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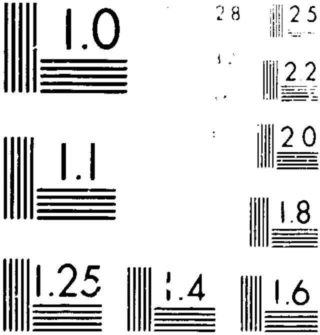
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org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MICROELECTRONICS: ITS IMPACTS AND POLICY IMPLICATIONS*

by

Juan F. Rada**

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** UNIDO Consultant.

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The purpose of this paper is to explore two closely related issues. The first is the general characteristics of current technological change and the second is to examine current and likely developments in the field of electronics with particular emphasizes in the component sector of the industry. Both aspects are of crucial importance to design public policy.

I. TECHNOLOGY AND POLICY DESIGN

A conceptual approach is a necessary starting point because there is an implicit or explicit concept of technology in policy design that needs to be carefully reviewed. Technology, from the point of view of developing countries has been treated in three distinct forms. The first relates to the characteristics of the technology to be used in order to make the choice of technology compatible with the economic environment, skill endowment and development aims of any given country. It is in this area that concepts such as appropriate, intermediate and hybrid technologies have emerged. The search has been for adaptation of technologies to local conditions, particularly in rural areas and the so-called "informal sector".

The second has been the issues related to mechanisms of transfer of technology particularly foreign investments, licensing agreements, use and nature of patents, trade secrets and other forms of know-how. The principal aim in this area has been to maximize access to technology while minimizing cost and conditions for developing countries. The main international discussion in this area - not yet completed - is the code of conduct on its transfer of technology elaborated by UNCTAD. Several concrete mechanisms for compilation of technical information and transfer has been devised at the intergovernmental level and by international agencies such as UNIDO. Discussions on the pros and cons of foreign investment and of off-shore plants as mechanisms of transfer of technology has been prominent in the debate.

The third element has been the development of science and technology policy to upgrade the technical infrastructure and have the capacity to choose technology and innovate. Too often the emphasis in this area has been tilted towards institutions of higher education and "pure" science and not enough to encourage enterprizes to innovate and to create enough human resources at the technologist and managerial level.

The above three points are not comprehensive of all the aspects of the technology-development debate and the aim is to highlight that there are two elements absent or not properly emphasized.

The first is the fact that technologies are dynamic, constantly changing either slowly or by sudden jumps. The second is that technologies today are composite of a number of disciplines and developments. It is the effect of the meeting of several areas of technology that has produced the most important innovations during this century. Thus, from a policy point of view it is important to develop conditions for education in certain disciplines as it is to focus R&D in order to make these disciplines meet and interact. This latter process is the one that normally takes place to transform an invention into innovation and it is characteristic of successful commercial R&D with sharply focused objectives.

The first aspect namely the dynamism of technology is a recognized fact. Furthermore, it is also recognized that technological change has accelerated its pace after World War II. This is partly due to the institutionalization of the R&D function and the growing fusion of science and technology. Incidentally, I should mention here that current technological change is the result of only about 30 years of systematic R&D efforts, although the theoretical elements of most innovations can be traced back much further.

The inherent dynamism of technology in all fields is not readily incorporated into policy. Technology, whether for products, processes, agriculture, administrative and office work is often taken - for policy purposes - as given, exogeneous in the planning process and more dangerously still, as something which is not normally understood by policy makers.

As the pace of technological change accelerates in a number of fields one of the most apparent consequences are important shifts in comparative advantages by the alterations of the relative importance of one or more of the components of economic activities.

This is not a new phenomenon and history shows many instances where new discoveries and innovations have contributed considerably to changes in comparative advantages. What is important in current technological change is not simply that one sector (i.e., electronics-telecommunications-computers) is out-performing the rest but that the entire productive infrastructure is changing in technological profile. This change in profile is likely to increase further as genetic engineering leaves the academia and enters the commercial field and also because of developments in human-engineered materials.

The combined process of change in all fields produce an explosive set of issues for development strategies and policies. However, the areas of immediate concern here is information technology.

- Information Technology is the composite of:	- Electronic Components - Computers - Telecommunications

This technological trilogy is essentially concerned with the creation, processing and retrieval of information. Its importance is essentially related to its pervasiveness since no intellectual or mechanical activity can take place without some form of information exchange.

It should be kept in mind that this area of technological development is only one and where our knowledge of its consequences nationally and internationally is more advanced. From a proactive policy stand point at least two other areas should be considered that I shall simply mention. One is obviously development in genetic engineering with tremendous potential applications in fields ranging from pharmaceuticals to agriculture and mining. (1)

The ability to programme microorganisms for particular tasks will undoubtedly shift advantages, although it is not possible yet to determine how. The other is the case of materials, where the trend towards substitution is accelerating with very important new developments in areas such as crystals, composites, ceramics and fibre optics.

The dynamism of technological change must be recognized and this implies a degree of uncertainty concerning future developments that cannot be avoided in policy design.

The second factor mentioned was the composite character of technology. This grows out of the nature of current technological change as well as its complexity and has two important consequences for the international division of labour. The first is growing "embodiment" of technology and thus more difficulties on unpacking and reverse engineering. The above is due to the requirements of system design as well as the complexities of process technology. An immediate consequence of this process in the transfer of value added to original producers at the hardware and system level.

A second, closely related aspect, is that technology is becoming more "intangible", embodied into people, organizational forms, trade secrets and long learning-by-doing processes rather than the traditional "blue print" of the mechanical age. The role of management in this respect surfaces again in a different light and not just merely as a coordinating role since the capacity to motivate and know-what becomes as relevant to success as the know-how.

It is significant in this respect that there is a decreasing relevance of patents and similar forms of protection of technology as companies rely more on "intangibles". This is due to the fact that dynamic technological developments are difficult to describe in patentable form. Secondly, that application for patents disclose information that companies prefer to keep to themselves. Finally, that given complexity of products or processes a slight modification by competitors renders the enforcement of patents impossible. These elements make transfer of technology processes for more complex than in the past. The transportability of services which is one of the most important consequences of developments of information technology further complicates the process of transfer of technology. This is due to the fact that instructions can be transmitted through the telecommunications networks to machine and equipment rather than transferring the software that makes the instructions possible. These are the developments in areas such as computer aided design and machining data bases as well as the older computer services of data processing or time sharing.

The consideration of the dynamism of technology and its growing abstraction implies that the discussion of technology should increasingly cover, from the point of view of developing countries, how technological advances in the developed countries condition its development strategies and capacities to compete. This implies a far more sophisticated process of policy design and an up-grading of policy-making bodies in tune with the country capacity and perceived strategic sectors.

To summarize, technological advances need and must be seen in a wider framework considering as essential its dynamism, composite character, growing embodiment and nature.

II. THE ROLE OF ELECTRONICS

Developments of technology have changed electronics from being considered a light industry geared to produce consumer products to an essential industry for the future influencing all sectors of economic activities. The importance of electronics lies in the fact that as an industry it is essentially concerned with the processing of signals.

Electric current and voltages have been used to convey different types of signals since the invention of the electron tube in 1906. The fundamental change taking place now is the increasing use of digital electronics (as different from analogue) to convey signals in pulses of current and/or voltage. As a consequence of the development in integrated circuits, particularly the microprocessor and microcomputer, the electronic bit or basic unit of information is used because of its capacity to convey, process, store and manipulate information based on a uniform digital signal. This is revolutionary in that it provides a "universal language" to treat and manipulate information in a comprehensive, accurate and speedy fashion. The development of digital electronics has increased the speed, reliability, and complexity of devices. As a result, more and more functions which belonged to the field of analogue electronics can now be performed by digital devices. This process of increasing "digitalization" and the capacity to transform analogue signals to digital and vice versa permits the coupling of activities which in the past were separated although interacting. Thus, growing numbers of electronic components operate with same language as computers and digital telecommunication systems.

Semiconductor technology is essentially concerned with the manipulation of "signals" (information) by electronic means. Understanding the technology from this perspective provides the correct approach to assess its implications and potential. This explains the pervasiveness of a technology that provides a comprehensive system to handle and process information and why much of the equipment being produced is called "intelligent", with the microprocessor the "brain" of information handling systems. Information and its use has provoked the development of new concepts such as the emergence of the "information society". The treatment of this issue remains superficial and the analysis requires much more refinement inasmuch as the so called industrial society is not post agricultural, nor the emerging social texture will be post-industrial.

Industrial production will remain central to it with ever-growing amounts of information incorporated into goods, solidified into products. The nature and quality of activities change while fundamental aspects of society remain basically the same. Nevertheless, looking at things from an information point of view, current evidence does point to a quantitative and qualitative shift in the economic and social structure. (2)

At the base of the electronic industry today are semiconductor components. Semiconductors are electronic components made from materials such as silicon or germanium which contains small amounts of impurities which make them neither good electrical conductors, nor good insulators. They can, however, amplify, switch and rectify electrical current. The semiconductor industry includes discrete individual function devices such as diodes, rectifiers, transistors, and integrated circuits, both monolithic (with thousands of components per "chip"), and hybrid (with discrete semiconductors attached). Also included in this industry are opto-electronic devices such as photovoltaic cells, light-emiting diodes (LED) and laser diodes.

