on the part of Indian engineers. The policy of liberalization enabled companies to become more technologically up-to-date, but largely through the simple assembling of imported products, placing great strains on the country's balance of payments. The ballooning trade deficit and the decline in local R&D initiatives, has led to growing criticism of the liberalization policy and to a partial reversion to policies aimed at local self-reliance.

This policy vacillation in itself creates serious difficulties as it introduces significant uncertainty into the investment environment. India's electronics industry captures, in a particularly dramatic form, a dilemma which is not unique to developing countries. In any high-tech industry, a country which values technological independence above all, may have to pay a very high price for it. In the end, technological self-reliance may turn out to be an elusive goal. Nor is the sophistication of technical know-how any guarantee of the ability to build up a competitive industry.

Louis Emmerij
President of the OECD Development Centre
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I. INTRODUCTION*

India's electronics industry is a relatively small but rapidly expanding sector as evidenced in its annual growth rate of production which has consistently exceeded 30 per cent since 1985 (see Table 1). Its production value in 1988-89 was estimated at approximately Rs. 70 850 million [1]. The Indian government has accorded special attention to the modernization and growth of this sector with the hope that it will generate at least 7 per cent of the GNP by the year 2000 [2], or approximately Rs. 100 000 million according to Department of Electronics estimates [3].

Until the end of the 1970s, this was the most protected of all Indian industries. The country's electronics policy strongly favoured self-reliance and technology and capital imports were actively discouraged [4]. Furthermore, the manufacture of certain electronic products was restricted to either the public sector or to small firms.

While this protectionist policy produced isolated instances of impressive technological advances, by and large the industry was very inefficient producing outdated models at high costs. Having access to only low quality and expensive raw materials compounded the problem. Not surprisingly, sales in those years were very limited.

The slow growth of the electronics industry, and its technological obsolescence began to receive the attention of Indian policy makers by the late 1970s. In 1979 the Sondhi Committee set up to examine the sector's performance strongly encouraged the dismantling of most of the controls which had been imposed [5]. It was, however, only in the early 1980s that the process of liberalization began in earnest. The first measures announced in 1983 aimed at reducing input costs through the lowering of import duties and local taxes [6] and encouraging economies of scale by removing some of the restrictions on the entry of large firms. A number of ambitious plans for setting up high-tech production facilities for integrated circuits (ICs) and electronic switching components were also announced.

Since 1983, the electronics policy has increasingly advocated liberalization, although some aspects of the policy have fluctuated, particularly those related to import restrictions and duties. Some of the important policy changes are outlined below.

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Licensing

The Indian government makes extensive use of licensing controls to influence industrial structure. In the past, these controls were imposed to prevent large private companies and those with foreign equity from entering the electronics industry as the sector was considered strategically important, and high technology electronics production was consequently restricted to state-owned enterprises. The production of components, considered a low technology activity, was reserved for small firms.

At the time of writing, the situation had been completely altered. Most restrictions which had prevented companies from entering the field have been removed and, in fact, very large firms and those with foreign equity are actively encouraged to invest in high-technology industries. Only a few strategically important products, such as large electronic systems, are restricted to state-owned enterprises.

With the realisation that the cost-effective production of high quality components is a technologically intensive activity requiring very large investments, this activity, formerly reserved for small firms, has been completely deregularized. Not only are there no limitations on production capacities, but companies are actively encouraged to set up economically viable manufacturing facilities.

Greater flexibility in the product range has also been introduced, by allowing companies to manufacture a wide gamut of related products without having to obtain permission, a move expected to increase capacity utilisation.

Technology Imports

As with licensing, the situation regarding the import of technology and component parts, has also been reversed. Prior to the 1980s, imports were severely restricted, with few exceptions. Only those required by the state for defence and telecommunications were permitted. Under the new electronics policy, permission to import technology is very easily granted [7].

More importantly, restrictions on technology payments including royalties and technical fees, have largely been removed and higher royalty rates are commonly permitted.

Restrictions on the importation of Semi-Knocked-Down kits (SKDs) and Completely Knocked-Down kits (CKDs) in the initial stages of production have also been relaxed. In fact, a substantial proportion of electronics production in recent years has been based on the assembly of imported kits. Manufacturers of PCs and CTVs have particularly benefited from this policy.

Before examining the electronics industry in detail, it is useful for an overall understanding to highlight some of the major developments in the industry since the policy has been liberalized. The most important and conspicuous development is the very wide range of modern electronic products being produced including a variety of consumer products, such as colour TVs, push-button telephones and video recorders; the latest models of PCs, and even more complex products such as advanced mainframe computers are already under way. The time lag between the introduction of a product in developed countries and its production in India is often very small. This is particularly true for consumer products, which have shown a very fast rate of growth in recent years as evidenced in the figures available for 1987-88 which reveal a growth rate of 42 per cent, accounting for more than 38 per cent of total electronic production [8].

Liberalization has attracted a large number of manufacturers often resulting in intense competition and consequently a pushing down of prices. Indian products are still considerably more expensive than those available on the international marketplace.

When examined in greater detail, however, these developments are overshadowed by some discouraging signs. First of all, the industry is very import-dependent. While producing a wide variety of new products, most of these are based on the assembly of imported kits. In 1985, 80 per cent of the value of components used by the electronics industry were imported [9] with the trend continuing in subsequent years, particularly in the case of PCs and CTVs.

It also appears that a large majority of the companies attracted to the electronics industry in recent years are not interested in setting up manufacturing facilities, contenting themselves with the assemblage of imported kits. As a result, the process of indigenisation has met with little success. Indigenisation has also been feeble in the production of component parts attributable to their long gestation period and comparatively low returns [10].

Even the most enthusiastic supporters of a liberal electronics policy are beginning to express concern over the high dependence on imported inputs. In a recent official document [11], the Department of Electronics acknowledged that while liberalization has allowed the industry's rapid expansion, it has also been responsible for weakening its technological base. The report's major findings point to:

- a significant drop in R&D activities with even simple products which could feasibly be designed locally being furnished through imports;

- foreign collaborative efforts being undertaken exclusively for the import of plants and kits to the neglect of technological know-how and know-why;

- a sharp decline in domestic production's share of total consumption;

- the stagnation of exports to hard currency areas.

These concerns have already begun to influence government policy. A number of measures to restrict imports and increase the pace of indigenisation have recently been introduced, particularly aimed at ensuring that the users of imported kits move in the direction of production based on indigenous inputs. The building up of design competence will also be given greater importance than in the past. One measure being considered is whether companies which import technology should be required to spend up to 15 per cent of their turnover on R&D activities.

This is clearly a crucial period for the electronics industry and the policy changes being considered will have a profound impact on the nature of future growth. At the date of writing of this paper, it was too early to predict with any degree of real certitude the future course of policy initiatives but a shift towards reduced liberalization can most likely be expected.

The rest of this paper examines various aspects of India's liberal electronics policy, in particular whether it has been successful in transforming the stagnant industry of the 1970s into a modern, cost-effective and internationally competitive industry. Considerable attention will be paid to the study of technology-related activities as they play a crucial role in the development of an internationally competitive industry [12]. Information available on the performance of the electronics industry is, by and large, limited to macro-level indicators such as the value of production, imports and exports. Company-level information about the nature of production techniques employed and R&D activities undertaken is particularly scarce. To fill some of this information gap, detailed studies of a number of electronic products were conducted, namely, personal computers (PCs), colour TVs (CTVs), integrated circuits and electronic exchanges. The results of these studies, based on interviews with manufacturers and policy makers, and on published information, are presented in the following sections.

II. CASE STUDIES

1. Personal Computers (PCs)

An Overview of India's Computer Industry

Although computers were first introduced in India in the 1950s, for many years their diffusion was limited to a few research and educational institutions. For a number of years the market was monopolised by comparatively older models of IBM and ICL. It was only in the mid-1970s that microprocessor-based computers became available. Even these computers were a generation behind the computers being used in developed countries at that time.

The 1970s also saw the emergence of the first Indian computer manufacturers. By the early 1970s four firms (PSI, DCM, ORG and HCL) had introduced 4-bit machines. When IBM left India in the late 1970s, a large number of Indian firms obtained licences to manufacture and market mini and micro computers. However, their limited production capacity and the high prices charged by these companies severely restrained domestic industrial growth.

The early 1980s witnessed a considerable expansion in the demand for advanced computers, notably for minis and PCs required by the banking and insurance industries. As a result, powerful machines based on Intel 16 bit chips began to appear on the Indian market by 1981. In this same year, a Bombay-based firm, Minicomp, introduced India's first IBM-compatible PC.

The year 1984 heralded the next major change in India's computer industry with the promulgation of a new policy aimed at achieving a faster growth rate through the removal of various licensing and import restrictions [13].

The new policy permitted all Indian companies, including private firms and those with less than 40 per cent foreign equity to manufacture and market PCs and minis (including minis using 32-bit microprocessors). Only the manufacture of super minis and main frame computers was reserved for public sector firms for the first two years.

Through the suppression of various restrictions policy makers hoped to induce Indian manufacturers to produce the latest computers at internationally competitive prices. The policy also facilitated technology, plant and machinery imports considered necessary to achieve these goals. Components parts and raw material imports were also liberalized. In addition, to take advantage of the economies of scale, all restrictions on production capacity were removed.

The policy also aimed at expanding demand by simplifying the procedures required to acquire computers, particularly those applied to imports, thereby reducing delays. Other important measures introduced in 1984 included:

1. Tariff structure revision to reduce the cost of imported components;

2. Exemption of the industry from the purview of the location policy as undeveloped areas might not attract skilled manpower and would assuredly suffer from a lack of infrastructure;

3. Elimination of controls governing the import of designs and drawings for firms with officially recognized research and development facilities;

4. Stimulation of the import of software in source code form;

5. A progressive reduction of the high import duties, originally designed to protect local producers, to encourage the latter to become more internationally competitive.

These measures have completely transformed the industry, particularly with, respect to personal computers, where the easy availability of imported inputs has attracted a large number of producers with a new generation of PCs at steadily declining prices as the end result. Indian prices, however, are not internationally competitive and, in fact, are on the rise. The industry is also heavily dependent on imported inputs.

Profile of India's PC Industry

A very large number of firms are competing for a comparatively small market. Of the approximately 150 firms currently producing and marketing PCs in India, 120 are very small [14] with some employing fewer than ten people and averaging only five PC sales per month.

The number of producers has increased from 101 firms in 1985 to 142 in 1987 [15] and a further reported increase in 1988 to 150 [16].

The top ten firms accounted for 77 per cent and 73 per cent of total sales in 1984-85 and 1985-86 respectively [17] while, in 1986-87, 80 per cent of PC sales could be attributed to five manufacturers (see Table 2).

Even the largest of the Indian producers, however, is very small with HCL showing sales figures of only 4 000 PCs in 1987, and only three of the other leading contenders with sales in excess of 1 000 PCs in that same year. Considering the internal market's very small growth modest production volumes will likely continue.

On the whole, the market is extremely price sensitive. Companies claim that irrespective of the quality, considering that most PCs available in India offer comparable features, even a difference of Rs. 500 is sufficient to influence the buyers' choice.

Prices declined steadily between 1984 and 1988, initially attributable to international price reductions and the lowering of import duties in 1984. In more recent years, however, the need to compete in a small and price sensitive market has perhaps been the most influential factor in forcing prices down [18].

In 1984, computer prices were very high: a 16-bit machine sold for approximately Rs. 0.25 million [19]. A comparable machine is currently available for only Rs. 25 000. The latest of the price reductions were effected in 1986, when market leader HCL reduced the price of their PC from Rs. 35 000 to Rs. 20 000. The ensuing price war led to an across-the-board decline with prices averaging between Rs. 20 000 and Rs. 25 000. (For average price changes, see Table 3).

