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# The International Telecommunications Industry: The Impact of Microelectronics Technology and Implications for Developing Countries*

prepared by

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## Summary

The transition to microelectronic technology during the 1970s started a radical process of restructuring the international telecommunications (TC) industry. Competition among the major multinational corporations increased dramatically, market growth accelerated, and digital techniques produced a merger of computing and TC technologies. TC equipment manufacturers are increasingly competing for shares in the new information technology (IT) markets, while competitors from traditionally separate industries are attempting to enter various segments of the telecommunications market. Technological changes at the levels of product and process lie at the root of the present industrial upheavals. Microelectronics changed the nature and performance of TC products, leading to sustained increases in demand, and a new compatibility and convergence with computer products. At the same time the role of TC equipment as infrastructure for the new IT services, further stimulated the demand for products. In contrast to electromechanical technology, a range of new information-based skills are required to design and develop digital TC systems. The process of manufacture also underwent a complete transformation with the diffusion of microelectronics.

In the light of these changes the prospects facing the developing countries are very uncertain. Regarding infrastructure, the late entry of Third World countries may prove to be an advantage both in terms of capital savings, and in terms of 'leapfrogging' older less efficient forms of technology. On the other hand, to develop and manufacture modern TC technology, DCs will need to master a range of new information based skills. The fierce international competition for DC markets suggests there may currently be a 'buyers' market' for TC goods and technology. However, without deliberate and informed government policies, developing nations run the risk of failing to acquire the capabilities necessary to prevent a widening of the technology gap, and to fully exploit the potential advantages digital technology has to offer.

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## INTRODUCTION

As a result of the diffusion of microelectronic technology the world telecommunications (TC) industry is undergoing a period of dramatic upheaval, transformation and uncertainty (1). Digital, microelectronic technology has given rise to a plethora of new products and services - far superior to electromechanical technology in terms of cost and performance - and led to a rapid expansion of the international market, despite economic recession. At the same time the convergence of several industries around microelectronic technology is progressively eroding traditional market boundaries. New entrants, particularly from the computer and office equipment markets, are challenging the traditional market leaders in several important product areas. In the face of increasing competition from inside and outside the industry the major TC multinationals have invested massively in research and development in digital systems. This technology based competition is aimed at protecting existing market shares and capturing shares in the new, rapidly growing, information technology markets (2).

From the perspective of the developing countries, an understanding of these trends is vital. A modern telecommunications network not only represents the infrastructure necessary to support information technology activities, but is also crucial to the whole process of economic development (3). Many developing nations are currently investing heavily in TC, but there exists little appreciation of whether or not the shift to microelectronic technology will bring advantages in terms of use and local manufacture, or lead to a widening of the technology gap between the developed and developing countries. The problems and opportunities facing the developing countries vary considerably according to the size of the domestic market, the level of technological and industrial infrastructure, government policy objectives and so on. This paper seeks therefore to provide a preliminary assessment of the changing international economic and technological environment facing the developing countries in TC.

Chapter I begins by analysing how microelectronic technology has altered the nature and performance of TC products and goes on to examine the actual manufacturing process involved in the production of equipment. This chapter presents the argument that it is precisely these changes at the level of

product and process technology which underly the transformation of the industry throughout the world. Chapter II examines the current restructuring of the industry, focusing on market growth, the strategies of multinational corporations and the newly emerging forms of competition. Chapter III briefly discusses the general implications for the developing countries. Potentially at least, the shift to digital technology could bring benefits to these countries in terms of use and acquisition of TC technology. However this will depend critically on well informed and purposeful government policies. Before examining the issue of technological change it is helpful to briefly define the parameters of the industry.

Introduction to the telecommunications equipment industry

TC equipment can be defined as all the products and systems required to produce instantaneous, two-way communications across distance (4). Conventional postal communications are excluded from this definition as they are neither instantaneous nor two-way. Television and other forms of broadcasting equipment are also excluded as they are not interactive, although TC facilities such as satellites and fibre optic transmission equipment are increasingly employed to carry broadcasting signals. The closely related informatics and telematics sectors are also excluded except where public TC equipment is employed for data transmission and switching. The telephone industry accounts for approximately 80 per cent of TC equipment sales while telex, telegraph and data transmission form a large share of the balance.[1/] According to the report of the Organization for Economic Co-operation and Development for 1983, page 20, the TC industry accounts for roughly 30 per cent of output of electronics based goods and 10 per cent to 15 per cent of electrical engineering goods' sales worldwide. Although the conventional public TC network accounts for the bulk of equipment demand, private applications are rapidly increasing in importance.

Table 1 presents estimates of equipment sales of the major TC product lines for 1980 and 1985. The TC products shown constitute a 'family' of equipment necessary to provide TC services (via operating companies or carrier

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1/ Arthur D. Little, 1983.

networks). The equipment market is normally sub-divided into three main segments according to function, i.e. switching, transmission and peripheral equipment. Switching or exchange equipment represents the technological 'heart' of the TC system performing the central operating function of connecting calls within and between networks. Large capacity public exchanges constitute the bulk of the market, but the private automatic branch exchange market is growing very rapidly and becoming increasingly important (5). Transmission equipment is responsible for carrying the signals between exchanges and terminals and includes paired wires, coaxial cables for long distances, microwave radio, satellite systems, and more recently, fibre optics. Peripheral equipment includes all other components and equipment necessary for the functioning of the network. Peripheral equipment is responsible for sending and receiving signals and includes a wide range of terminal devices from simple telephone handsets to sophisticated multi function intelligent terminals. Other input/output devices are also included such as modems and codec equipment together with mobile radio and key systems.

Table 1. Shares of major telecommunications product lines in world sales, 1980 -1985 (estimated)

| Equipment category | Value of World Sales (US$ billions*/) | | Percentage of Total | |
|---|---|---|---|---|
| | 1980 | 1985 | 1980 | 1985 |
| 1. Switching | 12.5 | 18.4 | 31.9 | 31.7 |
| 2. Transmission | 12.2 | 17.4 | 31.0 | 30.0 |
| 3. Peripheral: | | | | |
| Terminals | 5.8 | 8.0 | 14.7 | 13.8 |
| Private systems | 4.3 | 6.4 | 10.9 | 11.0 |
| Mobile radio | 3.8 | 4.9 | 9.6 | 8.5 |
| Other | 0.7 | 2.9 | 1.8 | 5.0 |
| Totals | 39.4 | 58.0 | 100 | 100 |

*/ constant 1979 prices.
Source: Amended from OECD 1983 p. 20.

As Table 1 shows, in 1980 total product sales stood at just under US$ 40 billion and were expected to reach US$ 58 billion in 1985. Despite relatively slow economic growth, sales have in recent years continued to grow at an

annual average rate of approximately 8.5 per cent. In the latter half of the '80s growth is expected to slow only slightly to 8 per cent p.a. (Arthur D. Little 1983). By the early 1990s the overall size of the equipment market is forecast to exceed US$ 100 billion (at constant 1979 prices as discussed in Chapter II). Table 1 also gives a rough idea of the relative economic importance of the various market segments. Switching equipment accounts for approximately 32 per cent of total sales, transmission for 30 per cent, and all other products for 38 per cent.