Semiconductor components are essential for a wide range of products and processes ranging from watches to satellites. As the industry grows, its structure increases in complexity with specialized suppliers of material (such as silicon), equipment (such as testers), parts (such as ceramic packages for "chips") and many other activities, including software for microprocessors and microcomputers. Within the semiconductor industry, monolithic integrated circuits, often called microelectronic devices deserve particular attention. Microelectronics is the collective name for circuits which are characterized by the following features:

- The circuits are manufactured in integrated form simultaneously in a single process cycle.

- The integrated form implies that there are no individual separable components although the different parts perform individual functions.

- The integrated form, eliminating many connections and packing the circuits together, make them extremely reliable and shorten the time for electric signal to travel from one component to the other.

- The process of simultaneous pro   ion permits the grouping of hundreds or thousands of components on a semiconductor substance usually Silicon (Si), Germanium (Gi), and for certain types of applications, Galium Arsenide (GaAs).

- The extremely small dimension of the lines of the circuits reaching micron and even sub-micron level with Very Large Scale Integration makes possible highly complex circuits in one "chip".

- The above characteristics make the price per function or element very low and decreasing as the level of integration or the density of circuits increases and volume production is reached. (3)

The semiconductor industry became important with the discovery of the germanium point contact transistors by Walter Brattain, John Bardeen and William Shockley at Bell Laboratories in December 1947. This was followed by continuous improvements in germanium transistors and the development of the silicon transistor by Texas Instruments in 1954. In 1958 Texas Instruments' Jack Kilby invented the first germanium integrated circuit which it was possible to produce economically by the use of the planar process developed by Fairchild Camera and Instruments Company in 1960-1961. Table 1 shows a partial list of product and process innovations in the semiconductor industry from 1947 to 1981. Some of these innovations are seminal milestones in technical progress for products and processes while others are important changes of great commercial value. To screen innovations is a hazardous task, because it is difficult to establish the exact beginning of an innovative process. The purpose of the table is to show the composite nature of progress and the impressive collection of major changes in the last 30 years.

In parallel to these changes, other important innovations have taken place in consumer electronics, computers, military applications, telecommunications and instruments. About the time of discovery of the germanium point contact transistor, the Electronic Numerical Integrator and Computer (ENIAC-1946) with 18,000 tubes, signalled the beginning of the computer era. Transistorized computers were commercially available by 1958 and those based on integrated circuits in 1963-1964.

Cumulative changes during the 1960's led to the development of the microprocessor which is the Central Processing Unit (CPU) of a microcomputer. This is an extension of the integrated circuit chip that is used in programmed logic arrays (PLA's) which are hardwired logic circuits. The demand for complex circuits in the late '60's, the increasing availability of the Large Scale Integration (LSI) Metal Oxide Semiconductors (MOS), and Bipolar technologies led to the design of more general purpose chips. The first microprocessor was developed by Intel in 1971 for the calculator marketplace and integrated all the the arithmethical functions into a single MOS/LSI chip. A related development is the microcomputer which consists of one

TABLE 1

Partial List of Major Product and Process Invention and Innovations in the Semiconductor Industry, 1947 - 1981

Innovation	Principal Company Responsible	Year
Point contact transistor	Bell Laboratories (first demonstrated)	1947
Single crystal growing (geranium) (process)	Bell Laboratories	1950
Zone Refining (process)	Bell Laboratories	1950
Grown junction transistor	Bell Laboratories	1951
Single crystal growing (silicon) (process)	Bell Laboratories	1952
Alloy junction transistor	General Electric Corp./RCA Corp.	1952
3-5 compounds (process)	Siemens	1952
Jet Etching (process)	Philco Corp.	1953
Surface barrier transistor	Philco Corp.	1954
Silicon junction transistor	Texas Instruments	1954
Oxide masking and diffusion	Bell Laboratories	1955
Diffused transistor	Bell Laboratories / Texas Instruments	1956
Silicon controlled rectifier	General Electric Corp.	1957
Junction Field effect transistor	CFTH General Electric Co. - France (first demonstrated) (patent granted to RCA in 1957)	1958
Tunnel diode	Sony	1958
Planar process transistor	Fairchild Camera & Instrument Corp.	1960
Epitaxial process	Bell Laboratories	1960
Epitaxial transistor	Bell Laboratories	1960
Integrated circuit	Texas Instruments (patent application in 1958)	1960
	Fairchild Camera & Instrument Corp. (production in quantities)	1961
Flat pack (package)	Texas Instruments	1962
MOS transistor	Fairchild Camera & Instrument Corp.	1962
DTI Integrated circuit	Signetics Corporation	1962
MOSFET (MOS field effect transistor)	RCA	1962
TCTL integrated circuit	Pacific (TRW)	1962
Gunn diode	International Business Machines Corp.	1963
Beam lead (process)	Bell Laboratories	1964
TTL integrated circuit	Pacific (TRW)	1964
Light-emitting diodes (LEDs)	Texas Instruments	1964
Dual in line package (package)	Fairchild Camera & Instruments Corp.	1964
Flip-chip method (package)	IBM	1964
Ion Implantation	Bell Laboratories in 1952. First commercial use by Ion Physics Corp.	1967
Collector diffusion isolation	Bell Laboratories/Philips	1969
Schottky TTL	Texas Instruments	1969
Magnetic Bubbles	Bell Laboratories (commercial/Texas Instruments - 1977)	1969
Complementary MOS	RCA Corp.	1969
Charged-coupled device	Bell Telephone Laboratories/Fairchild Camera & Instrument Corp.	1970
Silicon on sapphire	RCA Corp.	1970
Ceramic Chip Carrier (package)	3M Corp.	1971
4-Bit Microprocessor	Intel Corp.	1971
Integration injection logic	IBM/Philips	1972
Erasable programable read only memory (EPROM)	Intel Corp.	1972
Large Scale Integrated Circuits	Intel Corp./Texas Instruments	1972
8-Bit Microprocessor	Intel Corp.	1972
Non-contact direct optical projection system (process)	Perkin-Elmer Corporation	1973
16-Bit single chip microprocessor	National Semiconductor	1974
Electron Beam exposure system (process)	Bell Laboratories	1974
8-Bit single chip microcomputer	Intel Corp. (patent filed by Texas Instruments in 1971)	1975
16K memory	Intel Corp.	1977
Mann 4800-Direct-step-on-wafer machine (process)	GCA Corporation	1977
X-ray Lithography system (process)	Nippon Telephone & Telegraph/Nikon (first commercial captive)	1978
16-Bit Single Chip Microcomputer		1979
64K RAM	Texas Instruments (non captive) IBM (captive)	1979
32-Bit microprocessor	Intel Corp.	1981
256 RAM	Hitachi/Fujitsu (samples	1982

Source: This table is based on a number of sources including the latest announcement. The main sources are listed below and their information has been corrected according to what seems, to the best of our knowledge, correct dates after extensive double-checks.

John E. Tilton, "International Diffusion of Technology: The Case of Semiconductors", Washington, D.C., The Brookings Institution, 1971, pp. 16-17. Anthony M. Golding, "The Semiconductor Industry in Britain and the United States: A Case Study in Innovation, Growth and the Diffusion of Technology", unpublished D. Phil. Thesis, Sussex, England: University of Sussex, 1971, p. 81. William F. Finan, "The International Transfer of Technology Through US-Based Firms", unpublished study, New York: National Bureau of Economic Research, October, 1975, pp. 33-36.

E. Braun and S. MacDonald, "Revolution in Miniature", Cambridge University Press, 1978.

Electronics International, "An Age of Innovation", McGraw-Hill, 1981.

or more microprocessors, supporting chips and discrete devices required to produce a programmable computer. The type of applications determine the complexity of the microprocessor and the lay-out and components of the microcomputer (MC). In 1975 Intel produced a microcomputer in one chip. The development of the microprocessor (MP) in many respects has had a more profound impact than the early developments of the 1950's and 1960's, although the MP and MC would not have been possible without them.

By the late 1970's the semiconductor industry was no longer just manufacturing discrete, integrated circuits and optoelectronics devices but also computers due to economic and technological trends.

It is this technological convergence which makes a definition of the industry difficult. For example, today's design of circuits increasingly depends on computer languages which in turn is mainly an area of the computer industry, while modern telecommunications switching systems are essentially dedicated computers. This convergence suggests that any policy approach to semiconductors would of necessity include many other sectors of the electronic industry.

As the level of integration of electronic components increases, two important effects take place. Firstly, the economy (price/performance) of the devices increase with substantial decrease in cost per function. This in itself increases pervasiveness and areas of applications. Secondly, with increasing integration the components become systems in their own right and in turn subject to being programmable. In other words while a decade ago a transistor was considered a component, today it is one element among thousands in a "chip", which in turn is considered a component. The important effect of this process is that as the level of integration increases, with all its effects in economy and performance, the convergence between computers, telecommunications and components also increases. This is illustrated in Figure I.

Technological change produce, therefore a change in the scope of electronics and alters the structure of the industry itself, changing towards an information or informatic complex.

In addition, the industry to be viable needs global markets and to have a global reach, thus as different from the past the process of diffusion of technology is quicker.

III. AREAS OF APPLICATION

In order to understand properly the importance of electronics a brief review of areas of application is in order. This could be done by a listing of sectors likely to be affected. It is preferable however to make a horizontal cut across economic activities to better understand current and possible applications.