The industry is currently at a critical stage. PC demand is growing very slowly with the trend likely to continue. As margins are already low, manufacturers will find it difficult to reduce prices further. In fact, prices have actually been increasing due to a sharp rise in imported memory chips and other components costs [20]. In addition, according to most PC producers, a large proportion of the demand has already been satisfied and future demand will not increase more than 30 per cent [21]. According to earlier estimates for the current year PC demand was expected to average 56 000 units; the major producers, however, anticipate that it will not exceed 45 000. (For production figures and values, see Table 3).

As the bought-in components currently account for a very high proportion of the total value of a PC, a company's profitability depends on its ability to identify low price suppliers and adequate financial resources to make bulk purchases. This is particularly true in the case of imported components such as microprocessors, where high-volume purchases mean substantially lower prices. According to an example quoted by one of the leading producers, one microprocessor can cost up to $100, a hundred, however, may only cost $40 each. Ten thousand units purchased at one time might be sold for only $20 each; a situation clearly benefiting larger firms with greater financial resources. The inability of small companies to compete with the large firms is becoming increasingly evident, and it is generally agreed that the top five producers will further strengthen their hold over the PC market.

This trend is likely to be further strengthened by a financial and technical venture between Modis, a large Indian business house, and Olivetti for the production and marketing of PCs in India. This is the first undertaking of its kind and is expected to transform the PC industry. The combined resources of Modis and Olivetti are likely to make their joint company the leading manufacturer of PCs and peripherals enabling them to produce a large number of units at a lower cost, and, perhaps, enter the international market. PC producers tend to feel that the entry of the Modi-Olivetti joint company will force other firms either to make comparable investments or move out of the market.

Faced with a situation of small margins and low demand, many of the large firms are modifying their sales strategies opting for marketing their PCs only as components of total information and communication systems, which involve a considerable amount of software inputs, thereby expanding profit margins.

Technology Gap and Technology Development

India's PC production is based largely on imported designs, most of which were initially imported with CKDs.

The majority of India's PC producers are too small to have either the financial resources or the technological capability to carry out design or R&D activities. They merely assemble imported kits/components on the basis of imported designs. However, some of the larger firms are technologically-oriented and have competent R&D and design departments, among them HCL, PSI, Wipro and ESPL.

The assembling of imported kits none the less offered a more attractive alternative and has, as a result, reduced R&D activities to a minimum. In fact, many firms who had previously been engaged in serious R&D efforts and had developed their own computer designs subsequently abandoned these efforts in favour of imported designs. PSI is a good example of one such firm. The company began its operations in 1974 with an order from a US firm, Syscom, to design a prototype for a microprocessor-based telex monitor. The design was a success and is still being used in the United States. By the late 1970s the firm was designing and manufacturing its own 8-bit computers [22].

After 1984, as the latest PCs, based on imported designs and kits, began to saturate the Indian market, design activities became less attractive. Furthermore, as the pressure to lower prices increased, companies responded to the squeeze by reducing their R&D activities. Even the most R&D-oriented firms began to adopt the attitude of traders, discovering that technological and manufacturing competence were no longer the keys to a successful business. In fact, to be successful it became necessary to minimize in-house manufacturing activities and to rely largely on easy-to-assemble imported sub-assemblies and components. As a result the value added of even those companies with relatively high levels of manufacturing activities became very low. PSI, for example, which in the past had a very high percentage of value added, considers that if the value added for any of their PCs exceeds 5 per cent of the selling price, the operation is unlikely to be profitable. Many other large firms are reported to have value added between 5 and 10 per cent.

Recently R&D and design activities have seen a limited renewal. Initially the process was aimed at indigenisation and began with the copying of imported designs on indigenous PCBs, as opposed to using imported Printed Circuit Boards (PCBs); and in some cases, to modify the designs to accommodate Indian conditions of heat, dust and power fluctuations. In addition, some of the larger producers attempted to identify and develop local substitutes for imported materials.

Improvements to imported designs have also been reported. For example, one Indian PC producer added a separate input/output processor unit to a 386-based imported design. This unit, distinct from the main processor isolates input/output operations from the main CPU, thereby substantially increasing the throughput of the machine. Subsequently, five or six other manufacturers followed suit [23]. In another case, a company producing Tandy PCs modified the mother board enabling the machine to support 720 Kbyte floppy drives.

Recent years have also seen a dramatic decline in the time lag between the introduction of a new PC design in developed countries and its subsequent appearance in India. Prior to 1984 the PC designs available in India were at least four years old. Recent statistics in the case of 386-based designs, for example, reveal a delay of only about four months. In fact, when five Indian firms introduced these machines to India in mid-1986, they were among the world's first 15 firms to do so and actual production levels of 386 machines are quite high [24]. More importantly, in most cases, the quality of these machines is comparable to that of international models.

Some of the technologically-oriented firms are now using computer-aided design (CAD) systems for circuit design. According to industry sources at least five producers are already employing these techniques, and others are expected to follow. Furthermore, those companies who have installed CAD systems use them intensively. For example, Wipro, which has had a CAD system operational since the mid-1980s, claims that every single board used in its PCs is designed on its CAD. Another producer, DCM, claims to be able to use its in-house CAD facilities for designing PCBs up to 8 layers. However, considering the heavy dependence on imported designs, a significant increase in the use of such techniques and other designing tools is unlikely.

Production Technology

Production technologies employed by Indian firms vary widely. They range from completely manual methods of assembly and soldering with very elementary testing facilities, to semi-automatic insertion devices, wave soldering machines and sophisticated computerised testing facilities.

Most small firms use manual production technology. They have very basic assembly and testing facilities. Many employ fewer than five people in assembly operations, and testing is done with the help of oscilloscopes costing less than Rs. 15 000.

The use of PCBs is generally limited to large producers. The high initial investment, as well as the frequent reprogramming required, makes them prohibitive for small firms. In India there is no standardization of PCBs and PC manufacturers are obliged to use PCBs with different layout designs, which entails frequent reprogramming.

The use of semi-automatic component insertion machines, however, is now quite common among large companies. Only a handful of large firms, mainly state-owned enterprises, are still using completely manual insertion techniques. As these machines can replace up to 20 workers, officials in these firms contend that their use cannot be justified in a labour surplus country. Moreover, as the use of manual insertion methods does not affect the quality of the boards, they feel no compulsion to use mechanized insertion techniques. However, even these officials admit that if their production sales increased to about 5 000 PCs a year, they would be obliged to mechanize. None of the manufacturers, however, uses completely automated assembling techniques as they are not cost-effective at current levels of production.

The use of advanced production techniques is more common in the case of welding, and wave soldering machines are used by many large and some small firms. As is the case for automated assembling devices, their greater diffusion is hampered by low production volumes making it impossible to amortize the high cost of these machines. In numerous instances, companies anticipating a higher growth rate invested in advanced production machines. However, the anticipated demand did not materialize and these high volume machines are lying around idle. One firm, for example, imported two wave soldering machines, one semi-automatic assembly station and three board testers at a cost of Rs. 4.5 millions. At present they are not even able to use their existing manual assembly facilities to capacity.

Case studies also revealed that some firms are not able to use their soldering machines primarily because of inadequate power supplies, lack of maintenance facilities and high operational costs. The last two represent major obstacles for small firms. One small company, PS Machines, having purchased a wave soldering machine had been able to use it only once in the first year. The machine had been out of order most of the time.

The high operational costs of wave soldering machines result from the need to cleanse flux from the boards in a special vapour degreaser which is itself costly to install and operate. Flux, which is applied to the board before soldering, is a highly corrosive substance and, unless removed, can seriously damage the board. However, it costs about Rs. 0.2 million to install a degreaser and the cost of cleaning one PCB is between Rs. 60 and 70, prohibits expenses for many small firms who opt, instead, for a mixture of soap and water, an inefficient and not wholly effective method.

Testing facilities also vary considerably. While most PC producers, particularly those with small production volumes, use very basic testing facilities, some of the large ones have installed sophisticated, computerised card testing facilities ensuring a higher quality of both individual components and complete circuits. Most R&D-oriented firms had placed particular emphasis on acquiring these facilities, even those who otherwise rely completely on manual assembly methods. One such firm had imported a Fairchild in-line testing machine costing more than Rs. 8 million (only three other Indian firms have comparable testing machines). It should be noted, however, that in some instances the companies have failed to optimally utilise these machines mainly due to their inability to write some very complex software to run the test programmes.

Surface mounted components are also beginning to be employed. At the time of writing, two firms were already using them for the production of PCs and drives and other firms announced plans to do so. Surface mounted ICs are very compact and each can replace up to ten conventional devices. Considering the large cost reductions which can result from their use, Indian manufacturers will have to follow international trends. As their use requires different assembly and soldering techniques, however, the diffusion of these components is likely to be slow for the near future.

Indigenisation

In the years immediately following the implementation of the policy of liberalization, PC production consisted entirely of the assembling of imported kits requiring very little technical competence or sophisticated facilities.

Producers, however, are expected to follow a phased manufacturing programme (PMP), approved and regulated by the government, of increasing indigenisation [25].

Some of the components, notably, PCBs, drives and cables, have already been indigenised. For a number of reasons, however, a large majority of manufacturers continue to prefer imported parts over those locally produced. As a result, the degree of indigenisation achieved by the PC industry is considerably lower than had been estimated.

The wide divergence in import levels is interesting. As one might expect, the smaller firms are highly dependent on imports; up to 80 per cent of the value of their components are imported. On the contrary, most of the larger producers show a much lower dependence with the value of their imports ranging from 30-50 per cent.

Cost data obtained from some of the leading manufacturers revealed the following breakdown of imported and locally produced component costs for a basic PC unit:

Imported components	Cost (Rs.)	
Mainly ICs and connectors	10 000	
Indigenous Components		
Power Supply	1 500	
Floppy Drives	5 000	
Monitor	2 000	
Key Boards	1 200	
Cabinet	500	
PCBs with Indian Discreet Components	3 500	
Cables	50	
Value Added	1 500	
Total		25 250

Source: Individual company data.

As these figures show, direct imports account for about 50 per cent of total costs in the case of larger companies. However, when the imports that go into the production of monitors, keyboards and drives are taken into account, the actual imported content is much higher. Exact figures are not available, but industry estimates put the figures for total import content for a typical PC at a minimum of 75 per cent.

The value of imports has further increased attributable primarily to a very sharp increase in the price of memory chips which comprise a high proportion of the imported content of a PC, skyrocketing from an average cost of only $2.50 per unit to more than $10 at the end of 1989.

Easy access to imported kits killed any incentive to indigenise. Kit importation is often cheaper than the assembly of imported components because Indian manufacturers import small numbers and consequently are required to pay higher prices. On the other hand, the kit suppliers in Southeast Asia purchase components in very large numbers at low prices enabling them to sell these kits to Indian firms at comparatively lower prices.

Even where locally produced components are available import substitution has not been easy to achieve. PCBs offer a good case study. PCB technology is not very complex. A number of Indian companies manufacture multi-layer PCBs; Bangalore alone counts more than ten producers. There have been, however, a number of complaints about the quality, and a large number of PC producers continue to use imported boards. A number of firms reported that while the quality of 2-layer PCBs is satisfactory, the quality deteriorates when more than two layers are introduced.

It is interesting to note that most of the firms who complained about quality are small. In many instances PC producers had tried locally produced PCBs, but finding the quality unsatisfactory, reverted back to using imported products. Their technological competence is low; they have no long-term interest in the PC business and consequently, they are neither equipped nor willing to undertake the efforts necessary for successful indigenisation. On the other hand, many companies with a strong technology base have already switched over to the use of locally produced PCBs.

Wipro was the first Indian firm to do so, though initially serious problems existed with the PCBs supplied by the local producer.