## I. TECHNOLOGICAL TRENDS

### A. The impact of microelectronics and technological convergence on telecommunications products

Traditional analogue TC systems are based on a standard set of telephones connected by two pairs of copper wires, channelled through an electromechanical switching system. The two major exchange systems, still in widespread use in the developed countries are Strowger (invented in 1889) and Crossbar (patented in 1916). Strowger exchanges are comprised of large banks of rotary switches connected in series and until very recently were still being installed in some OECD countries - despite being technologically obsolete (6). Crossbar, again obsolete, is used as an intermediate technology between Strowger and fully electronic exchanges. Analogue electrical signals are transmitted between the main exchanges through mediums such as coaxial underground and undersea cables and then routed to subscribers through paired wires.

Today almost all current equipment production has shifted to digital, microelectronic technology. This is largely due to two main sets of reasons: Firstly, the greater speed, efficiency and capacity of digital systems combined with steadily declining costs and secondly, the increasing demand for new information technology services which depend on digital TC networks. It is helpful to examine the trends in product technology in terms of the three subsectors, exchange, transmission and peripheral equipment.

In exchange technology massive R&D investments during the '70s succeeded in producing fully electronic, stored programme controlled (SPC) switching systems. Table 2 presents estimates of the research and development costs for

digital exchanges incurred by the leading manufacturers. Although the costings are very approximate they indicate the enormous dimensions of these investments in technology. The costs to the individual manufacturers range from US$ 0.5 billion for Ericsson of Sweden to US$ 1.4 billion for the British System X.

The general acceptance of the superiority of digital over analogue, electromechanical exchanges is gradually leading to the systematic replacement of Strowger and Crossbar systems in both developed and developing countries. Digital exchanges are solid-state (no moving parts) which means they are less susceptible to breakdown and require less maintenance than previous technologies. Control by software allows continuous adaptation of the exchange to new traffic conditions without physically modifying the hardware. Advances in semiconductor technology have led to steadily declining real prices and large capacity public exchanges are now cheaper than similar analogue units.[2/] Falling prices and other advantages of digital exchanges have also led to a surge in demand for PABXs from private users and it is estimated for example, that over 50 per cent of major European companies will have PABXs installed by 1990 (7).

Table 2. Estimates of research and development costs of digital switching systems (US$ billions)

| Company | Headquarters | System Name | Development Cost |
|---|---|---|---|
| ITT | U.S. | System 12 | 1.01 |
| Ericsson | Sweden | AXE | 0.50 |
| CIT-Alcatel | France | E10 and E12 | 1.00 |
| Northern Telecom | Canada | DMS | 0.70 |
| GEC/Plessey/BT | U.K. | System X | 1.40 |
| Western Electric | U.S. | ESS-5 | 0.75 |
| Siemens | W.Germany | EWS-D | 0.70 |

Source: Dang Nguyen (1985), p. 108.

A further major driving force for the adoption of digital exchanges is their key role in the provision of IT services. The expansion of many informatics and telematics services and the objective of many countries to provide so-called ISDN (integrated services digital networks), depends

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2/ Saunders et al, 1983.

crucially on the installation of digital switching. Modern exchanges are capable of simultaneously processing large volumes of voice, data, text and other forms of information in digital format at great speed and low cost. Public TC networks are increasingly being used to provide a wide range of IT services as TC and computer technologies converge.

Transmission systems have also benefitted greatly from innovation with digital technology. The application of 'pulse code modulation' techniques to traditional transmission methods such as coaxial and microwave systems, has resulted in increased capacity and efficiency and reduced costs. Terrestial communications costs have fallen by approximately 11 per cent per annum in recent years, while satellite TC costs have fallen by roughly 40 per cent per speech/data channel per annum (8). New innovations centred around digital transmission are also gaining wide acceptance, notably fibre optics and laser transmission. Fibre optics have far greater capacity than traditional wire cables and are not resistant to transmission signals (therefore less signal regenerators or 'boosters' are needed). Installation costs are far lower than with conventional cable (e.g. the costs of laying submarine cables have been cut by 75 per cent). The rapidly falling costs of fibre optics means that they are likely to become cost effective in an increasing number of applications. Digital transmission is capable of simultaneously handling various types of data in digital format without cross interference and is therefore a vital component of modern informatics and telematics services.

Peripheral equipment is also at the forefront of the convergence of computer and TC technology. With the rise in private applications and the integration of TC with other IT activities, the range of intelligent terminals, key systems, mobile radios, modems and other office equipment has expanded considerably. With developments in word processing, multifunction microcomputers, electronic messaging and various other types of workstations, there is also an increasing demand to link up these office systems with TC services. Many peripheral products are needed both to provide an interface with the public TC network and to integrate electronic systems within firms and other private organisations. In fact, broadly defined, the share of peripheral equipment in total TC sales exceeds both switching and transmission technology, as Table 1 showed.

In short, advances in semiconductor technology and in particular the introduction of digital techniques to TC, have greatly expanded the range of products available and led to sustained improvements in cost performance ratios. Convergence with computer technology has also produced many new applications and products. These factors together with the pressures to provide a wide range of new information technology services, largely explain the increasing demand for TC equipment and services throughout the advanced economies.

B. Telecommunications production processes - techniques of manufacture with microelectronics

To understand how microelectronic based TC equipment is produced it is helpful to contrast the mechanisms of manufacture and technological development of electromechanical products with those related to microelectronic products. Indeed, the TC equipment industry provides a rare opportunity to make this contrast as it is the only major industrial sector which has undergone an almost complete transition from one technology to the other. Other industries are either: (a) in a relatively early stage of the adoption of the technology (e.g. the auto industry), or (b) generated from the new technology itself (e.g. computers and informatics) and have no previous counterpart of sufficient similarity to make such a comparison.

In general the production of electromechanical systems is a highly complex and closely integrated task. A large number of specialised component inputs, such as relays, screws and connectors, require exact interfacing, both mechanically and electrically. In contrast to microelectronic technology there is a large number of moving parts which must be engineered precisely to ensure the long term durability and reliability of the system.

Not suprisingly the production process demands a heavy concentration of engineering and technical skills to ensure the quality of the fine engineering and electromechanical interfacing involved. A thoroughgoing engineering capacity is required not only in the design and development stages, but also in virtually all stages of component production, equipment assembly, testing, installation and maintenance. One of the prerequisites for market entry in electromechanical TCs is a sufficient supply of TC specific engineering and technical skills. The very specialised nature of the skills and know-how

required to produce and install TC equipment may have assisted in preventing entry by non-TC manufacturers in the past. (The important role of government policy in preventing entry is discussed below). Certainly, within the industry there exists a recognition of the specialised and complex nature of the technology.