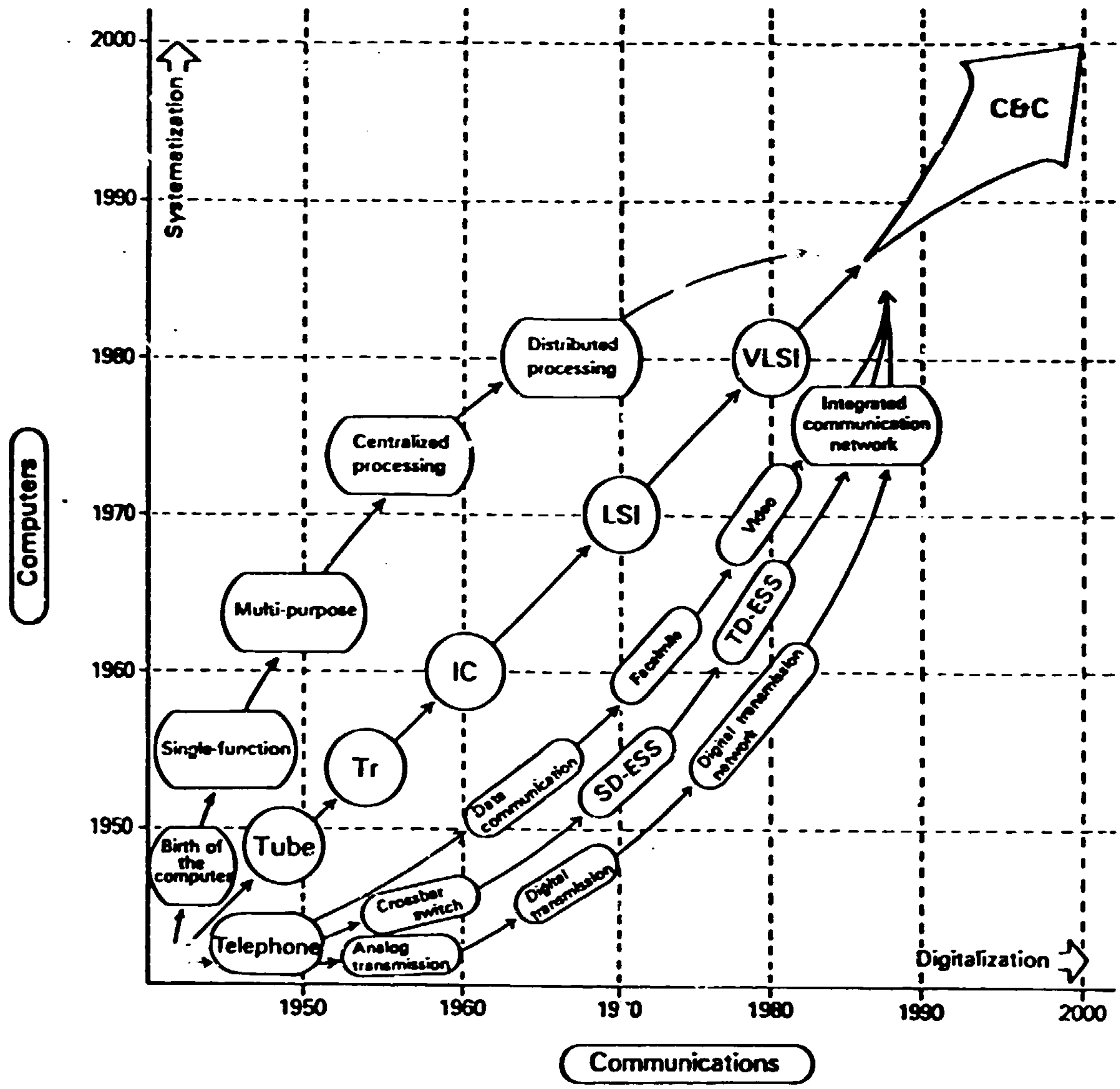
a) Changes in Products

Due to one or a combination of the following:

a. Replacement of mechanical components (e.g., watches);
b. Replacement of electromechanical components (e.g., calculators, cash registers, vending machines);
c. Replacement of older electronics and electrical components (e.g., computers, switching systems, terminals, TV sets);
d. Upgrading of traditional products by adding capability and electronics control (e.g., word processors, machine tools);
e. New products (e.g., speak and spell).

The listing above involves many industrial sectors ranging from

Figure I. Convergence of components, computers and communications



Source : Kobayashi, Koji. "The Japanese Telephone Industry in the year 2000" in International Telecommunication Union (ITU), 3rd World Telecommunication Forum, Part 1, p. II.6.4, ITU, Geneva, 1979 precision engineering to electronics and office equipment. The most important fact is the impact on the so-called traditional areas such as precision engineering. The classical example here is what happened to the watch/clock industry and how the industry is still changing significantly as new features and elements are added to the traditional function of the watch. What is important to visualize in the case of changes in products is that the manufacturing process changes and more often than not many of the business activities around manufacturing, such as marketing and the strategic position of companies or countries' economies. Let us illustrate this further with the ex mples of watches and cash registers. Table 2 shows how the different vital funcuions in a watch performed by mechanical components have been replaced by electronics.

Needless to say that the process has changed entirely and most of the value added, particularly for cheap watches was transfered to the manufacturer of electronic components. The same process of subtitution is applicable to many areas of precision engineering such as sewing machines, control mechanisms, telex equipment, taximeters, instruments, balances, vending machines, point of sale equipment, and many others.

Of additional interest in the case of watches is that the marketing structure, characteristics of the sale force and maintenance changed entirely. The watch from being a luxury item became a consumer product sold over the counter in general rather than specialized stores. (See Table 2).

The watch, however, remains essentially providing the same function with some additions (e.g., time-zones, stopwatch or calculator) in other cases the added function has also changed the very nature of operations. A good illustration is the electronics cash register. Once the cash register becomes electronized many new things are possible not only at the point of sale, such as consolidated totals and subtotals, but

TABLE 2

COMPARISON OF THE MECHANICAL, ANALOGUE AND DIGITAL WATCH*

	Technological Base	Number of Components	Number of Functions	Time Base	Source of Energy	Transmission	Display
Mechanical	Precision Engineering	100+	time/day/ date	Spiral balance wheel about 4 x's per second	Taut spring	Train of pinions & wheels	Hands/dial
Analogue	Precision engineering/ Integrated circuits	About 15 basic	time/day/ date/others	Quartz crystal vibrating at about 32,768 times per second	Battery	Motor syncro-nized with train of pinions and wheels	Hands/dial
Digital	Integrated circuits liquid crystal display	About 6 basic	time/day/ date/cal-culator/stop-watch/alarm/ second time/ others	Quartz crystal vibrating at about 32,768 times per second	Battery	Conductors & integrated circuits	Figures in liquid crystal display (LCD)

* Here the main features are considered. The je[illegible]ry part of the industry is excluded.

Source: Interviews and industry sources

beyond. If the goods are marked to be recognized by optical or laser scanners the possibilities are even greater. In fact the electronic cash register can update minute by minute the general movements of goods, type of goods being sold, average expense by customer etc. The different functions that it can perform depends, of course, on the degree of sophistication of equipment. Connected to a store computer, figures can be consolidated and stock levels known almost instantly with automatic reordering if necessary to headquarters, suppliers and distributors.

All of this has led to important changes in retailing, perhaps the most important in the future is that once retail-shops are on-line, particularly supermarkets, there is no reason why they cannot provide travel agencies or financial services (as some have already started to do).

Briefly, the substitution of mechanical components by electronics in cash registers convert it into a data entry terminal and not simply an adding machine. This obliges producers to provide upward compatibility, capacity to interconnect through telecommunications, and in the future to become much more interactive with capacity to check credit records on the spot or transfer funds directly to the store's bank. Thus the producer needs to offer system compatibility and in order to do that its product will have to be part of a total system. He will be obliged to increase its knowledge base and product mix and thus its strategy and conception of the business. On the other hand, the new capabilities of cash-registers oblige suppliers of goods to mark them in a way compatible with the system as well as offering computer-entry for orders from different stores. This type of chain-effect is becoming typical of current changes, as is also the case with trends in office equipment and automation.

The example of cash registers is conceptually applicable to many other areas. A case is machine tools where once the control is computerized the upward compatibility is simply a question of time.

The connection to machine data bases will be a reality by 1984 and CDC already offered in the USA, UK and the FRG time-sharing CAD/CAM services over the telephone which will make these sophisticated tools accessible to small and medium sized producers. This is the phenomenon of convergence where components, computers and telecommunications work as one in a single system. In the future, it will be difficult to determine where the processing is taking place because of proliferation of value-added dedicated networks.

When products change two important economic effects are induced by technology. The first, as mentioned earlier, is the transfer of value added to the manufacturer of components so when 300 tiny mechanical elements of a sewing machine are replaced by a microprocessor, the value-added obtained by the manufacturing and assembling of them is lost. Similar is the case with the development of electronic circuits to replace mechanical or electromechanical parts in cameras, toys, control devices, etc. These types of products often need custom-circuits that can only be produced economically in large quantities. However, it is now possible through a technique known as Uncommited Logic Arrays or Gate Arrays to produce economically small quantities of custom-made or tailored circuits. At the same time increasing amounts of instructions are being imprinted into the circuits themselves in the form of firmware customizing also in this form different types of circuits (e.g., ROMs). This will increase the amount of value going into components, and as they become systems through Very Large Scale Integration the embodiment of value-added will be even larger. This is one of the reasons why manufacturers of components are moving into systems, Intel being the latest case. As functions are incorporated into chips and they become more economical companies cannot maintain revenue out of hardware alone.