However, Wipro, a large firm with high technological capabilities, was able to appreciate the problems of the PCB manufacturer and extended technical support. As Wipro is the second largest PC manufacturer in the country and a large consumer of PCBs, the PCB producer was particularly keen to satisfy its client by improving the quality of its product. The complete process, nevertheless, was long; it was three years before the company was able to meet Wipro's quality requirements fully. The net result, however, has been positive: Wipro no longer imports any PCBs up to four layers.

Two Indian firms have recently begun manufacturing drives collaborating with American and Japanese companies, DEC and Ye Data, respectively. As in the case of PCBs, the acceptance of locally produced drives has been slow as they have suffered from some compatibility problems. These problems have been solved and most large firms are now using Indian drives. Many small firms, however, continue to use imported products as they are approximately 30 per cent cheaper. While the PMP programme stipulates that their import is permissible only during the initial stages of PC production, drives continue to be illegally imported in large numbers, creating serious problems for local manufacturers.

The indigenisation process is being hampered by high prices and poor quality. The large price differential in the case of drives is accompanied by that of a number of other components such as 386 boards and floppy drive controller cards [26]. The inferior quality of many of the locally produced components equally remains a concern to PC manufacturers [27].

This is particularly true in the case of discrete components, many of which are manufactured by small companies [28]. The cost of setting up a modern plant equipped with the latest production technology is high and few Indian firms are interested in investing such large sums to cater to the small Indian market [29].

Some of the large PC manufacturers have set up in-house production facilities for the more critical components. DCM, for example, has produced its own multi-layer PCBs. The production costs are high, but justified by the consistently superior quality of the components produced [30]. There are, however, some indications that the availability of locally produced components may improve in the near future as two firms are planning to make large investments in the production of components and peripherals [31].

It must be emphasized that companies with a serious commitment to the PC business are beginning to realize that overdependence on imports creates serious uncertainties which are not in keeping with their long-term interests. Factors of instability such as frequent changes in import policy, fluctuations in the exchange rate and in the costs of imports make long-range planning extremely difficult. Moreover, as the delivery of imports can often take up to six months, and the supply is not ensured, firms need to maintain a higher inventory of imported components than is required for most indigenous parts. In addition to these problems, the maintenance of PCs based on imported kits is difficult and expensive. To avoid these uncertainties and disadvantages, companies with a long-term manufacturing interest appear to be committed to increased use of locally produced components.

At the same time it should be noted that the scope for indigenisation has almost reached its limit. Most components used for PC production, with the exception of ICs, are presently being manufactured in India. As there is no possibility of Indian production of ICs in the near future, the import content of the country's PCs will continue to be at least 50 per cent.

What about the export competitiveness of Indian PCs? The volume of PC production in India is extremely small. Even the largest manufacturer produces less than 10 000 units per year while most others have an average annual output of less than 500. Compared with international production volumes, this is tiny. The disadvantage of small scales is compounded by the low level of capacity utilisation. Due to the wide fluctuations in demand, many producers have provided for additional production capacity, which remains unused for most of the year. Even the most efficient of India's PC manufacturers suffers from up to 50 per cent overcapacity. The high costs of components, both imported and local, contribute to the higher prices of Indian PCs [32].

Industry officials agree that while the quality of the PCs produced by the country's major manufacturers is comparable to those available on the international market, their high costs prevent them from competing in the international arena. It is, therefore, not surprising that in spite of a slow increase in local demand and the existence of unused operating capacity, the firms did not consider exports as a viable alternative. The country exports PCs only to the USSR and to eastern European countries, which have special trade relations with India. It should be noted, however, that if the government's plans to produce up to 200 000 PCs with a sales price of Rs. 10 000 each are successful, then PC exports from India will become a real possibility.

Before concluding this section, it should be emphasized that the relatively poor technological efforts made by most PC producers do not accurately reflect the actual technological strength of India's computer industry. There are indications that some companies have reaffirmed their commitment to strengthening their design capabilities and that they have used these for designing systems around the latest microprocessors. For example, systems using 386 chips have become quite common and some PC producers have already introduced PS/2 look-alike machines. Even more importantly, much of the R&D and design activity is concentrated in the technologically demanding areas of mini and mainframe computers, and a study of these products would have yielded a somewhat different picture of Indian companies' technological capabilities. The more prominent of these firms, such as HCL, Wipro and PSI, are producing an impressive range of computers, reflecting the depth of their technological expertise. HCL's Magnum is perhaps the most important computer to come out of India. This series of mini computers is a multiprocessor system running Unix version v.3 on MC 68030 processors, which are the latest chips from Motorola. Designed by HCL at a cost of about Rs. 72 million, the system has not only become popular in India but has also found wide acceptance in the United States where the company has set up an American subsidiary to manufacture and market the series. By mid-1989, HCL had already sold more than 1 000 systems [33]. Wipro has also designed an internationally marketable computer. The company is one of the few PC manufacturers in the world to have developed a Multibus II, 80386 board. The board was designed for a US firm, Mylex. While the design was produced in India, the fabrication of the board was carried out by Wipro engineers in the United States.

Another important achievement of India's computer companies has been the development of systems around Intel's 486 chips. Some of these firms are among the pioneers in using this chip. DCM, who was the first to announce a supermini built around a 486 chip, employed a team of 25 designers and has already spent approximately Rs. 256 million on the development work [34].

It is also noteworthy that many of the larger firms are progressively attaching less importance to their PC business and are concentrating on system-oriented activities, where technological challenges are greater but profit margins higher. PSI, for example, has set up a separate subsidiary to carry out its PC manufacturing business. Its main business activities are increasingly oriented towards the design and manufacturing of more powerful computers and telecommunications equipment. HCL and Wipro are heading in a similar direction.

2. Colour Television

The rapid expansion of Colour Television (CTV) production is perhaps the most conspicuous success of the new electronics policy. From a small beginning in the early 1980s, when kits were first imported and assembled in India, the production of CTVs has emerged as one of the fastest growing activities in the electronics industry.

The first attempts to produce a CTV occurred in 1982, when a government laboratory successfully developed a prototype [35]. In that same year, the technology was transferred to a state-owned electronics manufacturer for commercial production. Changes in the electronics policy permitting the importation of kits on a large scale severely damaged efforts to produce an indigenously designed CTV. As a result of the policy of liberalization, the first CTVs to appear on the Indian market were based on imported kits. When the first batch of locally designed TVs was introduced in 1984, it was too late as the market was already saturated by sleeker looking TVs assembled from imported kits.

Ninety thousand kits were imported from the Federal Republic of Germany and Korea, a move considered necessary to permit diffusion of the Asian Games to be held in New Delhi. The import of kits was to be barred after the Games. It was expected that the assembling of them would permit companies to become familiar with CTV production technology enabling them to acquire sufficient technological competence to begin local production. The suppliers of kits were required to provide the technological know-how necessary for this purpose [36].

Numerous companies were attracted by the possibility of assembling and selling CTVs in a highly profitable market without having to make large investments in the setting-up of manufacturing facilities. Continuing its earlier policy of encouraging small firms to enter the electronics sector, only the latter were permitted to assemble these kits. Most of these companies were already producing black and white TVs [37] and possessed the basic assembly facilities. They lacked sophisticated soldering and testing equipment but were expected to upgrade their facilities to meet CTV production requirements [38].

For a period of two years, kit imports were permitted. Subsequently, the government adopted a policy to induce firms to indigenise production gradually and their importation was banned. However, as a large number of components required by CTV producers were not locally available, the importation of these was permitted. To increase the pace of indigenisation, the government lifted earlier restrictions on the entry of large firms into the CTV field, including those with up to 40 per cent foreign equity [39].

The number of CTVs produced was 0.85 million and 1.10 million in 1986 and 1987 respectively, and rose to 1.3 million in 1988 [40]. A 35 per cent growth rate was witnessed when the colour TV broadcasting network was undergoing rapid expansion. The demand for CTVs has since levelled off and is expected to grow at a compound rate of 25 per cent over the next ten years.

The CTV field counts some 40 manufacturers, many of whom are very small, with an average annual production rate of 30 000 units. On the other hand, as of 1988 the 5 leading manufacturers were producing more than 0.1 million CTVs a year.

The industry is dominated by about ten firms who control approximately 80 per cent of the market. This concentration is likely to increase. With competition intensifying and declining profit margins, most of the small producers are likely to get out of the field and no more than five firms are expected to continue production [40].

The steady decline of profit margins in recent years is attributable to the sharp increase in the value of the yen, which, in relation to the Indian rupee, has more than doubled from 1983 to 1988. As imports account for a very large proportion of material costs, the value of the yen significantly affects production costs [41].

The market is characterized by a very wide range of prices. These vary from Rs. 7 000 to Rs. 15 000. Import duties and various taxes account for a substantial proportion of these price differentials. For a TV costing between Rs. 12 000 and Rs. 15 000, they represent up to 50 per cent of the sales price and import duties, which range from 85 to 145 per cent on imported components, account for up to 30 per cent of this.

Indigenisation

Official predictions of indigenisation projected that local production would completely replace imported goods by the end of 1987 [42]. Actual progress, however, was considerably slower than expected for several reasons. Firstly, the growth of the components industry has been very slow and in most cases local substitutes were either not available or were of poor quality. This was particularly true for some critical components such as picture tubes, fly back transformers, deflection components and ICs [43].

By 1990 the situation had already evolved somewhat. Many manufactured components, such as tubes, PCBs and turners are being manufactured in India. Production levels, however, are not sufficient to meet local demand and many components are still imported. According to industry sources, the import content of most CTVs still exceeds 60 per cent. The government's decision to restrict imports aimed at helping local producers, has not worked. Many components continue to be imported through replenishment licences available on the black market with which almost any item can be imported. Frequently CTV producers find it cheaper to import components using these licences than to buy locally.

The most ambitious indigenisation efforts are being made in the area of picture tubes. Initial efforts at localising production began in 1984 when three firms, Samtel, UPTRON and JCT, were granted licences to set up production plants with a total capacity of 1.3 million tubes per year [44]. Since then, their operating capacity has expanded and by 1989 the three companies possessed a total combined operating capacity of 4 million tubes per year. Samtel, UPTRON and JCT have also established collaborative ventures with Mitsubishi, Toshiba and Hitachi respectively.

It should be noted that the 4 million tube operating capacity greatly exceeds current demand, and there is little likelihood of demand augmenting sufficiently to utilize this capacity. The most optimistic projections estimate the demand for colour tubes in 1989-90 at no more than 1 million units [45]. Even by 1992 the demand is not expected to exceed 2 million. Clearly, unless tube manufacturers can find a large export market, their capacity utilisation will remain low. The only export possibilities are the USSR and other eastern European countries. Some Indian companies have already obtained large orders from the Soviet Union of up to 0.1 million tubes. Exports to hard currency areas, however, are not considered likely.

Picture tube production is an extremely capital-intensive activity. Modern plants are highly automated and operate at very high levels of capacity utilisation. Indian plants, on the other hand, are not only small, but use outdated technology affecting both the costs and the quality of local production [46].

Indian production is planned according to three stages. During the first stage, called yamming, imported tubes are joined with imported deflection components. In the second stage, more extensive assembly is carried out with imported components. Coated panels and shells are imported separately and assembled locally. The electron gun is also assembled locally at this stage. In the third and final stage, the panels are coated in India.

Indian manufacturers are in the first and second stages of their manufacturing plans. Current production levels are low and less than half of their potential capacity is being utilised. Production costs are high and as a large number of tubes are being imported under open general licensing, companies are finding it difficult to sell even their limited production. Indications are that imports will soon be banned to protect the fledgling local industry. In anticipation of this turnaround, some of the large CTV producers are already beginning to use locally manufactured tubes.