The complex and highly integrated nature of the production process was reflected in the vertically integrated market structure which prevailed in the industry for several decades. Virtually all major TC firms integrated backwards into the production of intermediate products (OECD, 1983, p. 42). The many specialised component inputs were either manufactured in house, or purchased from firms dedicated to supplying TC parts. According to the Belgian Ministry of Industry, material input costs to the switching industry amounted to around 20 per cent of the value of output in 1965; at this time production was predominately Crossbar and Strowger electromechanical technology. By 1978, with the gradual shift to microelectronic exchanges, total material input costs, primarily semiconductor components, represented 70 per cent of the value of the industry's output (OECD, 1983, p. 57). As semiconductor technology continues to advance and increasing numbers of switching functions are integrated onto single chips, the value of components purchased is expected to continue rising.

In direct contrast to the manufacture of electromechanical products, the production of microelectronic equipment is characterised by modularity of design and divisibility in manufacture. Also the engineering effort is heavily concentrated in the design and development stages, rather than being spread throughout the production process overall. It is necessary to clarify these points in more detail.

Digital telecommunications are intrinsically modular or divisible in nature. A TC network is built up from a range of independent units (or 'building blocks') which together form an expandable sytem. This modularity holds true at the level of design as well. When a new product is being designed, increasingly complex software programmes are gradually built up from a range of standardised modules. This means that it is possible to design a small exchange, for instance, and gradually expand its capacity using similar hardware and software. The modular nature of the technology also means that

systems are 'evolutionary' and can be improved and expanded continuously. The development of modular software techniques occurred partly because of the incredible complexity of the tasks demanded of large scale exchange systems, and partly due to the inherent nature of the technology. Modularity facilitates the management and the execution of more and more complex designs.

At the level of manufacture microelectronic TCs can be viewed as 'divisible'. Modern systems do not demand the high degree of electromechanical interfacing and fine engineering of previous technologies. The main functions are built into the system logic. Consequently the emphasis on engineering and technical effort in the manufacturing process is substantially reduced and there is a shift in technological emphasis to the software task of programme design. Semiconductors represent the 'building blocks' of the products and with technological advance increasingly take on the functional characteristics of the final product. Following the highly complex design and development stages the microchips are assembled in a fairly simple assembly style operation. The scale of the integration of circuits used in manufacture are becoming increasingly standardised and purchased 'off the shelf' from semiconductor manufacturers (either in house or from outside companies). The components are then mounted onto printed circuit boards (PCBs) and tested. Some engineering supervision is required but in general the operation is an unskilled task. Once assembled the PCBs constitute the functioning units of the various systems. Almost all functions are solid state and consequently there is relatively little need for trained engineers and technicians in the actual manufacturing, or more precisely, assembly stage.

With microelectronic technology, engineering effort is concentrated mainly in the research, design and development stages of manufacture. A small range of information based design skills are required, rather than the broad range of mechanical and electromechanical skills demanded throughout the production of Strowger and Crossbar systems. Indeed, the most formidable technological barrier to entry in digital TCs lies in mastering the software involved in the design and development stages. For example, public switching software must be capable of interconnecting, storing and transmitting many thousands of messages simultaneously while at the same time controlling hardware operations, recording subscriber traffic, billing and so on. The complexity of exchange software has proved to be the greatest challenge to

leading manufacturers and absorbed a large share of the development costs described above. Partly as a result of the complexity of the software and the huge R&D thresholds, so far the traditional TC manufacturers have maintained their dominance of this particularly important market segment. In other areas such as private exchanges (PABXs), new competitors are seriously challenging the dominance of the 'traditional' TC producers.

## C. Technological convergence and microelectronics

As a consequence of the convergence in product and process technologies between TCs and other areas of information technology, the leading TC manufacturers are now competing directly with firms from traditionally separate industries including office equipment, computer, aerospace and microchip component manufacturers (discussed below in Chapter II). Although other factors, particularly government policy, are also important for a full understanding of industrial change within the sector, the root of the present industrial upheaval can be traced directly to the convergence of several industries around digital, microelectronic technology. In the information technology industry technological convergence not only applies to finished products and manufacturing processes, but also to the actual raw materials of the industry - microelectronic components. Although these devices are employed in many different industrial sectors and applications (spanning consumer goods, military equipment, computers, industrial process controls, communications etc.), they are all made in basically the same way.

The emergence and diffusion of semiconductor technology has acted in several ways to break down the traditional market structure of the TC industry and allow the entrance of new competitors. Before the adoption of microelectronics the slow changing oligopoly of the leading manufacturers was supported by the vertically integrated market structure and the control this permitted over input supplies. Close, collusive links between local manufacturers and government buyers and the heavy capital investment requirements of the industry also acted to prevent competition. In addition, the highly complex and specialised nature of the engineering skills required in the manufacturing process mitigated against entry from other industries. The break down of the vertically integrated market structure under electromechanical technology entailed a loss of control over input supplies, and indeed a transfer of value added to micro component manufacturers (OECD, 1983).

The information-based software design skills which now characterise the TC industry are common to several other industries in the area of information technology. The divisible nature of digital technology means that it is increasingly possible for firms outside the TC sector to select a specific product area and to gradually accumulate the technological know-how and skills needed to move up the scale of technological complexity. It is not surprising that the ability of TC firms to appropriate technological know-how has steadily declined in many product areas. Furthermore, the demand for new products and services has led several OECD governments to relax their monopoly control over the supply of TC services and to permit greater competition in the equipment supply sector. The following section attempts to examine in detail the present restructuring of the TC industry and, in particular, the response of leading manufacturers to technological change.

## II. INDUSTRIAL TRENDS - COMPETITION AND INDUSTRIAL CONVERGENCE

Technological change has undoubtedly led to a transformation of the TC industry, altering market boundaries and giving rise to competition from other industries. The outcome of these changes has yet to be fully realised and will depend on many economic, institutional and political factors as well as technological change. Although a great deal of uncertainty surrounds the future of the industry, it is possible here to outline some of the main trends occurring within TC and between TC and the wider area of information technology. This chapter attempts to identify some of the competitive strategies currently being adopted in response to technological change, and illustrates the important role of government policy in defending domestic TC firms and facilitating technological change. Section A. presents estimates of the growth and dimensions of the industry throughout the world, and points to the increasing importance of devloping country markets. Section B. examines the market structure of the industry and assesses the impact of microelectronic change on competition both within the TC sector, and between TC and other major information technology areas such as the computer and office automation industries.

### A. TC market size, growth and geographical distribution

The TC sector overall is one of the largest and fastest growing of the major sectors in the world economy. According to Arthur D. Little (1983), total TC turnover (comprised of one third equipment sales and two thirds

service sector revenues) for the EEC, Japan and the USA amounts to an equivalent of roughly 3 per cent of world GDP. (Arthur D. Little's figures do not refer to the actual share of TC in GDP, but to TC turnover in relation to GDP. The share of TC in GDP is the value added of bought in components, material, products and services from other sectors - a far smaller figure). This ranks TC alongside the largest industries worldwide including motor vehicle manufacturing, electricity production, aerospace and petrochemicals. In recent years worldwide annual growth averaged 8 per cent per annum (approximately 10 per cent for the DCs) despite slow economic growth. By 1990 TC activities will reach an equivalent of 4.4 per cent of GDP, second only to the motor vehicle industry. By the year 2000, if this very rapid growth continues, TC will have surpassed all other major sectors with turnover around 7 per cent of GDP. Furthermore, the closely related telematics sector which includes data processing and communications is expected to reach similar proportions by the early 1990s. (Although one must be sceptical of consultancy forecasts, Arthur D.Little's is probably the most widely respected and comprehensive study of the worldwide TC industry available).