The second main effect is that as integration grows so does the embodiment of technology through essentially two mechanisms, a) the complexity of chip manufacturing and b) the need for systems and design knowledge. This type of technology is largely "intangible", acquired through learning-by-doing processes and organizational forms it is often classified as trade-secrets and not patentable.

B). Changes in Processes

In many instances no significant changes in products take place but the manufacturing process is substantially altered. This is the case of the automobile, garments, shoes and leather and wood-processing industries. The basic alterations take place:

a. Through the incorporation of functions and skills into equipment (e.g., computer controlled machine tools and robots);
b. Through increased complexity, flexibility and capability of control systems and monitoring devices for continuous production (e.g., use of computer aided manufacture (CAM) and computer aided design (CAD)).

The consequence is essentially one which permits greater levels of flexibility in the manufacturing process and also the possibilities of automating functions that were possible to perform earlier only by humans. At the "intelligence" of equipment increase the possibilities of substitution and enhancement of human work also increase.

Flexible manufacturing is possible due to the programability of machines or entire processes where the programme is change rather than the machine when other specifications are required. A very powerful combination in this respect is CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) which permits greater flexibility as well as a shorter transition between design and production. Ultimately, the aim is self-optimizing processes whereby ordering of supplies to warehousing, manufacturing and dispach is automated. The shop-floor in turn will be interconnected with the professional-clerical area and it will be difficult to distinguish between the two. Often the lack of capability of machines are compensated by changes in the product they handle in order to permit automation. Thus, most of the colours of products on the shop-floor are inadequate for the vision of robots and therefore a process of colouring is used rather than optimizing robot-vision which is technologically far more complex.

Current processes are most suitable to batch production, that is production of small quantities in continuous form with change in specifications. Programability here optimize machine utilization and reduce considerably down-time. This permits mass production with economies of scope (individualizing goods) rather than traditional economies of scale.

Of greater importance, however, for the future is automation of assembling rather than simply manufacturing operations. This is the area that cover most of the cost and labour force of manufacturing and substantial efforts are underway to automate, particularly through the use of robots. All robots producers are aiming at this sector since it promises to be the one with greater potential growth.

The main areas of process technologies with very important developments now and in the future are:

- Computer Aided Design (CAD)
- Computer Aided Manufacturing (CAM)
- Group technology and manufacturing cells
- Automatic inspection
- Automatic warehousing
- Robotics

The above means that the process of manufacturing is slowly becoming one in which the optimization of the use of equipment and capital becomes overriding. This was already the case of flow-processes such as petrochemical plants, but it is now becoming generalized in many other sectors of industry. This explains the efforts to operate plants in 3 shifts, the third being operated automatically. This simply acknowledges that production is increasingly the result of capital rather than other factors such as labour. This trend was historically evident first in agriculture. But as capital intensity increases there are also savings of capital per unit of output for a number of reasons. Among the most important are very short down-time of equipment, less time spent in transport of items on the shop-floor, optimization of size of stock with rapid turnover, resistence to obsolescence of equipment due to programmability and in many cases the possibility of off-the-shelf automation without expensive trial and de-bugging procedures typical of purpose-built equipment.

As a general comment in the area of process technology it is necessary to point out that under conditions of low growth much more attention is being focused on manufacturing areas due to cost constraints as well as competition. In the high-growth era, marketing and finance were much higher in the managerial list and a slack was possible in manufacturing. Increasingly in the advanced countries, especially due to the success of Japan in process technology, growing efforts, R&D and funds are being focused in this area and already results are evident in the rationalization of automobile companies, normally at the forefront of automation.

C) Office Work

Part of the "industrial culture" is the division of business activities into shop-floor and office-work (blue and white collar workers). Technologically this distinction will be increasingly difficult to make. Part of the reason is that the trend is to operate as single businesses with a closed information-loop. Therefore one could argue that manufacturing automation as well as office automation are transitions to "integrated business systems" which is now possible to envision because of information technology. In addition the changed skill-mix on the "shop-floor" is making the distinction between the layers of the enterprise sociologically difficult. The transition will be long, but the trend is definately underway.

A degree of office automation is possible today:

a. By further automation of formalized work (e.g., data processing and word processing);
b. By increasing the independence from traditional information channels for those who work in less formalized environment (e.g., on-line systems).

The importance of office automation lies in two distinct facts. Firstly, that substantial productivity increases are unlikely to come from manufacturing activities alone and traditionally clerical activities have lagged behind in productivity. Furthermore, a majority or an increasing number of people are engaged in office-work. Secondly, that the office sector is undercapitalized, with investment per worker in a ratio of 1 to 30 as compared to manufacturing.

The search for total business productivity justified the frantic search for automation of office functions. It is not clear as yet the exact impact that office automation will have in overall productivity nor the influence on location of enterprises. What is clear however, is that office work consists largely of information handling and processing and therefore is most suitable to the characteristics of information technology.

Needless to say that changes in office work affects all sectors regardless of its activities. The speed of diffusion of technology is however different mainly because it is not clearly perceived how it might affect competiveness and also because of a number of cultural and social barriers.

In areas where quick response, customer service or great amounts of routine activities take place the diffusion is rapid. The use of distributed processing, cheap desk-top computers and economical word-processors will further increase the penetration of office automation as the economy of equipment increases.

Of crucial importance to office automation is compatibility of equipment and their capacity to communicate. In this respect the telecommunications infrastructure lies behind the current capabilities of equipment. The use of coaxial cables and fiber optics will, in the near future, alter this substantially in many developed countries.

D). Services and Information Flows

Applications of information technology in this area is perhaps the most evident while at the same time the most complex. Changes in services take place:

a. By permitting transportability of services (e.g., banking);
b. By increasing self-service (e.g., petrol stations);
c. By growing replacement of human-to-human services by good (there are many examples here from the past such as substitution of laundry services by washing machines, a clear example now is reductions of maintenance requirements due to the self-diagnosis systems and modular repairs);
d. Development of new services (e.g., teletext).

Changes in information flows take place:

a. By extensive digitalization of all types of signals (e.g., digitalization of all types of signals (e.g., digital networks);

b. By the use of vast network to transfer, process and retrieve information (e.g., interface computers-telecommunications (telematique).

The essential feature of change in services is that for the first time in most cases, many services become transportable and this in turn creates the possibility of great numbers of new services. This is, or course, on top of the alterations within the production of services themselves though office automation or more self-service. Therefore, today it is possible to transport the contents of a library, using telecommunications, to a living room. Similarly, a banking service can be transported to a shopping center or many other places by utilizing automatic cash telling points connected with the banks central computer to check on the status of accounts or in the future tele-banking. As the cost of communications diminishes the amount of services to be transported increase. By analogy is a similar process that took place with the steam-boat that by decreasing the cost of transport, bulk and large cargo was possible to move economically. The consequence was that international comparative advantages in producing goods became evident once transport cost was no longer a "natural" barrier. Similarly, as telecommunication costs decrease it renders evident the relative advantage in production of services, particularly information intensive ones. A case in point are time-sharing services, data-bases and banks, electronic libraries and teletext services. This adds a new dimension to international-trade in services for which neither the international legal system nor policy makers are yet prepared. The changes in services referred to are those linked to goods (i.e., insurance) as well as "pure" services (i.e., data bases).

It should be borne in mind that changes in services take place in the context of growing "service content" of manufacturing activities as well as grow in services in the traditional sense of "tertiary sector". The example used earlier concerning cash-registers is a good illustration of "service-content" of manufacturing activities. Similar is the trend in machine tools. With computers the trend has been clear for a number of years. This pattern is likely to be repeated with many products as they become electronized. Thus today cost of harware is decreasing as compared to total system cost, as follows.(See Table 3).

Table 3
Software as a Percentage of Large Microcomputer Systems Cost

Year	Hardware	Software Development	Software Maintenance
1970	55%	24%	21%
1975	45	30	25
1980	35	33	32
1985	30	35	35

Source: Creative Strategies International, 1981.

The most significant increase as it can be seen from the table is on software maintenance, that is a recurrent service and the variable cost to end-users. In addition new "services" are emerging rapidly through the use of cable TV, more portable and economic audio visual equipment, cheap satellite earth stations, home computers and local or national networks.

It is difficult today to dis-associate changes in services and telecommunications, they are both closely linked. The digitalization of information flows, the development of powerful value-added networks, direct satellite broadcasting, processing and business satellites will, out of necessity, alter comparative advantage in a number of areas, notably services. From the policy point of view this area raises a number of issues ranging from tariff and non-tariff barriers for services to the distribution of frequencies in the radio-spectrum. This is beyond the terms of reference of this paper but suffice it to say that it is no longer viable or even acceptable to design policies in a peace-meal fashion due to the technical as well as policy interconnection of different areas. This posed a clear challenge to traditional planning and industrial policy methods and calls for a much more organic approach.

The areas of application described produced a "pull-effect" on at least the following, seemingly unrelated areas:

- Materials (e.g., crystals, plastics, castings);
- Sensors and activators;
- Electric engines (e.g., miniaturization and performances);
- Performance on energy sources (e.g., batteries);
- Peripherals (e.g., printers, plotters, disk-drives);
- Display systems (e.g.,C.R.T., plasma displays);
- Performance of mechanical parts (e.g., maintenance-free ball-bearings);
- Communication transmissions (e.g., coxaial cables, fiber optics, laser technology).

The above areas only illustrate related changes but by not means are comprehensive of all possible alterations.