Imported ICs also comprise a significant proportion of the imported components and indigenisation efforts have largely failed. While there is some local production by the Indian firm, BEL, their ICs are only being used by two state-owned enterprises, ECIL and ETTD who are using a specially locally designed circuit capable of accepting these ICs. The other CTV producers are using imported designs which cannot accommodate these ICs. According to some industry officials, only minor modifications would be required to enable utilisation of these ICs. As imported ICs are still available, however, there is no incentive to do so.

As is the case for PCs, the predominance of small firms has seriously limited the indigenisation process. The process is further restrained by a number of governmental concessions exclusively available to small firms, encouraging them to limit their growth. Take the example of one of the market leaders. The firm began operations, without much success, in the late 1970s, with the production of digital watches and telephone answering machines. In 1982 they diversified their product line with CTVs assembled from imported kits. Through a very aggressive marketing campaign, the company was able to increase its turnover from Rs. 10 million in 1982-83 to Rs. 1 250 million in 1986-87. Both their prices and sales are among the highest in India and they have captured 10 per cent of the total CTV market. By very deliberately limiting investment in manufacturing machinery and testing facilities, however, the company has managed to remain within the limitations set for small firms. Their total investment in capital goods, including testing equipment, is only about Rs. 3.5 million. Their assembly operations are completely manual and much of their testing is done through oscilloscope. Compared to this, many of the larger firms are already using semi-automatic component insertion machines, and some have installed very sophisticated testing facilities, costing up to Rs. 20 million.

The removal of restrictions on the entry of large firms and firms with foreign equity, which was expected to accelerate the pace of indigenisation, has not been very effective either. In fact, few of these companies have been attracted to CTV production. Only two such firms, Philips and BPL-Sanyo, have a significant share of the CTV market and both had already been active in the electronics industry and possess a long experience of import substitution. They have developed extensive networks of quality-conscious local suppliers. Both firms have attained a higher degree of indigenisation than their competitors. BPL-Sanyo, for example, reports that local production accounts for 80 per cent of the value of its components. These firms also use their technological competence and manufacturing facilities to increase the value added. The value added by BPL-Sanyo, for example, is reported to be Rs. 3000. This is almost double the average of most other firms, who are merely assembling CTVs. They also manufacture many components, such as fly back transformers, deflection components and electronic tuners, which other companies continue to import.

R&D and Design Activities

R&D and design activities are virtually non-existent. Most CTV producers do not have R&D facilities. Even large electronics firms, who have design departments and CAD facilities for their other products, do not employ these for designing CTVs.

Most companies' manufacturing operations are based on the designs originally imported with the kits and have not been modified. Through informal arrangements with their Japanese suppliers (ONIDA-JVC, Orson-Sony, Weston-Hitachi), some companies are able to obtain new designs as well as technical assistance in solving production problems. As these arrangements are carried out without government approval, and therefore cannot officially be reimbursed, the foreign companies, as suppliers of components as well to their Indian associates, tend to boost their prices to compensate for these services.

The reliance of Indian CTV producers on foreign designs is likely to continue. By late 1989 many manufacturers were planning to introduce flat square picture tube TVs [46] and in all cases the designs for these will be imported. Local production of picture tubes is likely to suffer from these design modifications. While some tube manufacturers claim that their production lines are flexible and can be used for producing flat square tubes, TV manufacturers do not express the same degree of confidence. Some companies are also considering introducing digital TVs in the near future.

Exports

The quality of Indian TVs is comparable to that available on the international market; Indian prices, however, are not competitive. Even after various incentives and subsidies are accounted for, Indian TVs are still about 30-35 per cent more expensive than those available on foreign markets. Thus, the chances of exporting CTVs from India are small. In addition to the relatively inefficient production methods and the high cost of capital which inflate costs, Indian producers have to buy replenishment licences at a premium to import components considered necessary for the production of CTVs which would be internationally marketable. The premium paid for the purchase of these licences can be up to 30 per cent of the licence value and constitutes the critical difference between Indian and international prices.

3. Electronic Switching Equipment

Main Automatic Exchanges (MAX)

The production of switching systems for main exchanges is exclusively reserved for India's largest telecommunications producer, ITI. Until recently, only strowger and crossbar exchanges were being manufactured. Electronic exchanges were first introduced in large cities in the early 1980s. At about the same time, the government decided to begin production of these exchanges and to gradually phase out strowger and crossbar production.

The choice of technology has, since the beginning, stirred considerable controversy and in particular, the question of choosing between indigenous and imported designs. Research into the design of an electronic switching system was undertaken by Telecommunications Research Centre (TRC) in New Delhi in the early 1980s. By the time that it was necessary to select a technology supplier TRC had already developed an experimental exchange. Although its performance was reported to be satisfactory, it was not considered a suitable choice primarily because it was an analogue design. The international trend towards digital equipment already in evidence influenced Indian decision makers in their rejection of analogue technology. India's lack of experience in using modern electronic production techniques, which TRC could not provide, also helped to sway government officials.

In the end, officials chose to enter into a collaborative agreement with CIT Alcatel of France. A plant with a production capacity of 0.5 million lines a year was set up in 1985. Initial production was based on the import of SKDs from its French supplier for 28 000 lines. Production has since risen with 0.22 million lines being produced in 1987-88 [47] and expected to increase to 0.4 million in 1989-90 [48].

The production of electronic exchanges requires a large number of high quality electronic components. At the time the plant was set up, most of these were not being locally produced. To reduce dependence on imports, in-house components production was undertaken. As a result, the plant was forced to have a very high level of vertical integration, with a corresponding increase in production costs.

Some of the important components produced by the plant include hybrids and PCBs. The PCB plant, which is the most advanced in India, including computer-controlled drilling machines, has the capacity to produce 30 000 square meters of double-sided PCBs. The raw material, copper-coated glass epoxy sheets, are imported as sheets of this thickness (17.5 microns) are not locally available. The plant also produces 1 million relays, 1.8 million connectors, 0.4 million bus bars and 1.4 million coils and transformers [49].

Efforts to develop a commercially viable design for digital electronic exchanges were also initiated with the creation of the Centre for Development of Telematics (C-Dot) in 1984. The Centre was expected to develop a design for the Main Automatic Exchanges (MAX) at a cost of Rs. 350 million and the work was to be finished within three years. These plans were thought to be overly ambitious as, according to many observers, the C-Dot did not dispose of sufficient resources.

C-Dot's design efforts were aimed at producing a digital electronic exchange more suitable to Indian climatic conditions of high temperature and humidity, able to accommodate the country's high telephone density and to withstand wide voltage fluctuations. It was also expected that C-Dot's efforts would provide a cheaper digital exchange and reduce the country's dependence on imported components.

C-Dot has used the Motorola 68 000-based UNIX system in their switching design. It was the first organisation to obtain a source code for the UNIX system version V.2 from AT&T which was required to modify the UNIX kernel to work with the switching system [50].

C-Dot was able to attract a large number of competent Indian engineers, some of whom had previously been engaged in electronic switching system designs at TRC. It also had access to the large industrial capabilities in and around Bangalore for prototype production. However, the development of software was found to be difficult and time-consuming, primarily attributable to the unavailability of appropriate software tools.

Two experimental versions were tried in Bangalore and in Delhi. As the next step, a pilot plant will begin production of 20 000 lines. Once the production technique has been perfected, the plant's operating capacity will be expanded to produce 0.1 million lines.

Local production of telephone lines falls far short of the demand. As of May 1988 there were 1.3 million customers on the waiting list for new connections [51] and a shortage of 0.2 million lines is expected during the seventh five-year-plan period (1985-90) [52]. To help meet demand, the Indian government decided to set up a second plant with 0.5 million lines/year capacity. Initially, the plant was to be set up as a cooperative venture with CIT Alcatel, and a memorandum of understanding with the French company was signed in 1986. This decision attracted strong criticism, however, as by that time India was already committed to developing a local design for digital switching systems. Since then, a number of contradictory decisions by the government have added to the uncertainty, and the final choice of a technology for the second plant has yet to be made [53].

One of the major attractions of the French technology is the fact that Indian engineers are already familiar with it, enabling them to operate and maintain the plant and the exchanges without much difficulty. On the other hand, the C-Dot design has yet to be proven on a large scale and could pose unexpected problems during its commercialization.

The CIT Alcatel technology, however, is comparatively expensive and is considered obsolete. According to available information, the setting up of a 0.5 million lines plant with CIT Alcatel technology would cost about Rs. 1 380 million [53] while the same plant equipped with C-Dot technology would cost between Rs. 300 million and Rs. 580 million. Production cost estimates for the CIT Alcatel plant are also higher, approximately Rs. 6 750 per line, when compared with those for the C-Dot plant where estimates range between Rs. 4 000 and Rs. 5 000 per line. The C-Dot costs are lower as comparatively sophisticated micro circuitry is employed reducing the number of components required [54].

Another important advantage of C-Dot design is that its modular nature permits capacity to be reduced without increasing costs. While the CIT Alcatel exchanges begin to be economical at 4 000 or more lines, the C-Dot design can be used economically even for 2 000 line exchanges, clearly an advantage given the large number of small towns in India which do not require large capacity exchanges.

If C-Dot and ITI's pilot plant proves to be commercially viable, the lower costs which they are able to offer will give them a definite advantage over CIT Alcatel and other foreign technology suppliers. The Department of Telecommunications, the sole buyer of telephone lines, has not even sufficient purchasing power to be able to absorb the full production of the existing ESS plant [55]. As a result, the decision to set up the second plant has been indefinitely postponed, clearly to the advantage of C-Dot, which consequently has more time to prove the viability of its design.

Electronic Private Automatic Branch Exchanges (EPABX)

One of the telecom equipment products affected by the policy of liberalization, PABX exchanges had been exclusively produced for the Department of Telecommunications by state-owned enterprises. In 1985, private firms were permitted to enter the market. The government also decided to adopt electronic switching technology. As this technology was not locally available, three foreign firms - Jeument Schneider of France, GTE of Belgium and OKI Data of Japan - were selected to provide technology transfer on a centralized basis.

While short-term needs required the import of technology, indigenous designs were envisaged which would eventually take into account the specificities of Indian conditions. C-Dot, which was already engaged in designing a MAX, also undertook the design of an EPABX. Their design became available in 1986 and was licenced to a number of companies.

Approximately 50 firms have licences to manufacture EPABXs, 40 of which are for C-Dot technology. About 30 of the licensed firms are already producing and marketing EPABXs. Most of these, however, are very small with very low production volumes. This is particularly true for C-Dot licensees.

An anticipated annual demand of approximately 0.2 million EPABXs increasing to 0.5 million by 1990 has not materialized. The lack of demand is already causing serious problems for manufacturers with the exception of a few large firms producing EPABXs with foreign technology.

It is noteworthy, however, that EPABXs represent one of the few examples of a product based on local technology and components underpricing products based on imported technology. A per line comparison of costs demonstrates the magnitude of difference between the two: while in the case of C-Dot technology costs vary between Rs. 2 500 and 4 000 per line, foreign technology costs range from Rs. 7 000 to 12 000. Moreover, except for total capacity, the capabilities of the various systems are more or less comparable (see Table 4).

While early versions of C-Dot design showed a number of limitations, such as no provision for data transmission, later models offer facilities comparable to those available with imported designs. The most recent version of C-Dot can be linked to telex, facsimile machines and computers. In addition, the C-Dot design is more suitable to Indian climatic conditions of high temperatures and humidity. While foreign designs permit operation between temperatures of 35 and 40 degrees celsius, the C-Dot design can continue to function up to 45 degrees celsius [56]. It can also withstand up to 95 per cent humidity and higher voltage fluctuations (between 50 and 56 v). Foreign designs can tolerate fluctuations of only between 44 and 56 v DC. The C-Dot design is also easy to maintain and reliable as it is equipped with a duplicate control.

These advantages, however, have not helped C-Dot design to gain acceptability in the Indian market. According to industry sources, only about 150 of the design systems have been sold. A number of reasons are responsible for this poor market showing.

