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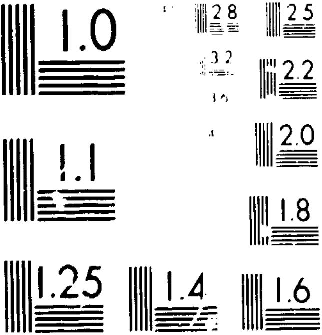
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RESTRUCTURING WORLD INDUSTRY IN A PERIOD OF CRISIS - THE ROLE OF INNOVATION

An Analysis of Recent Developments in the Semiconductor Industry*

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Prepared by the
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FOREWORD

This study was undertaken in the framework of the research programme of UNIDO on industrial redeployment and structural change. Through the programme it is attempted to carry out a continuous surveillance of the international process of industrial restructuring. By identifying major determining factors and indicating the likely direction and possible implications of this process, uncertainties and rigidities of international restructuring may be reduced and a basis created for a forward looking concept of industrial co-operation between developed and developing countries.

In this study the role of innovation in the changing industrial structure is treated, through an analysis of a particular type of innovation, i.e., the manufacturing and application of micro-electronic circuits.

The study was carried out by Mr. Dieter Ernst, Projekt Technologietransfer, University of Hamburg, as UNIDO Consultant.

AN OUTLINE OF THE STUDY

The Issue

Amidst a serious economic crisis, world industry today is undergoing important structural changes. One of them relates to the application of major innovations to industrial products and processes which has already initiated a process of turning upside down established modes of industrial production. In addition, a new breed of "industrializing industries" is emerging together with new patterns of a social and international division of labour in industry which will have considerable implications on how science and technology and economic and social development will be related in the future.

What are we to expect? Will the application of new technology help to contain the crisis of the world economy, and thus allow major actors to switch to more accomodating positions with regard to international competition and co-operation? Will it further broaden the base for an integrated and increasingly self-reliant transformation of Third World societies and thus improve their scope for choice of international specialization patterns and their bargaining power in the newly emerging global economic and geopolitical conflicts? Or will it rather lead to an increased hierarchization of international economic, political and military relations, especially with regard to the North-South context, with all the resulting consequences for growing misery and the proliferation of global and regional conflict scenarios?

Purpose of the Study

Obviously, the present study cannot give ready answers to these questions. What it will try to do however, is to set out a framework for analyzing the interaction between the introduction of new technologies and the restructuring of world industry, particularly with regard to emerging new international location patterns.

Its main purpose is to contribute to recent attempts to redefine and operationalize the concept of "industrial restructuring" in order to make it a more viable guideline for international negotiations. To achieve this goal, it would not be enough to be responsive to the structural issues which are clearly visible today. Future structural changes must be anticipated. The vulnerabilities of the world economy and particularly of non-oil exporting developing countries generated by such structural changes must be taken into account right now, in order to formulate a strategy for the future.

Research for this study has been guided by one overriding concern which is reflected in the following three basic questions:

- How will innovation in a period of crisis affect global patterns of control over international trade and strategic assets needed for developing and producing industrial products and services, particularly technology and capital?
- What impact are we to expect on the capacity of major actors in the restructuring of world industry to push through their strategies?
- And, finally what are the implications for developing countries trying to implement strategies of transition to more self-reliant patterns of industrialization?

Focus on Microelectronic Innovations and their Impact on Semiconductor Manufacturing

The study focusses on one particular type of innovation, i.e. recent breakthroughs in designing and manufacturing microelectronic circuits and in applying them to industrial products and processes. In particular, it analyses how recent developments in microelectronic technology, both hardware and software, have already changed considerably the economics of semiconductor manufacturing and how this is going to be reflected in corporate structure and strategies and in changing patterns of industrial restructuring, both sector-wise and geographically. The key question is: what have been the driving forces behind recent changes of international location patterns in semiconductor manufacturing and in particular, what lessors can be drawn from this sector concerning the interaction between innovation and industrial restructuring in a period of crisis?

The Basic Message of the Study

Based on a vast body of empirical material, this study tries to convey four basic arguments:

- First, amidst a severe crisis of the world economy, innovation and industrial restructuring are interacting in a rather different manner than during a period of high growth of industrial production and trade, as experienced until the early 1970s. This is reflected in particular in the choice of priority areas for the development of microelectronic technologies, ranging from circuit design to applications software, and in the speed of introducing these technologies into industrial products and services and to the process of production.