In essence, what is taking place from the point of view of developing countries, is that traditional industries which at one time were thought to be transferred to developing countries can be potentially viable in advanced countries. This is already evident in areas such as assembling of semiconductor components and it could also happen in other areas. This takes place while at the same time a growing concentration as well as transnationalization of "information intensive" services occurs.

Since current changes are system based and skill intensive one can expect an uneven diffusion between developed and developing countries. Historically, the industrial revolution showed that the harnessing of technology was crucial to alter what was previously perceived as traditional advantages.

Briefly, the industrialization path is becoming narrower since options are decreasing as the advanced countries "re-industrialize".

IV. SIZE AND STRUCTURE OF THE SEMICONDUCTOR INDUSTRY

Worldwide shipments of the semiconductor industry represents in 1981 about $20.5 billion. This is the pillar upon which the $180 billion world electronic market is based. The impressive growth record of this industry is unparalleled. The value of shipments of semiconductors by US firms in 1952 was $19 million. In 1981, estimated US shipments of IC's alone reached about $5298 million, accounting for 75% of total US semiconductor shipments. (4) Table 4 following summariz. summarizes worldwide semiconductor shipments forecasted to 1985 and percent annual change.

The microprocessor and microcomputers segments of this industry were born 10 years ago. In less than ten years the industry worldwide went over the $1 billion mark, standing at $1,244 million in 1980. It is expected to grow to about $5 billion by 1985, a compound annual growth rate of 32%.

These impressive changes are reflected by many indicators, one particularly interesting is per capita consumption of IC's in the developed countries which reflects better than total market figures the pervasiveness of the technology as well as the rate of diffusion. (See Table 5).

Table 4

Worldwide Semiconductor Shipments

	—— Shipments in $bn (% subtotal*) ——				Percent Annual Change		
	1979	1980	1981	1985	79-80	80-81	81-85*
DISCRETE DEVICES							
Small Signal	1.91 (38)	1.98 (36)	2.06 (35)	2.62 (29)	4	4	6
Power	2.41 (48)	2.61 (48)	2.82 (48)	4.41 (49)	.8	9	12
Optoelectronic	0.71 (14)	0.84 (15)	0.97 (17)	1.88 (21)	18	15	18
Subtotal, discrete	5.03 (100)	5.43 (100)	5.85 (100)	8.91 (100)	8	8	11
% Total Semiconductor	36%	31%	29%	19%			
INTEGRATED CIRCUITS							
Analog	1.90 (21)	2.33 (19)	2.69 (18)	6.39 (17)	23	15	24
Bipolar Digital	2.33 (26)	3.05 (25)	3.47 (24)	7.89 (21)	31	14	23
MOS Digital	4.80 (53)	6.75 (56)	8.49 (58)	24.00 (63)	41	26	30
Subtotal ICs	9.03 (100	12.13 (100)	14.65 (100)	38.28 (100)	34	21	27
% Total Semiconductor	64%	69%	71%	81%			
TOTAL							
SEMICONDUCTORS	14.06	17.56	20.50	47.19	25	16	23

* Percent shares may not add due to rounding.

** Average annual compound rate.

Source: Mackintosh International, cited in Financial Times, July 1, 1981.

Table 5

Per Capita IC Consumption

	1965	1975	1985
USA	0.3	5.7	15.9
EEC	---	2.9	8.5
Japan	---	4.4	16.2

Source: Mackintosh, I., "A Prognosis of the Impending Intercontinental LSI Battle" in Mackintosh Publications, "Microelectronics into the 1980's," Luton, England, 1979, p. 66.

Integrated circuits are the most important semiconductor and where most technological change has been concentrated. It represented 78, 66 and 62 percent of the semiconductor market of the USA, Europe and Japan, respectively.

Besides underlying the growing importance of IC's, these figures also show more fundamental features of the electronic industries of each area. The United States, for instance, is more oriented toward professional rather than consumer electronics which explains the historical tendency to concentrate on IC's. The United States has an almost overwhelming supremacy in the computer industry which remains the main client of IC producers. By contrast, Japan concentrates on consumer products although this is changing considerably.

The fastest growing segment within integrated circuits is microprocessor and microcomputer components as well as dynamic memories. This market, which was non-existent in 1971, reached $1.24 billion in 1980. The importance of microprocessors taken in isolation is minimal since it represents in 1980 only 3% of the total semiconductor revenues. (5) However, when total revenue generation resulting from the use of microprocessors is taken into account (support chips, memory chips, boards, development systems, software and training) the total microprocessor/ computer industry accounts for about 30% of semiconductor sales.

Table 6 shows the trend and geographic breakdown of markets.

Table 6

Geographical Market Forecast Worldwide
Microprocessor/Microcomputer Sales
Chips, Boards, and Systems
1980-1985
(billions of 1980 dollars)

Market Size - Consumers

	1980		1981		1982		1983		1984		1985		Growth
	$	%	$	%	$	%	$	%	$	%	$	%	Rate
US & Canada	.74	60	.95	55	1.20	52	1.42	49	1.75	47	2.27	45	25
Japan	.18	14	.29	17	41	18	.56	20	.78	21	1.11	22	44
W. Europe	.30	24	.45	26	.62	27	.81	28	1.46	29	1.46	29	37
Rest of World*	.02	2	.04	2	.07	3	.11	3	.15	4	0.20	4	58
Total	1.24	100	1.73	100	2.30	100	2.90	100	3.73	100	5.04	100	32

* This includes developing countries as well as centrally planned economies.

Source: Créative Strategies International, 1981.

Besides the distribution of markets among developed countries, it is important to notice that the rest of the world represented only 2% in 1980 and will represent about 4% in 1985, $2 million and $20 million respectively. This category includes all developing countries as well as centrally planned economies. If a more detailed breakdown was available, it would probably show that only a handful of countries represent the bulk of the market.

An additional element is important in this category of state of the art products. This is the rapid obsolescence and short product cycle that can be seen when the market is broken down by architecture. (See Table 7).

Table 7
Worldwide Microprocessor Revenue Projections
by Architecture

	1980	1985	Compounded Annual Growth Rate
4-Bit	$ 50	$ 60	4%
8-Bit	105	184	12
16-Bit	38	391	59
32-Bit	---	100	88
Others	24	228	56
Total	217	963	35

Source: Creative Strategies International, 1981.

The 4-bit microprocessor which pioneered the field in 1971, represented 23% of the total microprocessor market in 1980 but will only represent 6% in 1985.

The semiconductor industry is a fast moving target and more powerful devices tend to replace rather than complement previous ones. The case of memories is similar. The 4K RAM (Dynamic Random Access Memory), which represented a US market of $91.5 million in 1979, will only represent about $1 million in 1984. The state of the art 64K RAM based on VLSI technology represented a US market of $1.4 million in 1979 and will go up to $472 million or more by 1984. (6)

In the context of a large and growing industry the structure of it has changed considerably in the last few years and likely to change even more in the future. Today the semiconductor industry is characterized by the presence of large vertical integrated companies dominating the world market and small innovative ones exploiting specialized niches. This was not the case in the early 70's where medium and small innovative companies dominated the market of IC's on a worldwide scale.

Producers of semiconductors can be divided into captive producers manufacturing for their own needs; captive-merchant producers producing for their systems and also selling in the open market, finally, merchant producers selling to OEM's (original equipment manufacturers).

The basic concern here is with the last two groups since captive producers have a dynamic and behaviour of their own with specific design and manufacturing processes.

The most apparent inter-related changes in the structure of the industry has been vertical integration; concentration with a great deal of takeovers and increasing amount of technology tie-ups and links. This has led to higher entry barriers.

There are many reasons for these processes, including technology and economic ones. The process of vertical integration is explained essentially by the need of manufacturers of components to move into systems and the latter to move into components. Semiconductor producers cannot maintain revenues out of components alone. As they progress through the learning curve they need to increase sales as fast as price decreases to maintain revenues in a fiercely competitive environment. Further more value-added and revenues are maximized through the selling of boards, systems and software, that is, by selling "solutions" rather than components. This is compounded by the increase in the level of integration which de facto implies that producers of components are in systems as is the case with VLSI. Thus, technology and economics oblige producers to move from components to systems. In fact the two largest producers of components (i.e., Texas Instruments and Motorola) generates less than half of their sales out of components. The trend is similar with other producers, being the latest the move of Intel into minicomputers. The implications of this process is that in the future the independent component producer will tend to disappear, exception made of market niches since they will be in essence producers of systems. Intel is by now also in computers and office communications (in agreement with Xerox and Digital) as is the case witn Texas Instruments. For system producers the need to individualize their equipment and the growing amount of firmware going into chips obliges them to consider manufacturing of components. Thus, companies which are heavily dependent on components have acquired this capacity either by buying companies such as in the case of United Technologies and General Electric or developing captive facilities such as in the case of NCR and ASUAG. The reasoning behind developing captive-facilities is of course related to volume of needs as well as technological base.

Together with vertical integration there is another closely related phenomenon of business concentration.