Firstly, C-Dot technology has generally been purchased by small companies who do not have the necessary technological and marketing skills to compete with the large firms producing foreign-designed EPABXs. Secondly, the small number of lines offered by the system has turned out to be its major disadvantage with most clients favouring systems which offer expansion possibilities [57]. Thirdly, there is strong resistance to buying locally designed systems in a high-tech area and as most customers for this type of equipment are corporate organisations, with low price sensitivity, they are prepared and able to pay prices as much as three times higher for imported systems.

A handful of manufacturers dominate the market. Of the 30 companies producing EPABXs, fewer than five had sold more than 50 systems over the two years prior to 1989 and only BPL, who is the market leader, has sold more than 100 systems. Most other firms have sold less than five systems and are facing serious difficulties.

As demand expectations in the past were very high, many companies built up large production capacities. One of the firms surveyed, for example, has an annual production capacity of 100 EPABXs and 50 RAXs but todate had only sold seven systems. While some of these companies have diversified product lines and can, therefore, use their facilities for manufacturing other things, others are suffering from serious capacity under-utilisation. C-Dot is planning to introduce a large scale standardization of cards which can be used to produce a wide variety of telecom equipment, and thereby enable manufacturers of such equipment to increase their capacity utilisation by using common facilities.

Although its commercial success has been small, the C-Dot design offers users the potential of building up technological capabilities as well as facilitating import substitution. As part of its technology transfer arrangement with licencees, C-Dot provides the source code and other software details permitting manufacturers to carry out design modifications. Similar arrangements are not available from foreign suppliers.

C-Dot also permits a high level of indigenisation as it uses 40 per cent local components compared to 20 per cent for foreign designs. In many cases, the latter require components with specifications which are not manufactured in India. As a result, even simple components such as transistors, diodes, capacitors and transformers have to be imported. The maintenance of these systems is also heavily dependent on imports as they use hybrid circuits which can not be repaired but need to be replaced with imports from the foreign suppliers. The C-Dot design, on the other hand, has taken into account locally available components. Its imports consist mainly of ICs and connectors, neither of which are made in India [58] and plans are to completely indigenize the system in the near future.

While the C-Dot design demonstrates that it is possible to produce a technically competent design in India, it also highlights the difficulties in commercializing such designs. Most of the deficiencies encountered were due to the inexperience of Indian designers in catering to users' requirements, including, as already signaled, its small capacity. A number of other design deficiencies such as the lack of data transfer and metering facilities were corrected in later versions. Since 1986, the design has been revised five times. While such modifications enhance usefulness, they nevertheless create serious problems for manufacturers as each new version of the design requires a new PCB, as well as changes in production and testing procedures.

While Indian producers will have to wait for the system to be stabilized before venturing into export markets, its comparatively lower production costs should make it viable in the international arena. Given its capacity limitations, however, exports to developed countries are unlikely. On the other hand, eastern European and the developing countries represent potential markets.

Rural Automatic Exchanges (RAX)

The development and production of rural electronic exchanges represent another important advance in the area of telecommunications. In spite of a very large potential market, rural systems development was, in the past, generally neglected. Statistics from the 1981 census reveal how enormous the potential customer base is: of the 576 000 villages in India, less than 9 000 were connected with telephones by 1976. Most of the exchanges in these areas were old and were based on strowger technology [59].

C-Dot and ITI undertook the development of a digital design suitable for these areas. In the latter part of the 1980s, principal design considerations included reliability, low maintenance requirements, economical at small capacities, with an independent and reliable power source.

Both ITI and C-Dot were successful in developing RAX designs, and both are being commercially produced. The C-Dot model, which has 128 ports, includes transmission equipment, solar panels and storage batteries. It can cover an area of 40 kilometers and costs Rs. 0.5 million [60].

While ITI is manufacturing its own rural exchanges, C-Dot has licenced its technology to a number of companies including most firms with EPABX licences. In 1986-87, 880 rural exchanges were installed [61]. The shortage of resources within the Department of Telecommunications, however, led to a drastic drop in demand. Even an unambitious programme of setting up one RAX a day has been postponed [62]. Although official estimates, were projecting a demand of about 1 000 RAX for 1989 [63], the actual demand is likely to have been considerably lower.

It is interesting to note that ITI is already exporting its system to Bhutan and considers developing countries a large potential market. It is a very cost-effective and rugged design with a remote monitoring facility obviating the need for manual operation, an attractive feature to developing countries which often suffer from a shortage of technical manpower. It is also cheaper: $100 per line compared to international prices of about $125.

4. Integrated Circuits

Small Scale Integrated (SSI) Medium Scale Integrated (MSI) ICs

Bharat Electronics Ltd. (BEL) was the first Indian manufacturer of ICs. It produces a wide range of SSI/MSI IC devices for use in both professional and consumer electronic products. The company manufactures about 90 varieties of Linear and Digital Bipolar and Digital C-Mos type ICs including clock, single chip radio, audio amplifier, tape recorder and colour TV ICs.

One of the largest and most diversified electronics producers, employing some 19 000 people, its 1987-88 turnover was Rs. 3 764.6 million with profits of Rs. 310 million for that same year. In addition to integrated circuits, BEL produces communications equipment, semiconductor devices; electron, transmitting, and microwave as well as quartz crystals [64].

The company has an annual production capacity of about 5 million ICs, although actual production levels are considerably lower as Table 5 illustrates. Even after more than 15 years of operation, the capacity utilisation is only around 80 per cent. Nevertheless, BEL is planning to expand its production capacity to 10 million ICs in 1990-91.

In BEL's early operating history, a low demand for ICs was largely responsible for very low capacity utilisation in those years. Since the mid-1980s, however, demand has risen and is no longer a factor limiting capacity utilisation. The main problems are related to the nature of the plant and prevailing work practices. Firstly, the BEL plant has a number of manual and semi-automatic operations. In particular, almost all assembly and testing activities are carried out by operators, all of whom are women. BEL's production capacity is seriously limited by the fact that it cannot run a second shift in these departments, as women employees are not permitted to work night shifts; which, in turn, explains the company's keen interest in modernizing its plant and automating its operations.

BEL's production volume is very low when compared with international levels. The company produces only 1 million units of even its most popular IC. In fact, in the past, BEL has been obliged to produce batches as small as 10 000 just to keep the process operating.

The small volumes and low capacity utilisation mean that BEL's production costs are considerably higher than international levels. Moreover, the quality of most of the ICs, which are produced in small numbers, is poor.

Other factors which contribute to the company's high production costs are: heavy import duties (Duties on capital equipment imports are 60 per cent; on spare parts, 100-180 per cent and on raw materials, 45-100 per cent); high power costs, interest rates as well as high rates of rejection.

Rejection rates as high as 60 per cent are attributable to BEL's antiquated plant and production process. Up to 40 per cent of the ICs are rejected at the wafer stage. Of the remaining 60 per cent, a third are rejected at the finishing stages. By comparison only 5-10 per cent of the ICs manufactured in modern plants in developed countries are rejected.

Between 1980 and 1985, IC operations were responsible for a total loss of Rs. 65 million to the company. In recent years, however, the situation has improved and IC production has become a profitable operation contributing RS. 11.8 million in 1986-87 (see Table 5).

ICs developed by BEL for use in black and white TVs and radios are the highest contributors to the sales and profits realized. BEL controls a very large share of these markets; in the case of B&W TVs, for example, more than 75 per cent of the market. In both cases, the ICs are protected by high import duties, and BEL's prices are comparable to the landed cost of import.

BEL is also producing an IC for use in colour TVs, but its efforts to capture a large share of the market have failed due to competition from imported ICs which enter the country as part of kits or are illegally imported [65].

The BEL ICs are not "one to one" (pin to pin) substitutes for the imported ICs. As a result, Indian TV producers need to modify their imported designs to be able to accommodate them. As ICs account for only a very small part of the total cost of components in a colour TV -- about Rs. 200 out of a total of Rs. 3 500 -- TV manufacturers are not keen to substitute imports with BEL's ICs even though the company is able to offer lower prices [66]. Nevertheless, two public sector TV manufacturers, ECIL and KELTRON, are using the company's ICs in their sets.

The company has now decided to design and manufacture a complete substitute for the most popular imported colour TV IC compatible with TV circuitry without requiring any modifications. A test version was expected by the end of 1988. Development costs were estimated at about Rs. 0.1 million. The company hopes to sell 200 000 to 300 000 of these devices at a rate of Rs. 25 each, considerably lower than imported prices. Total annual sales of some Rs. 5 million are anticipated.

As Table 6 indicates, a small number of specialised ICs have been exported to some developing countries. However, the export market for these ICs is limited due to high costs and poor quality. Even when there is a large market for the ICs as is the case for B&W TVs, Indian production costs are still considerably higher than those incurred by foreign suppliers [67]. As a result, BEL sells its ICs for B&W TVs for Rs. 10 in India, while internationally they are available for about Rs. 5. According to BEL officials, even when all government incentives and subsidies are taken into account, and their plant's modernization realized, the export market will still not be profitable.

Technology Acquisition

BEL's first attempts to manufacture ICs were based on indigenously developed designs. In collaboration with an Indian research institute (TIFR) the company fabricated its first chip in 1971. However, attempts to commercialize the design were unsuccessful as neither BEL nor TIFR were sufficiently familiar with production technology. In that same year, BEL began collaborating with RCA of the United States for the production of a wide range of devices. In fact, the agreement permitted BEL to produce any of the 400 devices for which RCA designs were available.

This collaborative venture, initially undertaken for a decade, was renewed in 1981 for another eight years. According to the new agreement, RCA is required to supply mask drawings, design data, processing technology and testing parameters for the devices to be manufactured by BEL. To date, however, BEL has produced only 15 types of RCA device due to the limited domestic market: 75 per cent of the company's IC production is destined for colour and B&W TV manufacturers with the remaining 25 per cent distributed among the radio receiver, defence and telecommunication equipment industries. Despite these limitations, BEL officials contend that the collaboration has been very economical considering the large range of devices covered and the amount of information transferred for their production. The company spent US$ 0.2 million on the initial agreement and US$ 0.4 million on the renewal. Compared to the technology transfer fees charged by other firms, these sums are considered small.

In addition to transferring circuit designs, production process know-how and other related information, RCA is also responsible for training BEL engineers. The training is an ongoing activity enabling the company to keep abreast of changes in RCA's production process.

In addition to the RCA range of products, BEL also manufactures other ICs which are in popular demand in India. In most cases, the circuitry has been copied by BEL designers making whatever necessary modifications to accommodate BEL's wafer fabrication line.

Production Technology

BEL production capabilities are limited to LSI circuits with 5 micron lines, considered sufficient to meet the demands of the domestic market. Nevertheless, the company plans to modernize its plant to be able to produce 3 micron VLSI circuits which, according to BEL officials, will be able to meet 80 per cent of the Indian demand for ICs even in 1995.

Much of the equipment used in the production process is over 15 years old [68] including some of the critical components such as diffusion tubes and epitaxial reactors. While BEL possesses some fairly sophisticated testing facilities for linear ICs, the testing facilities for digital ICs are very basic, having been installed in 1974. Neither the plant nor the process has been altered or improved since installation and its yields are considerably lower than international levels. The antiquated technology imposes a number of limitations on the size of the wafer which can be processed. When the plant was set up, the wafer size averaged 2 to 3 inches. Since then, 4-inch wafers on which more chips can be produced in a single operation have been introduced. BEL, however, is unable to use the large wafers as it does not have the necessary diffusion tubes.

Clearly, the BEL plant is inadequate to produce competitively priced ICs. The quality of its product also suffers from the lack of modern automatic devices and process controls. Even the maintenance of the plant poses a serious problem as replacement parts are not easily available. While most of the equipment necessary for modernizing the plant is available on the open market, the costs involved had, in the past, made it prohibitively expensive. A new diffusion furnace with six tubes, just as one example, costs about Rs. 15 million.