- Second, the study underlines that, in a period of crisis, the actors involved in innovation and industrial restructuring are confronted with rather different constraints than in the period of high growth and that this is bound to be reflected in their scope for compromise and in the intensity of the conflicts prevailing between them.

- Third, it is shown that innovation has been an important but by no means exclusive factor behind the new patterns of industrial restructuring and international location which have been recently emerging in the semiconductor industry. It matters of course, that new technologies are available for automating the whole cycle of semiconductor manufacturing ranging from design to final testing. But this is only part of the story. What this study basically is trying to show is that the use of new microelectronic technologies and the distribution of control over the relevant innovative capacities conditions, but does not determine by itself the restructuring of world industry.

In the final analysis, industrial restructuring is determined by the economic, social and political power structures within which the social actors who are engaged in industrial production, trade, and in the exchange of production factors, have to operate.

- Fourth, and finally, the evidence presented shows that most of the prevailing expectations of how restructuring of industries in the industrialized countries and redeployment of industries to the Third World would interrelate, will have to be considerably revised. Furthermore, established modes of analyzing trends in international transfer of technology are of only limited relevance today and a fresh approach is needed to the conceptualization of how control over technology and industrial redeployment are interrelated. In short, without a theory of the international economic crisis, it will be impossible to link together technology, demand and structural change in world industry.

The Contents of the Study

The study consists of seven chapters. Chapter One, entitled "Innovation and Industrial Restructuring - What can be Learned from Historical Experience?" sets the stage for the more empirical and policy-oriented chapters. It reviews the historical experience of innovation and restructuring in the OECD area and develops, albeit in a still tentative manner, a theoretical framework for analysing the interaction of innovation and industrial restructuring.

What this chapter basically tries to do is to relate the concept of industrial restructuring to a much broader context, i.e., the interactions between the crisis of the world economy and patterns of growth and innovation. It shows that, in a period of crisis, innovation and industrial restructuring are bound to interact in a different manner than in a period of high growth of industrial production and trade. In particular, this chapter analyzes some major structural changes underlying the present crisis which have caused a transition from a virtuous to a vicious circle of industrial growth and productivity.

Chapter Two, entitled "The Crisis of Semiconductor Manufacturing - from the Chip Shortage of 1979 to Demand Stagnation and Profit Squeeze" documents that, in contrast to the fashionable myth of a crisis-resistant industry, the electronics industry, and particularly semiconductor manufacturing have turned out to be highly vulnerable to cyclical ups and downs and even more so to the underlying structural crisis. It identifies some key factors underlying the semiconductor crisis cycle and analyzes in particular the transition from the chip shortage of 1979 to the demand stagnation and profit squeeze starting from mid-1980. In addition, this chapter shows how major actors in the semiconductor business are reacting towards the crisis and that the starting positions for the next round of a global semiconductor war are undergoing rapid change.

Chapter Three, entitled "Innovation and the Changing Economics of Semiconductor Manufacturing", presents an in-depth analysis of some basic interrelations between innovation and the changing economics of semiconductor manufacturing. Its main purpose is to identify the impact which new technological developments, both in electronics hardware and software, are going to have on market structures and on patterns of control over strategic assets of this industry. Recent trends in circuit design and production technology are discussed in detail and the convergence between circuit and system design due to the increasing importance of application requirements.

The chapter then documents that as a result of these technological developments, the economics of designing and manufacturing semiconductors have been subordinated to a radical change. This industry which used to be characterized by a relatively high labour intensity, today experiences sky-rocketing capital outlays and a dramatic upsurge in capital intensity. In addition, there has been a tremendous pressure to increase technical and industrial synergism and thus to go ahead with acquisition moves and vertical integration. In particular, three types of changes in the economics of semiconductor manufacturing are extensively analyzed: changes in the overall cost structure; the radically changing skill requirements; and the dramatic increase in the costs of market entrance. Finally, this chapter identifies some major causes underlying the increasing cost burden of semiconductor manufacturing.

Chapter Four, entitled "The Software Sector - Conditioning Factors and Possible Future Trends", analyzes some recent trends in the software sector and evaluates the perspectives for strategies to reduce the software bottleneck. This is in fact an issue of crucial importance for understanding the scope and constraints for applying microelectronics-related innovations to industrial products and processes.