The degree of vertical integration distinguishes Japanese, US and European producers, and explains to a great extent their behaviour and strategy. The Japanese industry is dominated by five vertically integrated companies producing end-products either in professional or consumer markets. The top five semiconductor producers in Japan hold 74% of the market in 1979 and the top ten account for 92% of the market. All of them, with the exception of OKI, are also the largest electronic companies in Japan. (7) In Europe the situation is similar to Japan inasmuch as the largest producers are also the largest electronic and electric engineering manufacturers such as Philips, Siemens, AEG-Telefunken and Thomson-CSF (part of the Thomson-Brandt group). The difference with Japan is the strong presence of US and Japanese producers in the European market. Thus in 1979 the five top producers held 65% of the semiconductor market but only the top two were European and the rest were US companies. The top ten producers hold 78% of the market, but only four are European based companies, while the rest are US companies. In the case of IC's, levels of concentration are similar, with 51% for the top five and 77% for the top ten, with one Japanese company among them (NEC). (8) For the USA the situation is more difficult to determine since totally captive production might account for about 50% of total production. This includes companies such as IBM, AT&T, Burroughs, Digital, and many others. In the merchant market in 1979 the top five producers held 53% of the market and the top 10, 70%. (9) In the top five only one was a foreign-owned subsidiary (Fairchild, subsidiary of Philips, and AMD which is partly owned by Siemens (21%)). Among the ten top US based producers, three are part of vertically integrated companies, either as a division or a subsidiary, (Signetics, Motorola, and RCA). Mostek is a subsidiary of United Technology, the 26th largest US company which is heavily involved in electronics, particularly for defense and aerospace. Semiconductors represent a very high percentage of total sales for the main US companies, as different from Japan or the main European producers. This is not to say that the others are not equally dependent on semiconductor technology, but due to a different sales mix their strategies are different. For instance, a Japanese or European company has a captive market for new components which might allow them to move through the learning curve faster as well as exploit economies of scope. This vertical integration puts them in a comparatively strong position for the future although they have not reached US innovation capacity except in some fields (i.e., Japan, in memories).

The result of vertical integration is that the producer cannot only afford lower rates of return in components but can also invest heavily in order to assure an important market share. By contrast, the purely merchant producers operate under different types of constraints since their main source of revenue and evaluation in financial markets is components. At the same time vertically integrated companies are better equipped to buy technology through the purchase of equity in innovative companies as it has been the case with NEC, Philips, Siemens and General Electric, among others. However, at the current stage in the industry, equity participation and joint ventures will probably become more important than takeovers. The fact is that there are no significant medium size producers without important corporate links.

The need of capital or technology has significantly contributed to change in structure in such a way that small companies in need of capital have obtained it through corporate participation on their equity (e.g., Zilog with Exxon) or large companies in need of increasing capacity and technology have acquired firms (e.g., Philipps acquisition of Signetics). Thus, the situation in the USA since 1967 is shown on the following page.

Tie-ups have also increased significantly either through second sourcing, agreements to develop complementary products and most importantly in the last few months joint R&D programmes particularly in areas of basic research.

Behind these changes in structure there are two main interrelated reasons, a) increases in cost of manufacturing and R&D, and b) technological complexity.

The US industry will need about $15 billion during the 1980's in order to keep pace with an 18% growth in semiconductor sales. This calculation is an adjusted projection based on the estimate that the US semiconductor industry needed $3 billion of capital in 1979 for about $6.5 billion of shipments. (A ratio of $1 of capital for $2.5 of sales). (10)

For current competitors in microprocessors a "critical mass" of about $25 to $30 million in net assets is needed for on-going operations, while a new entrant will probably need double or triple this amount. (11)

US Semiconductor Firms - Main Acquisitions by Year

Company	Year	Buyer
Monolithic Memories	1969	Northen Telecom (12%)
Amperex	1972	Philips
Exar	1972	Toyo Electronics (53%)
Zilog	1974	Exxon (80% in 1979)
Dickson	1974	Siemens
Signetics	1975	Philips
MOS Technology	1976	Commodore Int.
Supertex	1976	(HongKong interest minority share-Exxon)
Semtech	1976	Signal Co. (12%) Teledyne (11%)
Frontier	1977	Commodore Intern.
Micropower Systems	1977	Seiko
Adv. Micro Devices	1977	Siemens (20%)
American Micro Systems	1977	R. Bosh Gmbh(25%)(See 1981)
Analog Devices	1977	Standard Oil of Indiana
Litronix	1977	Siemens
Interdesign	1977	Ferranti
Synertek	1978	Honeywell Inc.
Spectronics	1978	Honeywell Inc.
Electronics Arrays	1978	Nippon Electric Co.
Precision Monolithics	1978	Bourns Inc. (96%)
Western Digital	1978	Emerson Electric
Fairchild	1979	Schlumberger
Unitrode	1979	Schlumberger(15%)
Mostek	1979	United Technologies (93%)
Siliconix	1979	Lucas Industries (22%)
Databit	1979	Siemens
Microwave Semiconductors	1979	Siemens
Intersil	1980	General Electric
Solid State Scientific Shindling(25%)	1980	VDO Adof
Semiprocesses	1980	CIT-ALCATEL (25%)
Threshold Technology	1980	Siemens
Maruman IC	1980	Toshiba
American Micro Systems	1981	Gould

In the period 1975-1979 the members of the United States Semiconductor Industry Association increased their capital spending at an annual rate of 7[illegible]%, while for the same group of companies sales increased by 31%. Table 8 shows percentage changes by year.

Table 8

Increase in Capital Spending of US Producers

(percentage)

	1975	1976	1977	1978	1979	1980
Increase in Capital Spending (percentage)	140	63	67	46	59*	51*

Source: Semiconductor Industry Association "Semiconductor Industry Economic Ratios", SIA, 1981, p. 11.

* Includes only 7 producers Rosen Research as reported by the Economist, March 1, 1980.

By 1977 the companies member of the US Semiconductor Industries Association, absorbed almost all of its internally generated funds in plant and equipment. Thus, capital spending relative to internally generated funds was as follows, in percentage from 1975 to 1979.

1975	1976	1977	1978	1979
45%	70%	98%	112%	108%

Source: Semiconductor Industry Association, "Semiconductor Industry Economic Ratios," 1981, op.cit., page 12.

The largest acquisition and takeovers of semiconductor companies by larger groups and corporations take place precisely during and after 1977.

The need for capital is one of the explanations for the still extensive use of off-shore plants, since most of the expense is at the moment concentrated in wafer processing rather than diverted to increased capital intensity of assembly.

There is however an increase in capital expenditure in assembly as can be seen in table 9 following:

Table 9

Distribution of Capital Expenditure by Category

(in percentage)

Category	1975	1979
Design	5.9	4.1
Wafer Processing	29.0	39.0
Assembly	5.7	11.8
Test	9.3	14.9
Other	46.4	13.8
R&D Equipment	3.9	16.6
Total*	100.0	100.0

* (May not add to 100 due to rounding)

Source: Semiconductor Industry Association, "Semiconductor Industry Economic Ratios," op.cit., page 11.

Since 1979 the trend has accelerated essentially due to the decreasing economies of off-shore plants and most importantly because of quality considerations. OEM's and consumer of components in generals are demanding quality standards that oblige producers to take a "hands-off" approach in assembling. This is leading to integrated plants with wafer-manufacturing and assembling in the same site utilizing clean rooms for the entire process. Capital needs will only increase in the future and therefore the structure of companies as well as the characteristics of the economic environment in their home-base will condition their capacity to compete. It is in this point where a big difference exists between Japanese, USA and European companies.

Further details will not be made at this point, but to mention only the equity structure, the cost of capital and profit margins of Japanese companies puts them in a very strong position in electronics and all areas that required long-maturity. In this light European and the US Government are devising public policy mechanisms to help the industry in terms of capital, R and D funds and following a "buy national" policy. (12)

It was stated earlier that the increase cost also covers the R and D area.

Within the broad spectrum of the electric/electronic industry, semiconductors is perhaps the most research intensive activity - at least in the case of the USA. It is not possible to determine the exact situation in Japan and Europe due to the vertical integration of companies and information disclosure rules. It can be assumed that all producers spend similar amounts since no one can over or under spend in this area.

In 1980, 6 major US producers, including the 4 biggest, spent an average 8.5 percent of sales in R and D.(AMD, AMI, Intel, Motorola, National Semiconductors, and Texas Instruments). This compares to an average of 2.35 percent for the entire US industry. By sector the 5 main performers in the US were as follows. (See Table 10).

Table 10

R&D Expenditure in Sectors of the US Industry

	R&D Expenses as Percentage of Sales	R&D Expenses as Percentage of Profit	R&D Dollars per Employee
Semiconductors (6 companies)	8.5	135.5	3266
Computers (20 companies of which at least 11 have captive semiconductor production)	6.4	64.1	3979
Information Processing (peripheral services) (31 companies)	5.9	126.2	3060
Drugs (27 countries)	4.9	51.3	3466
Information Processing (office equipment) (12 companies)	4.3	63.9	2659

Source: "R&D Scoreboard", Business Week, July 6, 1981.

Note: The R&D expenses are dollars spent on company sponsored research fo 30, as reported to the Securities and Exchange Commission orm 10K. Excluding any expenditures for R&D performed under contract to others, such as US government agencies.

As can be seen from this table, all sectors except Drugs are heavily based on electronics components, although the manufacturers of components themselves out-perform the rest in terms of R&D expenses as a percentage of sales and profit. R&D expenses not disclosed under the 10K form can be as large as the company sponsored projects, which alters the meaning of the statistics.

In abosolute terms, however, the semiconductor industry spent much less than the other sectors although its "R&D intensity" is the highest. Thus the 6 producers mentioned earlier spent together in 1980 $556 million in company sponsored R&D, as compared, for instance, to $1,520 million by IBM alone.