BEL is planning a major expansion and modernization of its production facilities designed to expand their capacity to 100 million devices a year and to enable them to produce VLSI of 1.25 micron line width by 1995-96 [69]. This will involve the installation of a number of highly sophisticated machines for improving plant throughput and device yield. The company has already ordered Rs. 150 million worth of equipment.

In comparison, only Rs. 74 million was invested in the plant for the entire period between 1974 and 1985. BEL is also attempting to renew its collaborative agreement with RCA.

Company officials are hopeful that the plant's modernization will sharply increase labour productivity. The plant employed some 180 people in 1989 and the annual turnover from IC sales was approximately Rs. 78 million. With the same number of employees, the turnover is expected to increase to about Rs. 200 million -a per employee output of about Rs. 1 million per year - a rise of approximately Rs. 0.6 million.

As Table 7 reveals, until the mid-1980s, imports contributed to more than 50 per cent of the production value. The level of imports, however, has declined to about 15 per cent in recent years.

Design Activities

BEL's design capabilities are limited. While they do not have the facilities to design ICs, over the years the company has developed sufficient technical expertise to permit them to copy designs of imported ICs. They also have adequate equipment and software capabilities to prepare layouts for the ICs made in collaboration with RCA with assistance from the latter in the form of mask patterns and other additional information. BEL has prepared layouts for most of its ICs, but it is a time-consuming process as their CAD facilities are very limited. It can require up to one year to prepare layouts for very complex LSIs, although a typical LSI of medium complexity requires only three months.

However, the company's ability to adapt existing circuit ideas to new chip design should not be underestimated. With the competence they have already acquired, BEL has been able to produce a number of telecommunications ICs for which designs were not available from RCA. In fact, one of the first ICs developed by BEL in 1975 replaced an IC being imported by the Indian Telephone Industries from an Italian firm. BEL was able to supply this device at Rs. 30 per unit while the imported price was Rs. 70.

The decision to undertake a particular design project is largely determined by the complexity of the design and the potential market. In most cases, BEL will venture into a design project only if there is at least a 50 per cent chance of success and a market of at least 0.1 million devices as the cost of design adaptation is high, ranging from Rs. 0.2 to 0.3 million for a typical IC. Even when a large demand exists the company may opt to buy a proven foreign design if the design requirements are too complex. For example, in the case of push button telephones, BEL is designing some of the simpler ICs itself but has sought foreign collaboration for the more complex ICs required.

The company did not have facilities for designing ASICs, relying on facilities hired in developed countries to prepare such designs. As part of the modernization plan, however, BEL is considering setting up in-house facilities.

The possibility that the company's collaboration with RCA would be terminated in 1989, will create serious design difficulties. Under such conditions, BEL would no longer have access even to the now obsolescent LSI chips of RCA. Unless it decides to go for a new collaboration, the company will need to strengthen its existing R&D and design capabilities considerably. The latest indications are, however, that BEL plans to renew their RCA agreement. That notwithstanding, the company will still need to build up a strong design team with access to sophisticated CAD facilities.

Such an undertaking, however, will not be easy. Apart from the problem of raising the large amounts of capital required, there is a serious shortage of designers in this area. As no training facilities exist, it is not even possible to hire schooled designers and the company must rely entirely on in-house training. It is also difficult to retain designers, as many of them leave for developed countries. By 1989 eight designers had left BEL over the preceding five years. However, the company plans to increase the number of design staff employees to 50 by 1991-92. In addition to these problems, BEL has encountered serious difficulties in purchasing sophisticated software design tools.

Large-Scale Integrated/Very Large-Scale Integrated (LSI/VLSI) ICs

These ICs are produced by the state-owned Semi-conductors Complex Ltd. (SCL). Although the decision to produce LSI/VLSI ICs in India was taken in 1975 and a company for this purpose set up in 1978, it was only in 1983 that a plant could be built. Manufacturing activities began in 1984 with the production of 0.53 micron width ICs [70].

In 1989, SCL was producing a variety of standard LSI/VLSI and ASICs including clock-watch chips, codecs and 8-bit microprocessors. In 1987-88 the company produced a total of 6 million LSI/VLSI chip and about 30 000 ASIC devices. Production levels are expected to rise to around 7 million devices in 1988-89 (see Table 8) [71].

The plant was set up to produce 4.5 million devices per year, expansion plans envisage boosting that capacity to 10 million devices annually [72].

As in the case of BEL, SCL's scale of production is very uneconomical. Its capacity, even after expansion, will be much less than world's leading producers of standard LSI/VLSI circuits. Furthermore, LSI devices for watches account for almost 80 per cent of the company's output, the remainder being divided between microprocessors, telecommunications ICs and ASICs. The production of these ICs is particularly uneconomical as they are manufactured in extremely small batches. Microprocessors, for example, are produced in batches of only 40-45 000. Even in the case of ICs for watches, the production volume is only 4 million devices, or the equivalent of one-fifth of the output of their main competitor in the export market.

Domestic demand for ICs is comparatively small. According to official estimates, the total demand for ICs will average 100 million devices a year by 1989-90 with SSI/MSI devices accounting for 80 per cent of this demand and LSI/VLSI devices for the remainder. If SCL were to control most of the Indian market for LSI/VLSI ICs, the demand would be sufficient to produce economically at least a small range of LSI/VLSI ICs. However, as a large part of this demand is met through imports of a total demand of Rs. 1 504 million ICs in 1987-88, only Rs. 96 million was met through local production - the actual market for SCL's ICs is actually considerably smaller [73].

The small demand for ICs seriously limits the possibility of a large expansion of production capacity. It also hinders diversification of the company's product line as certain ICs, such as memory devices, require very large minimum scales of production. SCL had attempted to produce memory chips of 16 K RAM using imports of ready wafers from ITT. The company's efforts were unsuccessful owing to the length of the production process. By the time the IC was introduced it was already obsolete, even for the Indian market.

A key to increasing domestic demand for locally produced ICs and thereby enabling economies of scale to be realized, is the standardization of ICs used in various end products. For example, a large demand exists for ICs used in the production of colour TVs. TV manufacturers, however, employ a wide variety of ICs greatly hampering indigenisation efforts. Where standardization efforts have succeeded, as in the case of ICs used for watch production, SCL has been able to create a large demand for its products.

Despite the fact that it is not very profitable, SCL exports some of its high-cost ICs to keep the plant operational even at a minimum scale throughout the year and thereby prevent the process from "dying".

Most of these exports consist of watch ICs to southeast Asia. Export earnings from these ICs are comparatively small as they are not packaged but are exported as die-on-wafers. These are then packaged and sold by the southeast Asian companies as watch modules, a comparatively high value product. SCL's main competitor is a west German firm Eurosil, which produces 20 million of these units per year out of a total annual IC production of some 200 million devices.

Past experience demonstrates that SCL cannot enter international competition for standard, mass produced products such as microprocessors and memory chips. Its potential for success in the international arena is limited to specialised LSI/VLSI devices as is the case for other IC producers such as Ferranti and Plessey in the UK and Alcatel and Thomson in France.

Technology Acquisition

It took eight years from the time the decision was made to produce LSI/VLSI ICs locally for the plant to be built. Most of the delay was caused by the difficulty in finding a collaborator [74]. A number of leading IC producers who were approached for technology transfer, simply refused to negotiate with SCL. The company was finally able to interest a small US firm, American Microsystems (AMI), which while not among the leading manufacturers of standard ICs, had a solid reputation as an ASIC producer. The agreement was signed in 1981.

This exclusion from the technical expertise of the major IC producers has seriously limited SCL's activities. The general reluctance of these firms to transfer know-how in this high technology area was compounded by restrictions imposed by the US government. It is generally believed that had US firms been approached prior to the government's decision to curtail technology transfer, SCL would have had a wider choice of potential collaborators. The length of time taken to reach a decision by various Indian government committees, has proved to be very costly in this case.

SCL's collaboration with AMI was aimed at building a complete infrastructure for LSI design, mask fabrication, and wafer fabrication and assembly at 5 micron level. Subsequently, the company entered into agreement with Hitachi for the manufacture of watch modules and with Rockwell for the production of an 8-bit 6502 microprocessor, a compromise as Rockwell refused SCL access to the technology for the more powerful 68000 microprocessors and Codec ICs [75].

Design Activities

As most of the ICs made by SCL are provided under collaborative agreements, the design parameters and other necessary production information is furnished by the foreign suppliers in magnetic tape format and converted into actual designs by the design department. The latter is also responsible for the development of ASICs.

The department has 60 engineers which is large by Indian standards but very small when compared with major international IC producers. The competence of the design team is further weakened by a lack of sophisticated CAD systems and software tools. Most of the design support available in-house was purchased from AMI in the early 1980s and is outdated and inadequate. SCL is keen to acquire the latest software tools, which permit quick and detailed analysis. Speed is considered an essential factor in designing ICs for the international market.

One of SCL's future priority projects is the creation of a strong and independent design facility. The company purchased a library from AMI in the 1980s, which requires updating. However, as AMI has not undertaken much development work of recent date, the company cannot meet SCL's information needs. Nor is it feasible to buy a library from another source, as it may not be compatible with AMI processes; hence the increasing importance given to building up in-house design capabilities.

Similar efforts in the past encountered major difficulties, particularly with regard to the acquisition of software tools. SCL has since been able to purchase these tools from an American firm, Mentor Graphics. Concurrently, SCL has set up an in-house design group dedicated exclusively to the development of software tools.

In addition to strengthening its design capabilities, SCL has also enhanced its manufacturing facilities. The company's initial production facilities were limited to 5 microns. Relying on only in-house expertise, SCL was able to develop its own technology for fabrication at 2 micron line width. As a large part of India's IC demand will continue to be met with 3 micron technology, the upgrading has largely been carried out to produce strategically important ICs and ASICs. The latter are considered a particularly important area of expansion by SCL.

The company is able to produce ASICs from scratch, using gate arrays and standard cells. In 1987-88 SCL manufactured about 40 000 of these ICs. As its production volume is very low and the development costs high, ASICs have not been commercially successful. Most have been produced for strategic purposes where the development costs are fully borne by the clients.

The domestic demand for ASICs is severely limited due to the import of ICs and kits. The substitution of imported ICs with ASICs will require design modifications by equipment manufacturers, which most manufacturers are reluctant to do. An ASIC for colour TV, the only ASIC developed by SCL for commercialization (at a cost of Rs. 0.3 million) has not been very successful for this very reason.

Given the lack of a domestic market, SCL is turning its efforts to the production of ASICs for exportation. As, in ASIC development, software costs are a major component of total costs, SCL is hoping that India's low-cost design engineers will give them a competitive edge.

Indications are that India's design activities in this area are going to increase in the near future. A number of companies, among them PSI, have already signed collaborative agreements with foreign IC producers to design ASICs for the international market.

The Department of Electronics is also planning to set up ten LSI/VLSI regional design centres for ASIC development. It is hoped that the proximity of these centres to potential clients will increase the demand for and acceptability of ASICs in the domestic market place.

Another major step in this direction has been taken by the Indian Telephone Industry (ITI), the country's main telecommunications equipment manufacturer. ITI has a functional prototype production line for the fabrication of 5 and 3 micron LSI/VLSI chips. It has also designed Codec chips for telecommunications equipment. A recent arrangement for the purchase of a state-of-the-art electron beam lithography machine will permit the direct writing of 1 micron-width ELSI chips. It will also enable in-house generation of masks for these very high density devices.

ITI has also entered into agreements with VLSI Technology Inc. and Arcus Technology Inc. to set up facilities for the design and fabrication of ASICs for the telecommunications industry. The technology, purchased for Rs. 170 million, is for 1.5 micron-width devices. Construction of the plant will cost Rs. 600 million and it will require another Rs. 100 million per year to operate.