Table 3. Estimated regional markets for telecommunications equipment (Shipments in US$ 1979 prices)

| ITU World Zone*/ | 1982 | 1987 | 1992 | Growth Rate ( per cent/year) |
|---|---|---|---|---|
| North America | 19.9 | 29.1 | 41.9 | 7.8 |
| Europe | 12.5 | 17.2 | 23.7 | 6.7 |
| Asia | 11.8 | 19.1 | 31.7 | 10.1 |
| Latin America | 1.4 | 2.0 | 2.9 | 7.7 |
| Oceana | 0.9 | 1.2 | 1.5 | 6.6 |
| Africa | 0.4 | 0.7 | 1.0 | 8.2 |
| Totals | 46.9 | 69.3 | 102.7 | 8.1 |

*/ International Telecommunications Union

Source: Arthur D. Little (1983)

Turning to the equipment supply industry, Table 3 shows estimates of TC equipment sales according to region for the period 1982-1992. In 1982 shipments were in the region of US$ 47 million. This is expected to more than double by 1992. Over the total period average annual growth is forecast to be 8.1 per cent. The OECD countries account for approximately 80 per cent of total equipment sales which reflects the very unequal distribution of TC

infrastructure between the developed and developing countries. The North American market represents over 40 per cent of world sales and Europe 25 per cent. Japan accounts for around 45 per cent of the total Asian market (9).

Developing countries together account for only 11 per cent of world sales. However this market is more important than the low percentage would suggest. As potential export markets they are the focus of intense competition among the multinational suppliers because, unlike the developed countries, they are to a large extent open, uncommitted markets. Also, aggregate figures can be misleading; the Latin American market, for example, amounts to less than 3 per cent of the world total, but in terms of digital public switching Latin America accounts for 16.3 per cent of total sales - this compares with 27.3 per cent for the USA, and 28 per cent for Europe. Africa represents only 1 per cent of the world market yet accounts for approximately 4.5 per cent of digital switching sales. The International Telecommunications Union (1985) puts total developing country investments in TCs at approximately US$ 8 billion in 1983, and estimates that this figure will need to be increased to around US$ 12 billion p.a. to meet infrastructural needs (10). Given that developing countries are currently installing and expanding their basic TC infrastructure, there is enormous potential for future growth and the suppliers are keen to 'lock in' these markets to their particular systems.

## B. Competitive strategies and industrial convergence

Table 4 presents sales of the top 10 manufacturers of TC equipment for 1982 and 1983. The industry is highly oligopolistic with the 10 leading corporations accounting for approximately 70 per cent of total world sales for both years. The largest firm, AT&T, built up its sales lead through a long term monopoly of the large US market and until very recently was prohibited from competing in international markets. All other firms are multinational to various degrees with L.M. Ericsson and ITT almost wholly multinational as judged by equipment sales. The majority of the remaining companies rely on their monopoly of domestic markets for the bulk of their sales. Outside the protected OECD markets the dominant corporations for many years were L.M. Ericsson, ITT and Siemens. More recently NEC of Japan has made substantial inroads into relatively unprotected markets, particulary in the developing countries.

In 1982 new US legislation was introduced to allow AT&T, the world's largest company, to compete for overseas orders and to enter other areas of information technology which earlier anti-trust legislation prohibited. At the same time IBM, the world's largest computer manufacturer, was allowed to enter TC markets. The purpose of the new US legislation was widely seen as: (a) an effort to stimulate oligopolistic competition in the face of successful Japanese competition both at home and in Europe. Although this applies mainly to the computer industry, there was also the perceived capability of Japanese firms (NEC, Hitachi, Oki and Fujitsu) to gain larger TC market shares in the future; and (b) to encourage the introduction of new digital information services in the private and public sectors within the United States of America.

Table 4. Sales of major telecommunications equipment manufacturers, 1982 and 1983 (current prices)

| Rank | Company/Headquarters | | Sales, 1982 US$ billion | Company | Sales, 1983 US$ billion |
|---|---|---|---|---|---|
| 1 | AT&T/Western Electric | U.S. | 12.49 | AT&T Technologies*/ | 11.16 |
| 2 | ITT | U.S. | 4.87 | ITT | 4.86 |
| 3 | Siemens | W.Germany | 4.49 | Siemens | 4.49 |
| 4 | L.M.Ericsson | Sweden | 2.72 | L.M.Ericsson | 3.16 |
| 5 | GTE | U.S. | 2.72 | Alcatel-Thomson(Fr) | 2.74 |
| 6 | Northern Telecom | Canada | 2.72 | Northern Telecom | 2.66 |
| 7 | NEC | Japan | 2.17 | NEC | 2.41 |
| 8 | GEC | U.K. | 2.17 | GTE (U.S.) | 2.38 |
| 9 | Thomson | France | 1.63 | Motorola (U.S.) | 2.31 |
| 10 | Philips | Holland | 1.09 | IBM (U.S.) | 1.73 |

*/ New name following reorganisation

Sources: Arthur D. Little, cited in International Business Week, 24 October 1983 (1982 sales) and Financial Times, 12 July 1985 (1983 sales).

Governments throughout the OECD play an extremely important role in framing the competitive environment within which TC equipment companies operate. Government purchasing accounts for between 60 per cent to 85 per cent of all TC sales (OECD, 1983) and the service carriers are either owned or strictly controlled by governments through postal and TC administrations. Partly because of the perceived importance of a strong national supply industry and partly to ensure economies of scale in development and production, government orders were (and still are to a large

extent) allocated to local TC companies. This government purchasing support to local manufacturers led to very high concentration ratios within countries where major producers were based. For instance, in a study conducted in the late 1970s covering a sample of seven OECD countries, it was found that the four largest domestic firms supplied an average of 87 per cent of equipment sales (within those countries sampled) (11). Before the diffusion of microelectronic technology, government policy was therefore a key factor in supporting the relatively static cartellised and oligopolistic structure of the electromechanical industry.

Until recently there were few changes in the ranking of the top 10 to 15 major TC companies. Data for 1973 (cited in Dang Nguyen, 1985, p. 93) show almost exactly the same ranking for the major manufacturers as for 1982. However, as Table 4 shows, by 1983 Motorola (a leading semiconductor manufacturer) and IBM had entered the ranking in postitions nine and ten respectively. These two new competitors from outside industries are indicative of deeper industrial readjustments currently occurring both within TC and between TC and other fields of information technology. Two interrelated factors are responsible for the entrance of these and other companies into the TC sector: first, government deregulation of the TC sector in the USA. This enabled IBM to compete in telecommunications markets and also allowed AT&T to move into the computer industry and into markets outside the USA (the government response to technological change in other OECD countries is discussed below); second, technological convergence around semiconductor technology has permitted other information technology companies to gain a firmer grasp of TC technology.