The chapter sets out to define the concept of software and the functions software is supposed to fulfil. It then reviews the origin and driving forces behind the emergence of a separate software sector and recent structural changes in the software market. The main thrust of this chapter is to identify more clearly some major causes underlying the software bottleneck and the strategies of major actors involved. Finally, an attempt is made to evaluate the effectiveness of strategies to reorganize the production of software and to identify the impact of forthcoming structural changes in this sector on corporate structure and strategy.

Chapter Five, entitled "The Interaction between Recent Technological Breakthrough and Industrial Restructuring", is concerned with some new patterns of competition and control emerging in the semiconductor industry and their interaction with the application of recent breakthroughs in electronic technology. The combined effect of demand stagnation and profit squeeze and the semiconductor industry's high vulnerability to an economic recession has made this industry in fact less attractive as an investment opportunity. Consequently, the semiconductor business is increasingly running into problems of capital formation and investment.

It is in this context that this chapter discusses some recent approaches to a re-adaptation of corporate structure and strategy and the search for new patterns of a division of labour between firms involved in semiconductor manufacturing. The dialectics of forward and backward integration are analyzed in detail and the trend towards a new semiconductor industry of corporate giants. In addition, this chapter analyzes some recent structural changes in the semiconductor equipment and and the information processing sectors and shows that consequently the prevailing modes of integrating the semiconductor industry into the overall electronics sector are considerably changing.

Finally, this chapter documents the complexity of this process of transition to new patterns of hierarchical control and shows that, by and large, huge and highly diversified firms are best placed to reap the major benefits of this type of industrial restructuring.

The subject of Chapter Six, entitled, "Implications for the International Restructuring of Semiconductor Manufacturing and for Global Patterns of Technological Dominance and Dependence", is the interaction between innovation, comparative advantage and changes in international location patterns. In particular, this chapter identifies some major trends in the international restructuring of semiconductor manufacturing and presents an in-depth empirical assessment of recent developments in offshore chip assembly, especially in South-East Asia.

The main message of this chapter can be summarized as follows:

- First, the issue of immediate concern is not so much the possibility of outright relocation of industrial activities from the South, particularly some South-East Asian "export platform " countries, back to the OECD region. Manufacturing of semiconductors in the Third World will continue to expand - at least for certain product families, for those specific stages of production which are not essential for exercising systems control and restricted to a fairly small number of "exclusive" production sites.

However, offshore chip assembly is already undergoing major structural changes, with the result that positive effects to be reaped by developing countries on employment generation, forward and backward inter-industrial integration, skill formation and technological spin-offs might become even smaller and less viable than today. It is to these changes and their impact on industrialization scenarios in the Third World that future analysis should be mainly geared.

- Second, the new economics of semiconductor manufacturing are already having a considerable impact on international location patterns. However, our understanding of what is really happening is handicapped by a serious lack of empirical evidence which would allow us to differentiate the analysis of changes in international location patterns according to products and stages of production involved.

Moreover, the mono-causalistic approaches of prevailing theories of "international restructuring of industry" are unable to capture the complex interaction of factors conditioning the new strategies of international location in semiconductor manufacturing and thus could lead to a serious misreading of reality.

- Third, attempts to project the most likely future scenarios for the international restructuring of the semiconductor industry are based on very unsafe grounds. This would apply in particular to the role which production sites in the Third World are going to play. What is possible, however, is to identify some of the options facing the major actors of international restructuring in this sector, particularly private firms based in the OECD region, and to confront them with those bits and pieces of mostly conflicting evidence which is available today.

- Fourth, as long as developing countries would continue to rely predominantly on the willingness and capacity of private firms originating from the OECD region to redeploy production facilities and technology, they could hardly expect to increase the viability of their existing segmented world market - oriented chip assembly lines. Within such a scenario of passive and unselective world market integration, the vulnerability of these production lines to the economic crisis and to the impact of radical technological breakthroughs will remain excessive and there will be not much chance to proceed to an increasingly integrated electronics industry which could be subordinated to the specific requirements of these countries.