In all cases, including Japan, R&D expenditure grows faster than sales. In all main areas of semiconductor production companies receive substantial funds from the public sector, either directly or indirectly. Technological complexity is also contributing to the increase in funds from governments and to companies tie-ups.

In the developed countries one can roughly distinguish between government support and strategy as distinctively different approaches.In most of Europe and Japan there is a strategy which emphasizes the interrelationship between different mechanisms of public policy to achieve results. In the case of the US the mechanisms is essentially of support through defense and space expenditure although significant changes are taking place now. Essentially it consists of the use of defense expenditure to obtain state of the art technology rather than simply products. This is partly due to the strategic importance of the industry and the fact that in many areas the state of the art is dictated by commercial rather than military technology. A reversal of what was the case in the past. (13)

To summarize, we have a change in structure due to capital requirements, manufacturing and technological complexity. The main conclusion from this is that few companies will be able to remain internationally competitive. The name of the actors will not change substantially although the "ranking" will, with Japanese companies going up.

V. Specific Considerations for Latin America

From the point of view of the Latin American countries there are certain aspects that deserve specific considerations. Obviously capability in electronics and bargaining power in terms of size of domestic market are very different from country to country. Brazil and Mexico stand on top, followed by Argentina; the traditional "big three" in terms of industrial capacity. Cuba, as usual, remains an exceptional case with well developed domestic capabilities but with its basic economic and trading links to the COMECON.

The experience of Cuba, however, might be of great importance to the other countries particularly in the development of indegeneous R&D and innovation.

In such an heterogeneous context generalization are hazardous and only possible in certain fields.

There are two elements to explore:

1) The pervasiveness of electronics, applications and the industrialization and policy path to follow in light of current technological change and,
2) The dilemma vis à vis electronic components.

1) Pervasiveness, Applications and Policy

It has been argued that what is changing is the technological profile of the entire productive infrastructure and this in itself obliges us to take stock of current development policies in the region. The widespread use and pervasiveness of microelectronics technology leaves no choice but to assess possibilities of applications, and wherever possible, production in specific areas. Although sooner or later electronics will affect all sectors from the point of view of policy what is of interest is to link applications to the strategic sectors of each economy, rather than to aim for a broad front. Applications in industry, agriculture and services should be selective and aim at maximizing efficiency in those areas which constitute the engine of the economy. The argument put forward in this paper shows that there is a narrowing of the industrialization path and this implies that a long term view is necessary.

The applications of electronics could in many circumstances have important social effects, especially in terms of employment and polarization of skills. This is especially the case when change in products and automation of processes takes place. An additional question is "brain-drain" of highly qualified personnel due to scarcity in the developed countries.

In the service sector a rather different situation occurs, since, with the exception of data processing, most other normal clerical activities remain fairly competitive with current hardware in most of the Continent. Where equipment is introduced it tends to lead to jobless growth rather than retrenchment.

The above needs to be put into the context that from an employment point of view mechanization of agriculture tends to have a far deeper effect than electronically-based technology. This is an important policy consideration.

On the other hand, the social impact of systematically losing comparative advantage in industry, some agricultural products and raw materials could have even greater effects than the selective introduction of technology. One may remember the effects on the Chilean economy of the development of artificial nitrate and the fate of Manaos and its region, at one time the rubber capital of the world. Therefore, what a narrower industrialization path implies is a policy of selectivity and specialization within a long-term view. As a consequence, it also involves specific targeting of sectors, R&D and science policy.

2) The dilemma about electronic components.

Current policy in the region, particularly those of Brazil and lately Mexico, has emphasized construction of systems and equipment. National integration and diversified technological agreements have been the main tools. In addition, especially in the case Brazil, market segments have been reserved for nationally assembled equipment. Emphasis has also been given to peripherals, modems and other auxiliary equipment. Brazil has authorized a number of producers with different foreign technologies. (See Table 11).

Table 11

Authorized Brazilian Manufacturers

Company	Model	Technology
COBRA - Computadores e Sistemas Brasilieiros S.A.	COBRA-300	COBRA
	COBRA-400	SYCOR (US)
	COBRA-530	COBRA
EDISA-Eletronica Digital SA	ED-300	FUJITSU (Japan)
LABO Eletronica S.A.	LABO 8034	NIXDORF (W. Germany)
SID-Sistemas de Informaçao Distribuida S.A.	SID-5000	LOGABAX (France)
SISCO-Sistemas e Computadores S.A.	SCC-5000	SISCO
	MB-800	SISCO

Table 12

Major Brazilian DP Suppliers

1980 Ranking By Revenue	Company	Estimate DP Revenues (in $millions) 1979	1980	Capital Registered In Brazil (in $millions)
1	IBM	350	330	130
2	Cobra*	70	104	9
3	Burroughs	100**	100**	2**
4	Sid*	19	30	5
5	Labo*	5	22	2
6	Edisa*	7	13	3
7	Sisco*	.6	10	3
8	Globus*	.8	10	.8
9	Elebra Informatica*	.5	9	2
10	Scopus*	5	9	.8
11	Honeywell-Bull	7	8	3**
12	Polymax*	.4	7	.4
13	Microlab*	2	6	1
14	Coencisa*	5	5	2
15	Prologica*	2	5	.05

* Data on these companies furnished by DIGIBRAS, a federal-owned company that provides technical and financial support to national hardware manufacturers.

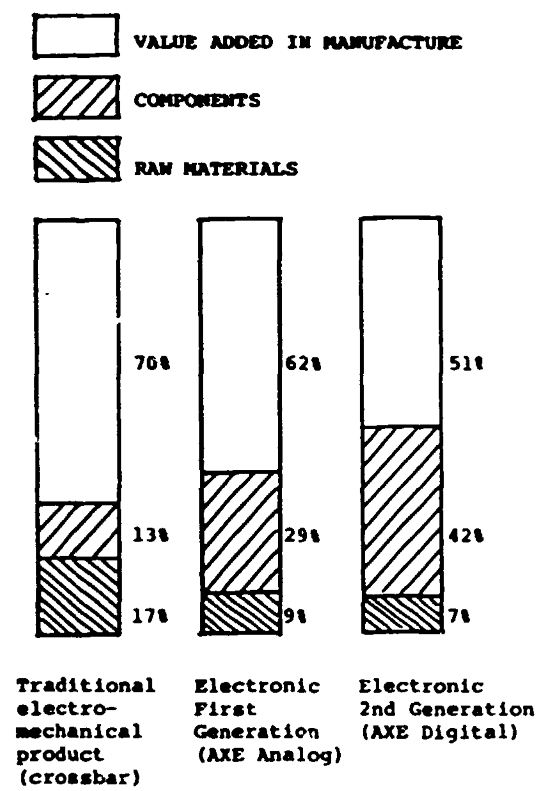
** Company-furnished data.

Source: Datamation, May 1981.

Table 12 shows that although foreign manufacturers in Brazil remain the largest, COBRA has been able to reach a second place in terms of DP revenues. This is partly explained by the policy of reserving market segments as well as the fact that the owners of COBRA are also large consumers of DP equipment. Another very important component of current strategy is the development of local software and service capability. The analysis of this area is a the adequate entry door to see the two basic dilemmas about components, namely, a) what happens to systems and software with growing integration and b) is it possible to develop manufacturing or application policies without an overall informatic policy?

As the level of integration of components increases they begin to invade the area of systems and becomes possible to incorporate more software into the hardware in the form of firmware. This implies that in the long run a group of chips or a "black box" perform the function of a system. Yesterday a computer was a collection of components, today it is obtainable in a chip but needs to be programmed and interfaced with the environment. Similarly, a work processor today consists of several boards, dozens of memories, several microprocessors and interface chips. In the futur through miniaturization more functions will be incorporated and the producer of system will provide the box, some cables and a VDU most likely to be flat screen of the plasma of LCD type. In essence the components will take most of the value added. Customized components and current developments in Uncommited Logic Arrays (ULA's) are accelerating this trend. This is illustrated below in the case of telephone switching systems. (See Figure II).

Figure II. Changes in the Structure of Manufacturing Cost: Telephone Switching Equipment



Source: Lamborghini, B., "The Impact on the Enterprise", in Microelectronics and Society, Pergamon Press, Oxford, 1982, p. 132.

The strategic alternative of buying components and assembling them into systems (e.g., minicomputers or control mechanisms) is then less clear than it use to be. On the other hand, it is not possible to jump into the manufacturing of semiconductors since entry barriers are extremely high, with the exception of discrete components and small scale integrated circuits.

In this light there are two questions that need to be raised. Firstly, since the trend is towards further integration in components the criteria for national integration must contain a technological parameter. In other words if national integration implies value/volume/weight only this is largely meaningless for electronics, since the real value is in the component. In fact in one Latin American case and using this criteria, the national integration for one system was large and basically consists in casing, cables, plugs and very little electronics.

As the technology becomes more "intangible" and "embodied" the relevance of the traditional criterions of national integration will diminish, unless some technological parameters are incorporated. This could mean designing and/or software services and not necessarily manufacturing of components.

The second question is one related to the structure of the industry in the Continent which in most cases is highly dispersed and fragmented. Any strategy will require, out of necessity, the streamlining of the industrial structure, searching for economies of scale, capacity to finance R&D and specialization. The government of Japan (MITI) and France have partly forced a change in structure in the early 70's through mergers and take-overs while at the same time maintaining a level of competition among domestic producers.