To help identify the emerging trends within the industry Table 5 presents a selection of major, recent joint ventures and acquisitions by leading manufacturers and service providers. The listing is not exhaustive and does not include a growing number of joint ventures in the developing countries. Also, the information technology (IT) product areas identified do not necessarily refer to the principal product range of the manufacturer, but rather to the central purpose of the joint venture. Among the large number of acquisitions, mergers and joint ventures, a wide variety of competitive strategies are developing (most of the above occurred in 1984 and 1985) which testify to the increasing risk, competition, internationalisation and industrial convergence throughout the TC and information technology industries.

Soaring research and development costs, coupled with the need to achieve economies of scale, have led many TC firms into joint ventures with other equipment makers and increasingly, as Table 5 shows, with the providers of TC services (or carriers). Successive 'waves' of Japanese firms have gained significant shares of the international IT markets and intensified the degree of competition (12). As yet Japanese firms have not yet established a stronghold in the main public switching markets, but in other areas such as PABX, transmission and peripherals Japanese corporations are steadily gaining market shares. In the deregulated PABX market, for example, NEC has already gained a 5 per cent market share (Dang Nguyen, 1985).

USA and European firms see greater export orientation as a means of gaining greater market shares and in the process increasing their own international competitiveness. European companies have entered into a wide range of commercial and technological joint ventures, both to improve technological co-operation within Europe and to gain entry into the large US market. In addition, the European companies hope to protect themselves against competition from AT&T and IBM. In their turn, US multinationals are engaging in joint ventures with European firms in order to gain access to the growing European markets. Some Japanese companies are also beginning to engage in joint ventures both to sell superior technology to European companies (mainly in semiconductors and other areas of IT, rather than in telecommunications) and to link up with US firms attempting to increase market shares in Japan.

The US government's response to technological change and the internal pressures to 'open up' the new value added networks to competition was to deregulate the local market. Under pressure from the US and Europe, Japan has recently agreed also to open its TC market (the second largest in the world) to foreign competition (13). In Europe, Britain has taken the lead in market deregulation with the privatisation of British Telecom and the approval of outside competition from the Swedish firm, L.M. Ericsson for the public switching systems. There are signs that several other European countries will also follow suit. The Federal Republic of Germany's government has appointed a commission to review the national TC strategy and in particular, the role of the Bundespost (the post office). In Italy the government owned TC company sold 30 per cent of its shares to private investors in 1985. The French right

wing opposition parties have indicated that they will press for deregulation if they win the forthcoming elections. In the Netherlands the government is in the final stages of legislating for a reduction in the power of the state TC monopoly and also allowing for some private ownership to take place. In Ireland too, the government has changed the status of the TC administration from a government department to a state owned company (14). In the USA and Europe these moves have one thing in common - to ensure that the TC monopolies become more commercially orientated and to accelerate the introduction of new information technology services.

Recognition of the generally weak position of European equipment manufacturers in relation to US and Japanese corporations (in the area of IT in general rather than telecommunications specifically), has led to major government support programmes for local industry and technology. Among others, these include ESPRIT (the European Strategic Programme for Research and Development in Information Technologies), the UK Alvey Programme engaged in reseach and development in fifth generation technology, involving co-operation between firms, universities and government, and more recently EUREKA (the European Technology Co-operation Programme). These programmes are all in the general area of IT and hope to galvanise domestic firms into successful competition with Japanese and US companies.

Turning to the nature of firms' competitive strategies, some major TC service providers are integrating backwards into the actual production of equipment. Following deregulation of the US market AT&T has taken the lead in this area. AT&T has already reached agreement with Philips, ICL, Olivetti and Ricoh (a major Japanese group) to market their TC products abroad. AT&T's lack of experience in international markets means that joint ventures are one means to forge instant marketing channels into Europe and other countries. In the UK, British Telecom (BT) has become the leading supplier of PABX systems, and is attempting to gain a controlling share in Mitel, the Canadian PABX manufacturer, to extend their in-house production capacity and possibly to gain inroads into the North American market. Several TC administrations (PTTs) in developing countries including Telemex (Mexico), Telebras (Brazil) and NPTIC (China) are currently engaged in various forms of joint venture with multinational corporations. Most major service companies have supported and participated in the development of digital systems. Market deregulation may permit more PTTs to exploit their technological base and gain additional equipment markets as well as service revenues.

As far as TC equipment makers are concerned there is an increasing degree of diversification by most major companies into the production of other areas of IT such as computers, office automation, semiconductors and data processing equipment. This reflects the technological convergence of telecommunications with IT and the desire for TC manufacturers to recover large development costs and capture new markets. In addition, diversification via joint ventures presents itself as a means of meeting competition. As Table 5 shows, several leading corporations including L.M. Ericsson, AT&T, MCI and STC have entered into joint ventures in the computer and data processing markets. TC makers are also entering joint ventures in semiconductor component production. With the breaking down of the vertical market structure which prevailed under electromechanical technology, value added has been steadily transferred to outside semiconductor manufacturers (OECD, 1983). At the same time the large electrical and TC companies have accumulated considerable experience in semiconductor development and production. Several major TC manufacturers are therefore attempting to gain or increase shares in the microcomponent market. Siemens, Italtel, CIT-Alcatel and Plessey are engaged in a joint European venture to develop VLSI (very large scale integration) chips. Siemens is also co-operating with Philips on VLSI development and recently began negotiations with Toshiba to acquire the know-how to produce the one and four megabit chips. These joint ventures in semiconductor production can probably best be viewed as straightforward diversification into other fields of IT rather than increasing vertical integration. This is because the components in question are not TC specific but are intended for general purpose IT applications.

Other joint ventures also reflect the effort by TC firms to gain a broader base in IT. AT&T, L.M. Ericsson, Plessey, STC and Siemens have all entered into joint ventures, or are competing independently for shares in the rapidly growing office automation and business equipment markets. In microcomputers AT&T are marketing a whole range of personal computers and as Roobeek (1984) notes, will almost certainly compete head on with the computer giant IBM. To gain an international marketing network AT&T has joined up with Philips who have well developed multinational distribution facilities. Even in fibre optic technology the traditional market leader, Corning Glass, is being increasingly challenged by ITT, AT&T, NEC, Northern Telecom, and Philips. The leading Japanese TC manufacturer Nippon Electric (NEC) now

provides a model of horizontal integration across the whole spectrum of IT products and the large electrical and TC companies may be following suit for fear of falling further behind the technological race.

One general trend illustrated by Table 5 is a diversification by IT firms into the traditional TC markets. In several areas the previously secure positions of the 'traditional' TC firms are being challenged for the reasons discussed earlier. So far, the public switching market has remained with the major TC suppliers due to extremely high R&D thresholds, technological complexity and market saturation (15). However many computer and office equipment manufacturers have entered the growing PABX market including IBM, ICL and Olivetti. This pattern is reflected in other areas of IT where manufacturers of office equipment, computers and semiconductors are increasingly competing in TC markets for shares in the transmission, peripheral and private applications equipment. These diversifications can be seen as aggressive market responses to new market opportunities, afforded by technological convergence, rather than the defensive strategies adopted by the traditional TC makers to resist competition.