- Fifth, any projection on possible future trends in international location patterns of industry could hardly claim to be realistic, if it would not be related to a much broader context, i.e., the overall perspectives for future interactions of innovation, international transfer of technology and international restructuring in a period of crisis. In the final analysis, it is the overall trend towards increased concentration of control over strategic assets and the concomitant emergence of new patterns of global and regional oligopolistic competition which should be in the centre of future discussions. Intra-OECD rivalry, particularly among US firms and between them and the Japanese firms is the main driving force and gives rise to ever new rounds of a global technological race.

Finally, Chapter Seven, entitled "Innovation and International Restructuring of Industry in a Period of Crisis - Some Tentative Conclusions Drawn from the Experience of Semiconductor Manufacturing" has a two-fold purpose:

- First, to identify the driving forces behind recent changes of international location patterns in semiconductor manufacturing, particularly the role of technology, and to assess to what degree prevailing theories of international industrial restructuring are capable of answering this question and thus could be used as guidelines for policy prescriptions.

- Second, based on the experience of the semiconductor industry, to present some theoretical conclusions on how innovation and industrial restructuring are going to interact in a period of crisis.

Based on a critical assessment of some of the more refined attempts to analyze how innovation, restructuring and redeployment of industries to the Third World interrelate, this chapter demonstrates that we still lack an adequate theoretical approach to these problems. It is shown in particular that this critique would apply also to three otherwise very useful attempts to demystify conventional wisdom on international economic relations: the neo-technological theories of international trade, those theories of the internationalization of capital which tend to restrict their analysis to a specific branch; and the "New International Division of Labour" school.

In order to understand the impact of innovation on industrial restructuring and on international location patterns, we need to know more about the conditioning factors of innovation and technological development and their interactions with the economic crisis. The study argues that two factors are of primary importance: the modes of capital accumulation prevailing in a specific historical and geographic context and the related changes in the social relations of production, particularly in the work relations. The study demonstrates that the interrelations between capital accumulation, work relations and technical change have been experiencing considerable changes. The once predominant focus on work and labour rationalization still continues to play an important role - but to view it as the all decisive factor of capital accumulation would be misleading indeed. In fact, the rationalization of constant capital, particularly of energy and raw materials used, machine utilization and product flow speeds, together with attempts to decrease the systems vulnerability of capital accumulation have gained considerably in importance

It is in this context that the introduction of new technology, particularly of new information technologies based on microelectronics circuits, can be expected to play a prominant role in the restructuring of world industry.

CHAPTER 1.

INNOVATION AND INDUSTRIAL RESTRUCTURING - WHAT CAN BE LEARNT FROM HISTORICAL EXPERIENCE?

1. Innovation and Industrial Restructuring - What Can Be Learnt from Historical Experience?

Industrial restructuring does not occur in a vacuum. If we want to understand its logic and its major constraints, we have to relate it to a much broader context, i.e. the interactions between the crisis of the world economy and patterns of growth and innovation.

The interactions are fairly complex and do not remain constant over time. We have shown elsewhere 1/ to what degree patterns of innovation and the economic crisis have been closely interrelated in major OECD countries and how this has been reflected in major industrial sectors. In other words, in a period of crisis, innovation and industrial restructuring are bound to interact in a different manner than in a period of high growth of industrial production and trade.

1.1. Innovation and Industrial Restructuring in a Period of High Growth - the Concept of a "Cumulative Virtuous Circle"

1.1.1. Some Basic Facts

For major OECD countries, explosive industrial growth rates were one of the basic characteristics of the post-war period - at least till roughly the first half of the 1970s. Whereas during the fifty years from 1900 to 1950, industrial production in these countries grew at an annual rate of 2.8%, it reached 6.1% during the period of 1950-75. [2/]

Obviously, this period of industrial dynamism gave rise to a wide range of structural changes both within industry and in other related sectors, particularly in agriculture and services. For instance, it modified considerably the prevailing modes of agricultural production by pumping in agricultural implements and chemicals and pulling out labour and a considerable amount of the agricultural surplus. It also caused significant changes in established patterns of service activities by increasingly subordinating them to the requirements of producing, financing and commercializing industrial goods. In addition, prevailing patterns of transport and communications infrastructure were considerably modified. Further, industrial growth and restructuring meant that the role of public sector activities and the prevailing modes of government intervention had to undergo significant changes.