Considering that SCL's production facilities are under-utilised, the decision to set up another facility is questionable. Moreover, the proposed new fabrication facilities will only permit ITI to manufacture ASICs from semi-processed wafers which are available only from its collaborator. For ITI, this could mean a long-term and costly dependence on its foreign supplier, perhaps obliging ITI to pay as much as three times the market rate.

III. SUMMARY AND CONCLUSIONS

The possibility of setting up an internationally competitive electronics industry is conditioned by a number of domestic and international factors. The following discussion describes the impact of the most important of these namely industrial structure, domestic demand as well as the technology development and imports of Indian firms.

In reviewing the growth of the Indian electronics industry in the 1980s, two of the most striking features are its rapid growth and its comparatively diversified product line. Over the period 1986-89, the industry grew at a rate of more than 30 per cent. The annual growth rates for 1981-86, 1987-88, and 1988-89 were 33.8 per cent, 37.1 per cent and 34.0 per cent, respectively and the production values for these same years were Rs. 38 550, Rs. 52 850 and Rs. 70 850 million. This rapid growth has largely been accomplished through an expansion of consumer goods production. Consumer goods, in fact, represent the most important segment of the electronics industry accounting for about 38 per cent of production activities in 1988-89 [76]. In this respect the industry is very different from that in developed countries, where consumer electronics in 1985 represented only about 11 per cent of total production [77].

The new electronics policy, by removing a number of obstacles to increased production, is largely credited for this rapid growth. The lifting of the major entry barriers and the liberalization of imports have been the two most important measures in this regard. The pre-liberalization industry was characterized by high production costs and obsolete product designs. At the same time, it was extremely self-reliant with a high indigenisation ratio. The post-liberalization industry has seen a sharp increase in the number of manufacturers who largely offer state-of-the-art designs. Production is heavily dependent on imports, and costs, as well as prices, have declined considerably. The positive contribution of the liberal electronics policy, both for producers and consumers, is quite obvious. Its long-term impact, particularly with regard to the evolution of technological competence, requires closer examination.

This study has considered two distinct types of products. The first type, including PCs and CTVs, are relatively simple and assembly-oriented products whose manufacture is open to both public and private firms. The second type is represented by ICs and main automatic exchanges, both technologically complex products, with a limited number of producers, all of whom are state-owned. The liberalization policy has affected these two groups of products differently as will be seen below.

The financial and technological requirements of the first group are small, as access to state-of-the-art designs, testing parameters, and reliable components at competitive prices largely constitute their manufacturing needs. During the pre-liberalization period, the strong emphasis placed on self-reliance required manufacturers to use local, and often out-dated, designs while the import restrictions in effect required that components be purchased locally. Many of these were high priced and of poor quality. The liberal electronics policy removed this obstacle by simply allowing the import of CKDs/SKDs for local assembly. The effects of the new policy were evident within a very short period. As production required very limited assembly and testing equipment, the investment and technology barriers for entering the market declined. A large number of companies, many of whom were small with no previous experience in these areas, were able to assemble PCs and CTVs through the import of CKDs/SKDs. Competition increased and prices experienced a sharp decline. For example, PCs which were being marketed for more than Rs. 100 000, became available for less than Rs. 50 000. Subsequently, prices declined even further.

In sharp contrast to these positive consequences, the policy of liberalization has had some very serious negative repercussions. In particular, it created conditions where innovation became extremely unattractive. Instead of attaining production efficiency and technological superiority, manufacturers found it more profitable to minimize in-house value added by assembling imported kits. There was little incentive to carry out R&D and design activities and in fact, often the only requirement for success in the marketplace was the ability to identify and obtain components at the lowest price.

Even those firms who had developed a certain level of technological competence found they could not compete with imports and were forced to abandon their in-house design activities in favour of imported designs and CKDs/SKDs.

The impact of removing import restrictions on local design activities was further aggravated by the presence of a large number of firms, many spawned by the liberalization policy itself. As the average size of these companies was very small, they simply lacked the resources for carrying out any design-related activities. Concommitantly, the extreme fragmentation of the market meant that the market share of even the largest producers was small, creating a market structure where investments required for setting up manufacturing and design activities were not forthcoming.

At the time this study was conducted, the industry was already showing signs of greater technological dynamism than in the past. This is particularly true of the leading computer manufacturers, many of whom have designed state-of-the-art PCs and mini-computers using the latest chips. They are also concentrating more on marketing high-value systems rather than low-value, stand-alone PCs. The initial impetus for these activities came largely from the pressure exerted by the smaller producers. As all the manufacturers were using imported kits, there was very little that the larger companies could do to differentiate their products. At the same time, greater overheads made it increasingly difficult for them to compete on the basis of price. Moving to the higher end of the market by producing technologically demanding machines and systems was the only alternative. Once the need to concentrate on this segment of the market was realized, the leading firms were fast to revive their design activities, which had been reduced or abandoned.

This trend has recently reversed with technological activities' being pursued with greater vigour resulting from increased pressure and incentives to indigenize production. There are three reasons for this turnaround. Firstly, a number of components which had not been available on the domestic market are being manufactured locally and their import has been restricted or banned. Secondly, concerned by the industry's large foreign exchange outlays for imports the government has demonstrated more interest in indigenisation activities than in the past. Thirdly, a large appreciation in the value of the Japanese yen against the rupee has increased the cost of imported components very sharply, and, consequently, the attraction of using local components.

The accelerated pace of indigenisation has not only stimulated R&D and design activities, it has also produced changes in the structure of the industry itself. While the use of imported kits had allowed a large number of small firms to infiltrate the market, the need to use indigenous components favours the larger and more technologically resourceful firms. Companies need to be able to adapt their designs to accept the local components. Moreover, as the quality of these components is still poor and unreliable, testing facilities, both at the component level and at the final stage of production, are required to be more efficient than in the past. The greater technological capabilities demanded for increased indigenisation have forced many of the smaller firms out of business, while the larger companies have consolidated their market positions. The nature of competition has also changed, as a manufacturer's capability to offer reliable equipment, a wider range of products as well as to solve clients' problems becomes increasingly important for success in the marketplace.

The technological advances made at least in the case of the leading manufacturers, have been significant. Not only are these firms able to modify their designs to accept local components, they have also been successful in developing and commercializing state-of-the-art products some of which such as HCL's Magnum series of mini-computers, have found wide acceptance in industrialized countries.

Production technologies, however, remain antiquated and consequently, inefficient. This is largely due to the low level of domestic demand. As a result, production volumes are too small to justify the large investments required for incorporating modern, automated manufacturing technologies. In sum, limited demand rather than any technological limitations on the part of manufacturers appears to be a major factor for the prevalence of older production techniques.

The situation with regard to telecommunications equipment and ICs, is somewhat different. As these industries are almost completely government controlled, the liberalization policy did not significantly alter their market structure. With the exception of EPABXs, the number of producers has not seen any substantial change. However, the liberal import of technology and equipment did impose serious constraints on R&D design and production activities, with particularly severe repercussions in the case of electronic exchanges. As a result of the import of switching technology, the design activities at the Telecommunications Research Centre were completely disrupted. However, the error of completely abandoning design activities in this vital area was realized and a new design team organised. The case of electronic exchanges is, in fact, a good example of the strengths and weaknesses of Indian technology. While the efforts of Indian engineers to design a state-of-the-art electronic exchange were successful, foreign collaboration was considered essential for the production technology.

While the IC producers, in particular SCL, have developed considerable technological capabilities, their performance suffers from the limited demand for locally produced devices. Although India's total demand for ICs is quite large, most of it is met by imports. As the imported ICs are extensively used in equipment based on imported designs, such as CTVs, the impact of a liberal import policy is quite obvious. The government's intervention to compel equipment manufacturers to carry out design modifications able to incorporate a standard set of locally produced ICs is crucial to increasing demand for Indian ICs. In an industry where economies of scale are extremely significant, the importance of these measures cannot be overemphasized.

Given that the size of the demand weighs heavily on the choice of ICs to be manufactured, it is very difficult to understand India's decision to fabricate standard ICs, requiring very large production volumes, instead of ASICs. It is particularly surprising as SCL's foreign collaborator is known for ASICs and not for standard IC devices. Clearly, with its cost advantages and India's particular strengths in the software field, ASIC production should be emphasized even to the exclusion of standard ICs. The measures taken by the government to set up design centres for this purpose are steps in the right direction. However, the continuing production of standard ICs in very small volumes - for example, the production of microprocessors by SCL - is considered wasteful and should be discontinued.

In sum, the rapid growth rate of the electronics industry in the 1980s has been the most important and positive impact of India's liberal imports policy. However, it is doubtful that this rapid growth can be sustained in the absence of sizeable exports. Domestic demand, especially for consumer goods, which showed a dramatic increase in the first two or three years following liberalization, may be ascribed to the previous unavailability of these products for a number of years. Once these products became easily accessible, most of the demand was quickly satisfied. According to industry sources, a very high proportion of the market for consumer goods, such as TVs and PCs, is already saturated, with limited potential future growth of the demand. This compression of domestic demand is emerging as one of the most important obstacles to the further expansion of the consumer electronics industry.

A similar constraint on future growth is also evident in the case of the telecommunications and IC industries. While the demand for ICs in India is quite large, the effective demand for indigenous ICs is very small. The lack of resources of the Department of Telecommunications, the sole purchaser of telecommunications equipment, seriously limits this sector's growth. During the early 1980s, the expansion of the telecommunications network was a high priority. The demand for electronic exchanges was expected to increase rapidly and new plants were planned to meet this demand. In recent years, however, the Department of Telecommunications has drastically reduced its purchases and, as a result, plans for expanding the production capacity for electronic exchanges have been cancelled.

Can the demand for India's electronics products be expanded through a large increase in exports? Past experience has shown that in spite of a number of incentives available to manufacturers, exports have not risen. In fact, one of the major assumptions underlying the policy of liberalization was that the lifting of import restrictions would lead to a dramatic growth in exports. It was anticipated that the export of electronic goods, including software and exports from Export Processing Zones (EPZs), would increase from 5.8 per cent of the total production to 10 per cent by 1990. However, this proportion has shown little change attaining only 5.9 per cent in 1987 [78]. Furthermore, software and goods produced in the EPZs comprise most of these exports while the export performance of electronic equipment manufacturers in the domestic tariff area (DTA) is extremely poor. According to our estimates, exports of these companies amounted to only 2.7 per cent of their production in 1987 [79]. The figures for 1983, 1984, 1985 and 1986 were 1.75, 1.54, 0.99 and 1.63 per cent, respectively.

A number of factors, such as low volumes, high costs of components and inefficient production techniques, which have already been discussed, are largely responsible for the poor export performance of these firms. It is noteworthy that the policy of liberalization which was expected to increase exports by permitting the entry of CKDs and SKDs at low import duties, in fact, created a fragmented and import-dependent industry. This was particularly true in the immediate post-liberalization period and, indeed, the policy was partly responsible for the small scales and inefficient production techniques prevalent in the electronics industry by fostering an industrial structure dominated by firms which were either too small to set up large-scale manufacturing facilities or only interested in quick profits which could be realized through the assembling of kits.

At the time of writing, the situation was already showing some positive signs of change. Larger firms, with greater technological capabilities and comparatively more efficient production technologies, are beginning to dominate the industry. At the same time, concerned with the sector's high dependence on imports and feeble export levels, the electronics policy is undergoing a major review. In fact a certain shift in favour of import restrictions and indigenisation is already evident. While there is no possibility nor justification to cut off the industry's access to essential imports, there is certainly a need to strengthen its technological base. In this direction, policy initiatives should favour the proliferation of firms who have the necessary resources as well as the will to set up modern production facilities. Access to imported kits should also be considerably restrained and the permission to import technology linked to R&D investment.