A final trend illustrated by Table 5 is the growing network of technological co-operation and marketing joint ventures and the intensification of international competition. This is clearly leading to a growing internationalisation of the industry. As already noted several European manufacturers are pooling their technological resources to meet competition from Japan and the USA. At the same time Japanese firms have had considerable success in gradually increasing their market share both in Europe and the USA. Other European led marketing ventures and acquisitions reflect the efforts by firms to increase sales abroad. For instance, Plessey (UK) has recently acquired Stromberg Carlson to sell switching technology to the USA. Siemens has a proposed joint venture with GTE for the same reason. L.M. Ericsson has also entered an agreement with Honeywell to market PABXs in the USA. Conversely, to gain entry to the European market AT&T has linked up with ICL, Olivetti and Philips. With the recent 'opening up' of the Japanese home market, North American manufacturers including AT&T, Canada's Northern Telecom, GTE and IBM's new TC acquisition Rolm, are all in the process of establishing marketing links in Japan (16). Although it is quite possible that several of the joint ventures will not be successful they demonstrate the increasing concentration and fierce technology based competition currently being waged.

**Table 5:** Recent Major Joint Ventures and Acquisitions Involving Leading TC Companies by Firm and Product Area.

| TC Company* | IT Product Area: TC Equipment Manufacture | TC Service Provision | Computers/ Data Processing | Semiconductor Manufacture | PABX, Office Automation and Other. |
|---|---|---|---|---|---|
| AT&T* (US) | Philips (H) | BT*(UK) | ICL (UK) | - | Convergent (US)<br>Olivetti (I)<br>Ricoh (J) |
| BT* (UK) | - | IBM (US) | - | - | Mitel (C) |
| Cable and Wireless* (UK) | - | TDX Systems Inc* (US) | - | - | - |
| CIT-Alcatel (F) | Thomson (F) | - | - | Italtel (I)<br>Siemens (WG)<br>Plessey (UK) | - |
| L.M.Ericsson (S) | - | BT*(UK) | IBM (US) | - | Honeywell (US)<br>Thorn/EMI (UK) |
| GTE (US) | Italtel (I) | - | - | SEMI (US) | - |
| MCI* (US) | - | Western Union* (US) | IBM (US) | - | - |
| Philips (H) | Thomson-Brandt(FR)<br>CIT-Alcatel (Fr) | - | - | Signetics | - |
| Plessey (UK) | Stromberg-Carlson (US)<br>Kyocera (J)<br>GEC, STC, BT*(UK) | - | - | - | - |
| Rolm (US) | - | - | - | - | IBM (US) |
| Siemens (WG) | GTE (US) | - | - | AMD (US)<br>Litronix (US)<br>Toshiba (J)<br>Philips (H) | Xerox (US) |
| STC (UK) | - | - | ICL (UK) | - | - |

C - Canada
F - France
H - Holland
I - Italy
J - Japan
S - Sweden
UK- United Kingdom
US- United States
WG- West Germany

Sources: Financial Times (Various Issues)
Roobeek (1984)

* indicates primarily TC service provider.

To sum up, the technological convergence and market deregulation has led to a wide variety of new alliances and new forms of competition. Within the complexity of the current upheavals the mains trends occurring at present appear to be:

1. Backward integration by TC service providers into equipment production;

2. Increasing diversification by TC firms into other areas of information technology such as computers, peripherals and semiconductors;

3. Aggressive moves by non-TC companies into traditional telecommunications markets;

4. An increasing internationalisation of the industry through new forms of joint ventures;

5. Increasing competition throughout the TC and IT industries;

6. The emergence of new market niches with lower economic and technological barriers to entry;

7. A steady increase in market shares for Japanese firms;

8. A progressive erosion of the traditional market boundaries, and the emergence of multiproduct information technology corporations.

Until the pace of technological change slows it is impossible to predict if and when new, stable, less transient organisational forms will take the place of the current uncertainty and industrial transformation.

## III. PROSPECTS FOR DEVELOPING COUNTRIES

To gain an understanding of how the transition to microelectronic TC may affect developing countries it is useful to look first at service sector or infrastructural propects, and then to problems and opportunities in the manufacture and development of equipment. It is beyond the scope of this paper to address this complex issue in detail, but it is possible to briefly mention some of the major factors involved.

## A. Infrastructural developments

In terms of infrastructure, microelectronics may well bring considerable benefits to developing countries currently installing and expanding their basic networks. The shift to digital systems opens up the very real possibility of 'leapfrogging' older vintages of technology (17). Fully digital systems are in general less costly, more efficient and more flexible than electromechanical systems. In tropical and inhospitable climates solid-state technology is far more efficient, robust and demands less maintenance than Crossbar or Strowger equipment. The older electromechanical technologies have many moving parts, wires and physical connections and require heavy insulation from the outside environment (called 'tropicalisation' in tropical countries). Tropicalisation can be very expensive and requires ongoing attention. Microelectronic technology on the other hand requires very little maintenance as there are very few moving parts and none in the crucial switching operation. Modern TC systems are also usually self diagnostic which means that if a breakdown should occur the problem is identified within the computer controlled system and the repair usually involves the simple replacement of a circuit board.

Usually this potential for leap-frogging older vintages does not in general apply to the developed countries but only to the developing countries. The advanced economies are heavily committed, in terms of fixed investment, to previous vintage technologies, mainly Strowger and Crossbar. In the UK for example, 59 per cent of all local exchanges and 72 per cent of trunk exchanges were Strowger in 1984 (Dang Nguyen 1985 p. 103). The most recent exchange of this type was installed in 1985. Bearing in mind that Strowger was invented in 1889, this indicates the difficulties facing the advanced economies in scrapping the old investments and moving to the new technology. The opportunity for developing countries to by-pass these obsolete forms of technology and go directly to information technology infrastructure is a very real advantage which should not be dismissed lightly.

These technological advantages are coupled with strong economic advantages. As semiconductor technology advances, TC equipment has continued to fall in real prices in almost all product categories. Where comparable, digital exchanges are now cheaper than analogue units (Saunders et al, 1983, p. 35). In terms of cost/performance ratios, as Muller (1982) shows, digital

equipment is far superior to electromechanical technology and costs per unit of data transmission are continuing to fall rapidly as the technology advances. Writing in 1977, Jequier estimated that DCs installing 1 million telephone lines would typically pay three to five times less than the developed countries did some 30 to 40 years ago. Since this time prices have continued falling and correspondingly, potential capital saving to developing countries will have risen still further.

In addition to these factors, the intense competition for developing country markets places many developing countries in stronger bargaining positions in relation to the major suppliers. Given that TC purchasing is normally concentrated in the hands of one central, government administration, this may especially enable the larger countries to bargain effectively with the large corporations. This particular feature of TC does not apply to other areas of information technology where purchasing is normally distributed across government, industry and individual buyers.