Innovation did play a crucial role in this process of industrial growth and restructuring. In fact, the rise of the two most important post-war growth industrie, i.e. bulk chemicals and the car industry, would have been inconceivable without a broad range of innovations concerning both product and process technologies and complementary changes in industrial organization techniques.

Let us take the case of bulk chemicals. It was due to the existence of basic innovations in chemical engineering, particularly in oil refining (fluid catalytic-cracking process) [3/] and in the development of synthetic materials to be substituted for natural resources (fibres, plastics and fertilizers) most of which date back to the early inter-war period, [4/] that after the war the leading chemical firms could set out and implement their radical strategies of converting this industry from one based on coal to one relying predominantly on petrochemical feedstocks.

In addition, product innovations were promoted in such a way that fibres and plastics became applied to an ever increasing number of industrial products. If we add to that the penetration of fertilizers into growing segments of the world agriculture, it is obvious that today practically all economic activities depend heavily on these products.

A third group of innovations which has been essential for the post-war industrial growth has been the application of highly centralized modes of industrial automation and control and the consequent proliferation of continuous-flow process techniques from resource-oriented basic industries like the steel industry into a growing number of mechanical engineering industries geared to the production of durable consumer goods, particularly electric household appliances and cars.

Overall, one of the most important effects of the post-war industrial boom in some major OECD countries was, what Fajnzylber called "... a generalized dissemination of the techniques, criteria and organizations typical of industry, within the economy as a whole." [5/]

In other words, when we talk about industrial restructuring, we should not restrict ourselves to sectorial and geographic changes taking place <u>within</u> industry, but should put them into the context of much more wide-ranging economic, social and political changes. For instance, if we would stick to conventional but outdated statistical classifications which strictly separate industrial production from industrial services, we would hardly be able to understand the logic inherent to one of the most pertinent features of post-war industrial growth and restructuring, i.e. the upsurge of service activities subordinated to the needs of financing, producing and commercializing industrial products. As long as one argues within such a limited concept of industrial restructuring, the proliferation of new services might easily be interpreted to mean that a process of transition to a "post-industrial or service society" is underway - which in my opinion is a very serious misreading of reality. 6/

But before trying to identify the scope for industrial restructuring during this period and its economic, social and political implications, let us first inquire into some of the conditioning factors underlying this period of industrial dynamism. It is in this context that the concept of a "cumulative virtuous circle" has been developed.

1.1.2. The Concept of a "Cumulative Virtuous Circle" of Industrial Growth and Restructuring - the Basic Message 7/

This concept tries to link together growth, innovation, productivity and international competitiveness. It starts from the assumption that the higher the growth rate of an economy, the faster the incorporation of innovations into industrial equipment, processes and products. This in turn would transform the overall structure of industry, enabling it to take advantage of the scale economies generated by the growth of overall demand, and increasing the capital-labour ratio. This type of industrial restructuring would take place both at the level of corporate structure and strategy and with regard to the overall division of labour between industries (the "industrial organization").

Increased productivity, on the other hand, would allow an increase in the market through a rise in remuneration; it would increase the resources available for r+d; it would facilitate the funding of the required expansion in public infrastructure services without affecting the financial capacity of enterprises for sustaining the expansion. Thus a "cumulative virtuous circle" would emerge which links and provides feedbacks between growth and productivity.

(a) The role of the capital goods sector

It is important to note however that there is a basic prerequisite for realizing this virtuous circle: the existence of an integrated capital good sector. Being "... an embodiment of technological progress...", the capital good sector "... exerts a strong influence on changes taking place in labour and investment, productivity, and, as a result, in the international competitiveness of national economies." [8/] This is why the capital good sector "... can be considered as a basic element for the analysis of special properties of different national industrial systems. The magnitude of its presence and behaviour, moreover, marks one of the fundamental differences between the advanced industrial economies and the semi-industrialized economies, especially those of Latin America." [9/] It is this strategic role of an integrated capital good sector which has been stated quite explicitely in the original versions of this concept but which, as we shall see, tendsto be neglected in more recent discussions.

(b) International competitiveness

A third element of this concept relates to international competitiveness. Let us assume that a country has been able to get moving a cumulative virtuous circle between growth, innovation and productivity. It is claimed that this would enable our country to enlargen the scope for integrating its economy into the world market and for participation in the expansion of international trade and transborder flows of investment and technology.