All of this is only valid in the context of a search for a certain level of technological capacity along the lines of that of the advanced countries and the real question is how to change from a state of total dependence to "control" dependence and later interdependence. There is no question of "independence" in electronics, not even for the most advanced countries. Components as such are only touched upon, but it should be recognized that complex equipment is necessary for manufacturing starting with pure silicon to ceramic packages, not to mention design and R&D.

These reflections are not valid if a country or region develops an industry behind protective barriers with a different criteria of technical obsolescence. This alternative is possible with very large domestic markets (i.e., India) and also considerable technological and industrial capacity. The argument exists that for developing countries type of applications medium scale integration will suffice and thus independence should be reached at this level. This argument might be valid for a country like India with a potentially market larger than the entire Latin American continent.

Specific strategies will evolve from each country domestic situation and here we are only revising general criterias. The entry door was software and services and I have argued that components are incorporating more value-added. The alternative is then to move to software creation, maintenance and service.

It was argued before that one of the characteristics of current change is tranportability of services including software in all its stages. Here is where the question of subordinating application and manufacturing policies to general informatic policies arise.

As telecommunications costs decrease import of software and services including maintenance, time-sharing services, etc., become economically possible through the lines and thus all advantages obtained in applications might be lost because of the incapacity of the local information industry to compete with international software and service houses. This might happen even if the software needs are cultural-specific.

In addition, in the product-cycle of software 20-40% of the revenue is generated by the creations of it while the rest is generated by service and maintenance (this is not applicable to package software). In other words software developments should aim at forward integration (i.e., service and maintenance) as well as backward integration (i.e., boards and custom-circuits).

Therefore, the "informatic industry" by being composed of hardware, software and services (e.g., data bases) requires an integrated strategy that will make all elements interact.

Informatic services have specific economies of scale, skill requirements, marketing and managerial needs. The advantage is that entry barriers still low in many areas and services are exportable providing the marketing structure is adequate. Joint ventures are in this area most suitable, rather than simply sub-contracting arrangements.

The arguments put forward above show that the "make" or "buy" alternative is not easy and is closely interrelated to all aspects of informatic policies.

Taking the European companies experience what is important is to control access to technology and be part of the technological process of change. Licensing agreements give access to a given technology rather than to the change. Access to the change is possible through development of domestic capabilities as well as control of equity in the advanced countries. In principle, there is no reason why the large Latin American companies could not buy equity in small innovative US or European companies in order to obtain technology within a planned strategy.

Coming full circle the question of selectivity arises again which implies specialization related to strategic sectors of the country's economy. In addition the possibilities of consumer electronics, specialized niches in instruments and other equipment are open providing some form of regional cooperation is established. This could be done at different levels such as joint design, R&D, division of labour on manufacturing and so on. The companies will be better equiped to deal with this forms of collaboration rather than creating complicated bureaucracies.

The thrust of what has been said above relates to product technology, it is important to recognize that there are a number of areas where process technology is as crucial if not more important. The example of Japan come immediately to mind since in the area of electronics it licensed product technology while concentrating heavily on improving processes. Their edge on quality and price of electronics goods including components is basically explained by their efforts on manufacturing processes.

The key to competitiveness in areas of relatively "stable" technology such as printers, modems, disk-drives and so forth, are given by process. The identification of this sector according to national capabilities is essential and an area where public policy could be helpful through a number of measures including rapid amortization of equipment, tax incentives for exports and incentives to R&D. In different areas the situation can be summarized as follows:

Components

- o Increasingly high entry barrier (few competitors will be left in the state of the art);
- o Complex policy combinations to have access to technology;
- o Lower entry barrier in discrete components and SSI;

- Semi-open and/or closed market options, depending on segments;
- Trend to vertical integration;
- Growing amount of value added to components;
- Crucial industrial parameters:
  - Access to capital
  - Technology base
- Crucial manufacturing parameters:
  - Yield/volume/quality.

Software and Services

- Relatively low entry barrier;
- Labour rather than capital intensive;
- Need for forward and backward integration due to revenue generation needs;
- Closely linked to informatic policy, particularly telecommunications;
- Development of services for exports;
- Semi-open and/or closed market options depending on segments;
- Crucial industrial parameters:
  - Human resources
  - Technology based
- Crucial manufacturing parameters:
  - Quality
  - Services

Products

- Possibilities in consumer electronics and specialized niches;
- Emphasis on constant improvements in process technology;
- Growing entry barriers;
- Crucial industrial parameters;
  - Process technology
- Crucial manufacturing parameters:
  - Volume/quality (mass markets)
  - Quality/service (specialized niches)
  - Customization/service (specialized niches).

Concluding Remarks

The importance of electronics lies not only on the size of the sector and its potential but its convergence characteristics. It is difficult to identify a sector where electronics-based technology cannot be applied. The areas of application reviewed leaves little doubt that transformation of profound consequences are under way in a score of sectors. From the developing countries point of view and most particularly Latin America the options are increasingly complex. On the one hand, the technology produces social impacts that need to be minimized and on the other the very dynamism of technological change implies that traditional comparative advantages are being eroded, and thus the need to upgrade the technological profile of strategic industries. This is easier said than done, as the case of Latin American agriculture shows. From a socio-economic point of view the main areas of impact are on employment, although they do not seem serious at this stage due to speed of diffusion of technology and the effects of other technologies in more socially important areas such as agriculture.

Addtitional social effects are to be found in changes in skill mix in industry and services.

However, of greater importance at this stage when Latin America is moving towards production and exports of manufactured and semi-manufactured goods is the impact on the external sector and its possible performance.

There are different gauges that can be used to assess socio-economic impact. For example, the performance of the external sector due to the characteristics of Latin American economic development that has emphasized diversification of exports and especially of semi-manufactured and manufactured goods.

Without plunging into the decades-old debate about import substitution or open-economy, it appears clear that as comparative advantages are shifting and the so-called "modern sector" is obliged to adjust the uneveness of industrial development and inter-industry links would certainly increase. The consequence is first felt in the labour-market and further polarization in income distribution.

In many areas crucial bottlenecks could be overcome such as in precision engineering, electronics, computer services, wood sector, leather and so forth, especially when modernization of processes are involved.

Two conditions seem to be essential to exploit technology for development aims. Neither are original proposals. The first is regional cooperation in terms of assessment, projection and policy design in sectors of strategic importance to the region/countries. Selection of technologies and specialization seems crucial to developments in the 80's. At a regional level instruments should exist to monitor technological trends in areas crucial to the region's economy. Needless to say, that this is valid in raw materials and agriculture as it is for industry. The difference lies in the fact that in the export of raw materials or primary products countries are in general de-facto operating as "open-economies" that is confronting international competition. This monitoring effort should be part of a concerted effort to increase South-South links and especially transfer of technology. The second condition is the compelling need to up-grade the policy and decision making machinery, especially in relation to industrial policy as explained in the first part of this paper.

Running the risk of oversimplification, it appears, from a political point of view, that the region is divided into two distinct sets of groups, with some notable exceptions. One that above all, emphasizes the distributions of wealth and implicitly or explicitly assumes that the creation of it will take care of itself. The other assumes that the creation and distribution of wealth will take care of themselves if government intervention is minimized and the economy is wide-open to international competition. It should be stressed that both groups seem to be in a process of reviewing assumptions.

Both views fail to recognize that in all countries where advanced industries has been developed whether in the North or the South, an explicit or implicit policy has been followed and the state has played a crucial role in understanding the process of wealth creation. In some countries in the region these faults are clearly at work. When public policy does not exist, which is equivalent to have a policy, the industry in general and electronics in particular has decreased in importance and its technological developments are either stagnant or non-existent. When policy exists it tends to be piecemeal, , dispersed with lack of consistency and short term.

It seems that the opposite are the ingredients for success. Current changes occur at a pace that makes the consideration of them urgent and if the countries of the region are not capable of mastering the complexity of policy required, the socio-economic impact will be great, the benefits minimal and once again the continent will be in a cycle of "eternal convalescense".

Notes and references

(1) - Congress of the United States,Office of Technology Assessment(OTA),"Impacts of Applied Genetics:Microrganism,plants and animals",Appendix 1-B.,1981.

(2) - This point is treated in detail in a report to the ILO, still in preparation,Rada,J. "The information economy and the International Division of Labour".

(3) - "The Social Impact of Microelectronics",Report of the Rathenau Advisory Group,Goverment Publishing Office,The Hague,1980

(4) - Federal Trade Commission,"The Semiconductor Industry",Washington D.C. 1977 p.11 and Semiconductor Industry Association, "Semiconductor Industry Economic Ratios",California,1981.

(5) - Creative Strategies International,1981

(6) - Electronics International,"World Markets Survey",January,13 1982.

(7) - Bank of Asia,"The Semiconductor Industry in Japan",Hong-Kong, 198o.

(8) - Based on data from Mackintosh Consultants,"Profile of the European Semiconductor Industry",Luton 1981

(9) - Based on data from Dataquest,California,1981

(10) - Stern,J.,"International Structural Differences in Financing", in Semiconductor Industry Association,"An American Response to the Foreign Industrial Challenge in High Technology Industries",California,1980,p.132

(11) - Creative Strategies International,1981

(12) - In this point see Rada,J.,"Europe:Competing in advanced technologies",in Outlook N.5 (A quarterly journal of Booz,Allen and Hamilton),1982

(13) - See in this point several U.S. Congress reports,the latest is Joint Economic Committee,"International competition in advanced industrial sectors:trade and development in the semiconductor industry",Washington,1982.