Policy makers must realize that in the absence of a strong technological base and a high level of domestic demand, a large expansion of exports is not possible. Instead of directing policy initiatives towards increasing exports in the near term, of which there is little possibility, they should aim at building an efficient production base. However, within the existing economic structure, the demand for most electronic products will continue to be small, which, in turn, will remain the most important obstacle to increasing the industry's efficiency and international competitiveness.

NOTES AND REFERENCES

1. See ARE (1989).
2. See DOE (undated).
3. See ARE (1988:5).
4. For details, see World Bank (1987).
5. See NEP (1985:5).
6. See NEP (1985).
7. Taken from DSIR (1988:2).
8. See ARE (1988:12).
9. See World Bank (1987:11).
10. Based on interview with Mr. P.K. Nambiar, Secretary, DOE. Published in *Data Quest* (1988:54).
11. See DOE (undated).
12. For background see Ernst (ed) forthcoming (a) and Ernst 1990.
13. See NEP (1985).
14. See ARE (1988:14).
15. See *Computer Age* (December 1987:29).
16. See ARE (1988:14).
17. See *Data Quest* (1986:11).
18. This is illustrated in a study carried out by one of the leading PC producers which found that only 20 per cent of their potential clients showed interest in buying a PC priced at Rs. 65 000 while 95 per cent displayed interest at a price of Rs. 45 000.
19. See *Computer Today* (January 1988:37).

20. Prices increased between 15-20 per cent in early 1989. See *Data Quest* (February 1989).

21. What might otherwise be considered a high rate of growth is actually regarded as inadequate, due to the very small base, to support the large number of producers.

22. See *Computers and Communications* (May 1987:39).

23. See *Computer Age* (December 1987:10).

24. *Ibid*.

25. Although, according to the phased manufacturing programme, each PC producer is expected to follow a programme of indigenisation, many firms simply stop production when they reach this stage. See *Computers and Communications* (May 1988:47).

26. Whereas the cost of assembling a floppy drive controller with imported components is about Rs. 500, imported cards are readily available for Rs. 450.

27. In order to cope with the poorer quality of Indian components more rigorous testing procedures are carried out by PC producers on locally manufactured components. The average rejection rate in the case of imported components is 3 per cent while it can attain 15 per cent in the case of Indian components.

28. See *Computer Today* (January 1988:44).

29. *Ibid*.

30. See *Computer Today* (January 1988:57).

31. One of these firms is the joint venture between Modis and Olivetti, previously cited. The other is TVS Electronics, which is planning to invest Rs. 500 million in setting up facilities to produce peripherals. See Computers Today (January 1988:37).

32. Imported components cost between 80 to 100 per cent more in India. Although the duty paid on components used in PCs manufactured for export is refundable, the refund process can take a long time. Delays of up to six months were commonly reported. Considering the very high cost of capital in India, these delays can be extremely expensive.

33. See *Computer Today* (June 1989).

34. See *Data Quest* (August 1989).

35. See EIP (August 1982:531).

36. See EIP (July 1983:686).

37. See EIP (November 1982:569).

38. See EIP (July 1983:686).

39. See EPW (March 29 1986:513).

40. See ARE (1988-89).

41. While the turnover of the market leader, for example, increased from Rs. 647 million to Rs. 850 million for the years 1985-86 and 1986-87, respectively, its profits declined from Rs. 40 million to Rs. 14 million for those same years.

42. See *Business India* (December 1985:152).

43. See *Facts For You* (May 1988:30).

44. See EIP (August 1984:956).

45. See EIP (May 1987:452).

46. BPL is already producing these TVs in small numbers. They are being marketed at Rs. 17 000 and are not selling well.

47. See *Telematics India* (January 1988:19).

48. See *Hindu* (1988).

49. See *Telematics India* (January 1988:24).

50. See *Computer Today* (January 1987:11).

51. See *Hindu* (1988).

52. See *Business India* (September 1987:108).

53. Ibid.

54. Op. cit., (October 1986).

55. See *Telematics India* (November 1987:4).

56. C-Dot uses C-Mos devices in its design, which consume less power and produce a smaller amount of heat, thereby facilitating temperature control. Many of the foreign designs use N-Mos devices, which produce more heat and usually require air-conditioned environment for proper functioning.

57. Originally, the C-Dot design did not permit expansion. However, the company is presently working on a software which will allow it to link up to 4 of its 88 line systems.

58. The IC used in the C-Dot design is a Rockwell 6502 and SCL has plans to manufacture it.

59. See ART (1986:8).

60. See *Telematics India* (January 1988).

61. *Op. cit.*, India (November-December 1987:50).

62. See Hindu (1988).

63. See *Telematics India* (1988).

64. BEL Annual Reports.

65. According to World Bank estimates, at least 50 per cent of the Indian demand for ICs is met through imports, largely smuggled in. See World Bank (1987:138).

66. Seventy-five per cent import duties raise the price of imported ICs to between Rs. 120-130. Comparable BEL ICs are sold at only Rs. 100.

67. As ICs are a very high value added product, (in the case of BEL, the cost of materials accounts for only 30 per cent of the final costs), the inefficiency of production processes and low volumes will keep production costs high.

68. The leading world producers replace their plants every three years. As their volumes are very large, they recuperate their investments within a single year.

69. See *Computer Today* (May 1989).

70. See EIP (March 1986:557).

71. This section was written before a large part of SCL's facilities were destroyed in a fire in early 1989. Its main manufacturing unit and R&D sections suffered serious damage and have been out of operation since then. It will be at least another two years before production at the plant can be resumed. At the time of writing, SCL was using the facilities of other Indian companies to get ICs fabricated to its design specifications. The damage occurred when SCL was reported to be on the threshold of developing a 1.25 micron technology and plans for a plant to fabricate 4-inch wafers at 3 micron level have already been prepared. The plant is expected to cost about US$ 50 million. See "Fire Deals SCL a Cruel Blow", *Computer Today* (March 1989) and *Computer Today* (August 1989).

72. See ARE (1988).

73. See *Data Quest* (January 1989).

74. See *Computer Today* (September 1985:24).

75. See *Computer Today* (September 1985:24)2

76. See ARE (1989:11).

77. See World Bank (1987:9).

78. See ARE (1988).

79. Calculated from figures cited in ARE (1988:71).

Table 1

ELECTRONICS PRODUCTION

Year	Production (Rs. million)	Growth (%)
1985-86	28 800	38.5
1986-87	38 550	33.8
1987-88	52 850	37.1
1988-89	70 850	34.0

Source: Annual Report 1988-89, Department of Electronics, Government of India, New Delhi, 1989

Table 2

TOP 10 PC MANUFACTURERS BY VALUE (1987)

Firm	Rank	PC Sales (Rs. million)	PC Sales (numbers)	Rank
HCL	1	267.6	4 112	1
WIPRO	2	172.6	3 344	3
Sterling	3	129.2	3 920	2
Hinditron	4	44.4	1 184	4
DCM DP	5	80.7	950	6
Usha	6	63.2	832	8
Zenith	7	55.6	815	9
ICIM	8	53.7	-	-
Minicomp	9	48.8	900	7
Eiko	10	42.9	985	5
PSI	11	-	550	10

Source: "The Top Ten", *Data Quest*, October 1987, pp. 324:31

Table 3

PRODUCTION OF PCS IN INDIA

Year	Number	Value (Rs. million)	Average Price (Rs)
1984-85	2 500	-	-
1985-86	10 500 (320%)	820	78 000
1986-87	19 500 (85%)	1 080 (32%)	55 000
1987-88	35 000 (79%)	1 520 (41%)	43 500
1988-89	56 000 (60%)	2 090 (37%)	37 000
1989-90*	75 000 (34%)	2 630 (26%)	35 000

* Estimated

Source: "Tying up to Win", *Data Quest*, March 1988, p. 75

Table 4

COMPARISON OF VARIOUS EPABX TECHNOLOGIES

	GTE	Jeumont Schneider	OKI	C-Dot
No. of Extensions	-2048	32-3004	40-6144	88
No. of Trunk Lines	3-512	12-298	8-960	8-16
Design Vintage	1984-87	1970s-84	1985-86	1986-87

Source: "Electronic Private Automatic Switching Systems", *Computers & Communications*, June 1987, p. 59

Table 5

PRODUCTION OF SSI/MSI ICS IN INDIA

Year	Production Number (million)	Production Value (Rs. million)	Profits
1975-76	0.189	3.625	-2.382
1980-81	0.686	13.017	-7.855
1981-82	0.674	13.679	-18.610
1982-83	0.614	12.191	-15.151
1983-84	0.988	19.798	-13.926
1984-85	1.723	31.365	-10.863
1985-86	2.852	48.484	-0.645
1986-87	3.603	52.829	11.817
1987-88	4.105	72.743	n.a.

Source: Based on Information provided by BEL.

Table 6

INDIA'S EXPORT OF SSI/MSI ICS

Year	Exports (Rs. thousands)
1975-76	-
1980-81	44.0
1981-82	0.4
1982-83	54.4
1983-84	-
1984-85	-
1985-86	4.0
1986-87	-

Source: Information provided by BEL

Table 7

IMPORT CONTENT IN SSI/MSI IC PRODUCTION

Year	Import (Rs. million)	Import Intensity (%)
1981-82	5.70	44
1984-85	12.73	64
1985-86	15.58	50
1986-87	13.42	28
1987-88	9.46	16

Source: Information provided by BEL.

Table 8

PRODUCTION OF LSI/VLSI ICS

Year	Production (million)
1984-85	0.62
1985-86	1.80
1986-87	3.20
1987-88	6.03
1988-89	7.00*

* Planned

Sources: Information supplied by SCL and DOE.

BIBLIOGRAPHY

"ARE" (see Department Electronics Annual Report).

"Bridging the Technology Gap-Interview with Dr. Shashagiri", *Computer Age*, December 1987.

"C-Dot Mid-Term Appraisal: Guided Optimism", *Business India*, January 1986.

Department of Electronics, *Annual Report* 1987-88 (ARE), New Delhi, 1988.

Department of Electronics (DOE), *Electronics Policy and Growth Objectives* 1988-91, New Delhi, undated.

Department of Telecommunications, *Annual Report* 1985-86 (ART), New Delhi, 1986.

"Design and Manufacture", *Computers Today*, January 1988.

"DOE" (see Department of Electronics).

"DOE's New Initiative: Cutting Down Current Imports", *Computers and Communications*, March 1988, 24.

Ernst, D. and D. O'Connor, *Technology and Global Competition: The Challenge for Newly Industrialising Economies*, OECD Development Centre Study, Paris, 1989.

Ernst, D., "Global Competition and New Information Technologies - Perspectives for International Technology Diffusion", invited paper, OECD Conference on "Technology and Competitiveness", Paris, 24-27 June 1990.

Ernst, D., Ed., *Technology Trends in Advanced Electronics - Implications for Newly Industrialising Economies*, OECD Development Centre Publications, Paris, forthcoming.

ESS II Bangalore: The Technology War Heats Up", *Business India*, September 7-20, 1987.

"The Exim Policy: Closing the OGL Window", *Computers and Communications*, May 1988.

"IIT Manakpur: Latest Exchanges", *Telematics India*, January 1988.

India, Government of, *National Electronics Policy (NEP)*, New Delhi, 1985.

"Made in India - The State of Manufacturing", *Computer Today*, January 1988.

"Poised for a Big Byte", *Computers and Communications*, May 1987.

"The Ten Largest Indian Computer Companies", *Data Quest* Special Issue, 1986.

World Bank, *Development of Electronics Industry - A Sector Report*, Washington D.C. 1987.

"Zero Technology Gap?", *Computer Age*, December 1987, 29.

Other Journals cited include:
Economic and Political Weekly (EPW), Bombay
Electronic Information and Planning (EIP), New Delhi