This would be so basically for two reasons:

- First, with a highly dynamic internal demand, the pressure to raise barriers for importations of foreign productions will decrease. In other words, for a country with rapidly growing internal markets, the scope for propagating "free trade" will increase as will the scope for subordinating this type of world market integration to the country's growth requirements.

- Second, the greater the growth of productivity and innovations, the greater are the possibilities for competing on the international market, with the additional incentive of reaping scale economies which in turn intensify growth, productivity and technological change. [10]

To conclude, the concept of a "cumulative virtuous circle" claims to have identified the economic mechanisms which would allow to link together growth, technological change and the internationalisation of trade and production. It underlines, albeit in a somewhat vague manner, the strategic role of capital goods production and shows that without a dynamic internal market, expanding world market integration could become a mixed blessing for most countries indeed.

(c) Lessons for today

What lessons can be drawn today from this concept of a "cumulative virtuous circle", particularly with regard to understanding the interrelations between the economic crisis, innovation and international restructuring in industry?

Originally, this concept was developed in an attempt to define a framework for analysing some of the basic factors conditioning post-war industrial growth and restructuring in some OECD countries, particularly in the U.S. and Western Europe.[11]

Today, there is a growing tendency, both in OECD and Third World countries, to use this concept as kind of a normative guideline for policies to break through stagflation and industrial decline.[12] Amidst a deteriorating economic crisis, expectations are in fact running high that strategies to reestablish such a "cumulative virtuous circle" for industrial growth could show a way out and the key variables are said to be innovation, productivity and international competitiveness.

Yet, in order to evaluate the chances of success for such an approach today, we need to be explicit on what have been the specific historical and structural conditions characterizing the post-war industrial development of OECD countries roughly till the end of the 1960s.

First of all, this was a period of very high growth linked with rapidly expanding international trade flows - and this is very much in contrast to what exists today. In fact, during 1950-75, growth of international trade in industrial products even exceeded the already very high growth rates of industrial production - 8.8% versus 6.1%,[13] whereas today both of them have very much declined.

Table1.1 documents recent structural changes in world industrial production. For Western industrialized countries the decline of industrial dynamism has been dramatic indeed - from an average annual growth rate of 6.4% during 1960-69, industrial growth was practically reduced to half.

Tab.1.1 Manufacturing Industries - Growth of Output in Volume Terms
(Compound average annual growth rates, in %)

	1960-1969	1969-1978
(1) OECD countries	6,4	3,2
(2) Developing countries	6,2	7,1

Source: UN - Monthly Bulletin, New York, August 1979

When these figures were collected, i.e. in the summer of 1979, it seemed that, at least for some growth poles in the Third World, industrial dynamism had become a major and irreversible fact. Since then however the picture has changed dramatically and a profound erosion of industrial dynamism became obvious even in some former show-pieces like Brazil and South Korea. 14/

With regard to international trade, latest figures released by GATT 15/ show that world trade in real value terms has been continuously declining since mid-1980 from a peak of $ 2.000 billion. According to GATT, such a real value decline occured only twice during the last 25 years: in the first half of 1958 and in 1975. Each time it was related to an important decline of industrial production.

In addition, world demand for industrial products has been significantly declining since around 1973 16/ with the result that,again according to latest GATT statistics, the share of trade with industrial products in world trade has declined from 60% in 1978 to 55% in 1980. 17/

1.1.3. Factors Conditioning the Post-War Industrial Growth Boom

One could hardly assume that the specific historical and structural factors which have played an important role for post-war industrial growth and restructuring in OECD countries could be reproduced automatically today. In fact, what this report is trying to show is that since then the once prevailing patterns of capital accumulation and industrial growth have been radically changing, as have international trade patterns and modes of moving around capital, labour and technology. In addition, new actors have entered this game and the patterns of conflict and cooperation prevailing between them have also been exposed to significant change.

Rapid post-war development of industry in OECD countries was due basically to the following four factors:

- First, the availability, at low wage rates, of a pool of skilled and highly disciplined labour. Originally, this cheap, highly trained labour force could be easily found within the OECD region itself. This was due to the very high unemployment, prevailing especially in Germany and Japan at the end of the war, and to the fact that real wages, particularly again in the fascist countries, had been kept at very low levels and some times even had declined and to the fact that the traumatic experience of the "Great Depression" was still very fresh. In addition, there was a huge mass immigration of workers from agricultural areas to the industrial sectors - witness in Germany the huge inflow of refugees from the former "Ostgebiete" or in Italy the massive immigration from the South. Further, the female labour force was dramatically increased and predominantly restricted to unskilled, low wage occupations.