B. Manufacturing and technological development

To assess the prospects for local manufacture and development it is necessary to weigh up the technological and economic barriers to entry, against any potential new opportunities for market entry. Obviously, the opportunities for market entry will differ according to the particular country in question. However, for larger countries such as Brazil, China, India and Mexico (18) there may well be improved opportunities for market entry due to:

(a) the breaking down of the old electromechanical oligopoly;

(b) the increasingly fierce competition for DC markets; and

(c) the divisibility of microelectronic technology which may permit smaller scale manufacturing investments and a gradual process of technological 'learning' (19).

Nevertheless it is important to point out that there exists a great deal of uncertainty as to the prospects facing individual developing countries, particularly those with medium and smale scale TC markets. The following points are therefore offered in a tentative manner.

The most significant financial and technological barriers to entry in TC are in the huge research and development expenditures required to develop new exchange systems. Even in the developed economies, within the exchange subsector, these barriers have so far precluded entry from other closely related information technology industries. As a result the 'traditional' TC multinationals still dominate the market. The complexity of the software required to produce these systems is also a very real barrier to potential entrants. In addition, the existing competition for developing country markets might suggest that the prospect for economically viable local production is severely limited. However, there are indications that in certain areas of TC the shift to microelectronics may have improved the possibilities for domestic production.

The competition for developing country markets and the improved bargaining position of some DC governments in relation to the multinationals, suggests that there may be a 'buyers' market' in relation to technology as well as products. When sales are tied to the setting up of production facilities within a particular country the contest for new orders is even more intense than for pure product sales and some corporations are willing to transfer technological as well as production facilities to gain orders. Malaysia for example is insisting on technology transfer and the establishment of local manufacturing facilities as a condition for tendering for the large new orders currently on offer. L.M. Ericsson of Sweden, NEC of Japan and ITT's subsidiary in Germany, have all expressed willingness to engage in joint ventures and technology transfer to gain market shares.[3/] In India, 10 major suppliers competed for a large exchange contract. Eventually the French company CIT-Alcatel won the order after pledging full technological training by French scientists (and a very favourable government-backed, 'aid for trade' arrangement.[4/] Brazil has successfully insisted on technology transfer, domestic location of production facilities and the use of local components in production (Hobday 1985). A similar picture seems to be emerging in China with the new plans to upgrade and expand the TC infrastructure of the Yangtze Delta industrial region. Cable and Wireless, the UK based multinational has agreed to help set up a research and development facility in China in order to

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3/ Business Times, Malaysia, 17 May 1985.

4/ Electronic Times, 20 May 1982, p. 10.

participate in the new business, estimated at US$ 500 million over a five-year period.[5/] Overall the buyers market appears to be favouring domestic industrial development and technology transfer.

The divisibility of digital technology, in relation to electromechanical systems, suggests there may well be opportunities for relatively small scale production and development. This applies mainly in the rapidly growing area of peripherals and also in transmission equipment. However there may also be possibilities for entry in small exchanges too. In private automatic branch exchanges (PABXs) the financial and technological barriers to entry are far lower than in public exchanges. In recent years the PABX market has witnessed extremely rapid growth. The software is less complex than with public switching and many new firms have entered the international market. In the USA for instance, in 1961 there were only four PABX manufactures; by 1980 there were 30 and in 1983 approved suppliers numbered over 1,000 (OECD, 1983). The shift to digital technology may have improved the opportunities for entry into small-scale public exchanges too. There is in developing countries a large demand for small-scale exchanges suitable for use in rural areas and small towns. This may prove to be an entry point for larger countries with sufficient technological resources and internal demand to justify the investment.

In terms of design the modularity of new technology may also prove to be a benefit. In earlier systems the design process tended to be centralised and development required achieving a high threshold or critical mass of technological resources. Modularity means that it is more feasible to enter the development of relatively simple products and gradually accumulate experience and skills needed to move up the scale of technological complexity. The modularity of design means that it is now possible to continuously improve and expand a particular system. This is, in fact, the Brazilian strategy. Brazil has developed a small exchange of 1,000 lines suited to rural use. Using much the same hardware the system is shortly to be

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5/ Financial Times, 4 March 1985.

expanded to a 4,000 line exchange (Hobday 1985). Ultimately Brazil intends to expand into medium- and large-scale exchanges on the basis of these developments.

The greatest opportunities for entry lie in the transmission and peripheral areas. Although discussions on TC tend to focus on exchanges the balance of the market represents nearly 68 per cent of total sales, as Table 1 showed. Given the technological capacity to ensure product quality and compatibility with imported equipment, local development and production may well be feasible. For example, in the areas of FDM and TDM transmission, fibre optics and satellite ground stations there may be possibilities for entry. Local production in important peripheral areas such as intelligent terminals, mobile radio, key systems, visual display units, modems and codec equipment may also bear consideration.

## CONCLUSION

The emergence and diffusion of microelectronic technology has irrevocably transformed the telecommunications industry. New patterns of competition are emerging, traditional industrial boundaries are changing and new manufacturers are beginning to challenge the traditional market leaders. There can be little doubt that the once stable, cartellised, electromechanical oligopoly is gradually breaking down as competitors from the computer, aerospace, office equipment and semiconductor component industries enter the TC market - and TC makers in their turn attempt to capture new information technology markets. Technological change and covergence at the level of product and process lie at the root of these widely observed industrial upheavals.

In terms of products, microelectronic technology has brought about sustained reductions in cost, improved performance and greatly enhanced operating flexibility in a wide range of new applications. The clear technological and economic superiority of digital over analogue equipment has led to sustained, rapid increases in demand, despite economic recession and resulted in an almost complete transition of the equipment supply industry from electromechanical to microelectronic technology. However, one must look beyond the TC industry to fully understand the market restructuring and

increasing demand for new products. TC play a leading role in providing the infrastructure for a wide range of new information technology activities and this 'leading edge' property of TC has further stimulated the diffusion and adoption of microelectronic products in the public and private sectors.

At the level of process technology, the diffusion of microelectronics has radically altered the nature of the manufacturing process, from the design stages through to assembly. Instead of the wide range of mechanical and electromechanical skills needed with earlier technologies modern TC require a relatively small range of information intensive design skills. With semiconductor based technology there is also a sharp reduction in the importance of manufacture which is reduced to a simple assembly operation. Many of the skills and technical know-how demanded in the development and manufacture of digital TC are now common to other information intensive industries. With the convergence of these industries around digital IT an increasing number of previously unrelated products and industrial sectors are becoming closely related on a manufacturing technology basis. As a result new competitors from other sectors have found it possible, and profitable, to enter the TC market.

During the 1970s leading TC manufacturers attempted to gain technological leads over competitors by investing heavily in semiconductor based technology. The new technology has been rapidly adopted by almost all major firms, either as an offensive strategy to gain the rewards from technological leads, or as a defensive strategy to avoid the penalties of failing to keep abreast of technological advance. US and Japanese firms have clearly forged technological leads over many of their European counterparts. In response, European firms appear to be attempting to catch-up through various forms of technological co-operation, joint ventures and acquisitions. For their part US and Japanese firms are establishing links with European firms to gain greater shares of the rapidly growing TC and information technology markets. Other forms of joint venture have been spurred on by microelectronic technology. Risk and uncertainty is clearly a motivating force in several companies' sharing R&D expenditures and resources. Other joint ventures are the result of technological opportunities as TC makers find themselves in a position to diversify into IT -- and vice versa.