  At the end of the 1950s, when the first signs of a scarcity of cheap and docile labour force apt for industrial production, were emerging, migrant labour then arrived on a massive scale - in Western Europe particularly from the Mediterranean region.

  When, as during the 1960s, international competition became more intense and labour more costly, the internationalization of industrial production, resulting in the location of new plants in countries with abundant and cheap labour, was able to counter for a certain while at least the shift to a labour shortage and increasing wage levels. During the 1970s however constraints inherent to this approach have gained in importance and have forced headquarters management of multinational corporations to look for complementary strategic concepts. [18]

- Second, the availability of a huge stock of scientific-technical knowledge, developed primarily for military purposes during the 1930s and the second world war. After the war and amidst a period of reconstructing and heavily subsidized investment, private firms were able to tap this stock of basic innovations at relatively low cost and could selectively develop and commercialize profitable "civilian spin-offs". 19/

- Third, as a result of the internationalization of capital, expanding now particularly in production and finance, growth patterns and the dominant technology systems of major OECD countries became increasingly homogenized and adapted to the U.S. model. Basically this model displays four major characteristics:

  a) Industrial expansion centers around three growth poles, i.e. durable consumer goods and particularly cars, bulk chemicals derived from petrochemical feedstocks, and a broad range of capital goods industries.

  b) The progressive separation of manual and mental labour in the very process of production itself. This separation of manual and mental labour strongly affects the way in which science and technology are produced and used for accumulation and social development. In fact, it has two highly interrelated effects. On the one hand it leads to a progressive deskilling of a majority of the labour force. On the other, it leads to a growing centralization of control over information and knowledge ("software") by "think tanks", engineering firms, software and systems houses and central management headquarters.

  c) A progressive computerization and automation not only of industrial production and services but also of industrial products. This relates particularly to the introduction of flexible industrial automation and control systems based on programmable microelectronic devices and their application both to manufacturing techniques in a narrow sense and to a wide range of productive services from r+d and design, plant layout, process flow planning and work scheduling, maintenance, inventory and global cash-flow management and the logistics of worldwide marketing. Products on the other hand tend to be increasingly homogenized; in some extreme cases they are already well on their way to become "black boxes" to be adapted to specific purposes by applications software. [20/]

d) An excessive consumption of energy and natural resources and the prevalence of highly capital-intensive, centralized and environmentally degradating modes of energy provision both for material production and human reproduction (foodstuffs). [21/] It was the availability, at a low cost, of oil, which between 1950 and 1970 decreased its relative price by 50% [22/]. that enabled a few key countries of the OECD, particularly the U.S., to stick for such a long time to this extremely wasteful pattern of energy generation and use.

- Fourth, a dynamic demand was secured for a relatively long period by the interplay of the following four developments:

a) Due to the depression and the war a lot of fixed capital had been devaluated or even physically destroyed, thus creating a huge demand for "reconstruction investment".

b) The demand boom related to the Korean war and the consequent establishment of huge government procurement markets in the U.S., and later on also in Western Europe.

c) The massive incorporation of durable consumer goods, particularly electrical household appliances and cars, into the consumption patterns of Western European countries and Japan, thus adapting the U.S. consumption model. As

Fajnzylber recently observed, in markets characterized by high per capita income levels, low birth rates and increasingly limited possibilities of transferring labour from the agricultural sector, "... demand growth was necessarily linked to the launching of new products whose characteristics might include either savings in time or effort, and at the same time goods that provide the possibility of utilizing the time saved through other products." 23/ This spread of durable consumer goods in turn implied an increase in the capital-labour ratio, and a growing differentiation, particularly in the production branches of foods, clothing, pharmaceuticals, household good and transport - an excellent breeding-ground for the development of oligopolistic competition. 24/

Yet, the afore-mentioned four basic factors hardly would have enabled major OECD countries to get off ground a process of cumulative and mutually reinforcing industrial growth and restructuring, had there not existed certain structural prerequisites, such as:

- A well-established scientific-technical and productive infrastructure, both in material and organizational terms, and embodied in individual and collective learning and innovative capacities of the labour force, ranging from skilled labour to entrepreneural skills à la Schumpeter, which, inspite of the vaste destructions caused by the fascist holocaust and the war regained relatively rapidly its former strength.