As microelectronic technology diffuses widely throughout these major world industries, OECD governments are retreating from their historical role of protecting home markets and giving support to the static, cartellised TC industries. Increasingly, it appears government legislation and intervention will be brought to bear on privatising local industry, opening up markets to foreign competition and providing technological support to local firms in an effort to speed up the diffusion of new IT services and force domestic manufacturers to become more competitive. While the nature of these policies differ from country to country they have one aim in common - to ensure the international position of local industry as the diffusion of IT continues.

In terms of the developing countries more empirical research is needed to assess the opportunities and problems facing them in this crucial sector. However, the new technology may, potentially at least, have improved the positition of many of these countries. As far as infrastructure is concerned, the late entry of developing nations may well prove to be an advantage in terms of capital saving and technological leap-frogging. In terms of technological and industrial development the position is far less clear. It appears that the greater divisibility of microelectronics, in terms of capital and technology, may have improved the possibilities for local industrial development for some, particularly larger, countries. The competition for developing country markets seems also to have increased the willingness of the multinational corporations to co-operate in technology transfer and joint ventures. If this is correct, there may well be new points of entry opening up. Ultimately much will depend on conscious government policy and the willingness and capability to translate any potential benefits into economic reality.

Notes

(1) See for example OECD (1983) and Roobeek, (1984). A glossary is provided to explain necessary technical terms and define such terms as information technology.

(2) The term 'semiconductor' refers to the special material used in the production of microelectronic circuitry. The terms 'semiconductor' and 'microelectronic' are used interchangeably here - both describing the inputs to, and the technology basis of, modern TC and computer technology. Again, see glossary for details.

(3) The role of TC as information technology infrastructure is illustrated by Barron and Curnow (1979). A review of the literature concerning TC and economic development is provided by Hudson et al (1981).

(4) Jequier (1977).

(5) International Business Week (1983) provides a graphic account of the dynamism of the PABX market.

(6) In the UK for example, Strowger is the most commonly used exchange.

(7) Financial Times, 17 June 1985. Muller (1982) gives full details of the economic and technological superiority of digital exchange technology.

(8) Again, see Muller (1982).

(9) Unless otherwise stated, these data are from the Arthur D. Little telecommunications programme. Arthur D. Little, (1983).

(10) It is not clear, however, how this investment is to be financed.

(11) OECD, (1983), p. 34.

(12) Wilmot, (1985) describes how Japanese IT firms have successfully 'targeted' US and European markets, each with the objective of achieving a given percentage of the world market. Once NEC, Fujitsu, Hitachi and

Toshiba had each gained 5 per cent of the world market in their respective fields, a new 'wave' of firms surfaced - Matsushita, Mitsubishi, Sharp and Oki - now being followed by a third wave, Ricoh Sony and NMB.

(13) Japan agreed, officially, to open its TC market to foreign competition in July 1985 (Financial Times, 31 July 1985). It is not clear, however, whether other unofficial barriers to entry will remain.

(14) Information on deregulation is from the Financial Times, Special Issue on Communications, 6 January 1986.

(15) Evidence of market saturation is presented in Muller, (1982).

(16) Taylor, (1985).

(17) For a general discussion on the prospects for technological leapfrogging by DCs, see Soete, (1985).

(18) Hobday, (1985) attempts to show how the shift to microelectronics benefitted Brazil's efforts to enter local manufacture and build up technological capabilities.

(19) See Bell, (1982) for a discussion of the importance of technological learning.

Glossary of technical terms

Analogue: Electromagnetic wave form analagous to a continuously variable quantity such as temperature. Digital on the other hand, is transmitted in discrete, separate pulses using techniques such as PCM (see below).

Crossbar: Near obsolete, electromechanical exchange used as an intermediate technology between Strowger and fully automatic electronic exchanges.

Digital: A discrete or discontinuous signal transmitted in intervals. Modern computer and TC technology is based on digital technology because of its superiority over analogue in terms of speed, reliability and low cost per bit of information. The term digital is often used to describe the technological basis of modern TC equipment. (Also see microelectronic and semiconductor).

Electromechanical: Semi electronic, incorporating moving parts (and analogue based), unlike solid state, microelectronic technology.

Exchange or Switching technology: is the technological 'heart' of a TC network. All messages are controlled, routed and switched within and between networks by a stored programme in electronic exchanges and by electromechanical connections in Strowger and Crossbar exchanges.

Frequency Division Multiplexing (FDM): A means of digital transmission which allows many messages to be simultaneously transmitted, by 'interleaving' samples of each signal, thereby increasing the capacity of a coaxial or microwave network.

Informatics: Automated digital data processing systems, incorporating two or more computers, involving data storage, manipulation and transmission.

Information Technology (IT): The term for the whole range of TC, informatics and telematics systems based on digital technology and allowing the storage, transmission and manipulation of data at low cost and great speed. In effect a coherent technology for handling information.

Information Technology Industry: The industry which provides the equipment and services based on IT. In this paper a distinction is mad between the information-intensive service industries and the industrial application of IT, for example, to the automobile industry. Sometimes IT is used to describe all applications of microelectronic technology.

Integrated Circuit: Any microelectronic component with more than one functioning element.

Integrated Services Digital Network: The concept of a wide range of fully interlinked IT and broadcasting services, utilising the most advanced digital techniques to achieve low cost, fast, integrated communications, data processing and broadcasting services.

Microelectronic: The term used to describe the technological basis of IT and the actual, miniaturised, component inputs.

Microwave: Very short electromagnetic radio wave used in TC transmission. In the overall wavelength spectrum of long, medium, short, infrared, ultraviolet, X-ray and gamma rays.

Modem: A device used for 'modulation and demodulation' of TC signals. In other words it takes an analogue electrical signal, converts it into a digital signal for transmission and vice versa.

PABX, Private Automatic Branch Exchange: A self-contained, usually digital, telephone exchange used in private institutions and separate from the public TC network.

Pulse Code Modulation (PCM): Digital transmission of information by modulation according to a pulse.

Semiconductor: The principal material used in the production of micro-electronic cicuits having special electrical conducting properties suited to the mass production of circuit components.

Stored Programme Control: An exchange with internal control performed by a computer programme.

Strowger: The first automatic telephone exchange. Invented in Kansas in 1889 but still in wide use. Based on banks of rotary switches connected in series. Slow, inflexible and costly in comparison to digital, solid-state exchanges.

Switching: See Exchange.

Telecommunications TC: See text.

Telematics: Sometimes known as tele-informatics, represents all those computer services based on digital technology which process data and employ the public TC network for switching and transmission, thereby gaining the cost advantage of using existing capital equipment. In many cases telephones and TV sets are used to request and view information.

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