- An agricultural sector which due to its early and far reaching "industrialization" was able to produce a sufficiently high agricultural surplus.

- The existence of well-established institutional and informal mechanisms to define areas of cooperation and to manage conflicts of interst between the major social carriers of industrialization, i.e. private firms, the state, and, to some degree, organized labour.

- And finally, an international economic and geopolitical framework conducive for the worldwide projection of OECD based firms via international trade, investment and transfer of technology.

1.2. From a Virtuous to a Vicious Circle of Growth and Productivity - Conditioning Factors of the Economic Crisis

1.2.1. The Profit Squeeze and Industrial Decline

A loss of dynamism of industrial growth and restructuring has become evident in major OECD countries since the end of the 1960s. Obviously, it has been reinforced and intensified by the fourfold rise in oil-prices in 1973 and by the recent second oil-shock of 1979/1980.

But the really decisive forces have been structural ones. In other words, the decline of industrial dynamism is due to some of the basic socio-economic properties and mechanisms built into those patterns of industrial growth and trade which, in the leading OECD countries at least, have been so successful during the 1950s and 1960s.

Table 1.2. shows that the erosion of industrial dynamism has been accompanied by a significant and lasting decline of gross profits and rates of return for practically all of the ten sample countries. In addition it shows that profits had already started to decline much before the first oil-shock of 1973.

Falling rates of profit and industrial stagnation are mutually interlinked in such a way that each tends to increase the other. On the one hand, falling profit rates reduced the propensity to invest and this applies particularly to capacity-enlargeuing investment. On the other hand, declining investment propensities and the consequent industrial stagnation add further to the decline of profit rates.

But it is certainly the profit squeeze which is the key variable for any analysis trying to explain why industrial growth and restructuring in the OECD are not anymore linked together through a virtuous but rather through a vicious circle of mutually cumulative structural changes.

Tab. 1.2 GROSS PROFITS AND RATES OF RETURN: MANUFACTURING

		1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Canada	P/Y	35.6	36.4	34.5	34.0	34.2	33.4	33.7	35.0	35.6	36.4	34.4
	Y/K	54.4	55.0	51.4	47.4	48.0	45.9	44.2	45.6	46.1	46.7	44.8
	P/K	19.3	20.0	17.8	16.1	16.4	15.3	14.9	16.0	16.4	12.0	15.4
United States	P/Y	28.0	26.0	25.4	23.6	26.1	27.0	26.6	26.8	27.5	28.0	23.5
	Y/K	86.3	82.0	78.0	70.0	78.2	80.5	78.5	83.3	85.2	88.1	92.0
	P/K	24.1	21.3	19.8	16.5	20.4	21.7	20.9	22.4	23.4	24.7	27.1
Japan	P/Y	43.9	43.4	49.2	27.1	47.1	51.8	52.1	49.7	49.3	49.8	47.6
	Y/K	45.4	48.9	53.2	51.6	55.0	63.4	53.2	58.9	33.5	58.7	54.7
	P/K	19.9	21.2	26.2	24.3	25.9	32.8	32.9	29.2	28.9	29.2	26.0
Germany	P/Y	41.1	33.6	39.3	39.5	33.7	38.4	36.7	34.2	33.8	35.2	35.8
	Y/K	58.4	57.6	56.3	55.3	55.8	56.9	55.7	53.6	50.7	52.2	52.3
	P/K	24.0	22.8	22.1	21.8	22.1	21.3	20.5	18.3	17.1	18.4	19.0
Italy	P/Y	41.3	40.4	40.4	38.8	41.2	4018	40.0	35.8	32.4	29.9	33.5
	Y/K	31.0	29.9	28.5	27.4	28.1	29.3	29.8	30.0	29.8	28.0	27.1
	P/K	12.8	12.1	11.5	10.9	11.6	12.0	11.9	11.0	9.7	8.4	9.1
Sweden	P/Y	31.3	31.9	32.7	32.0	33.9	32.5	30.5	28.9	32.3	29.4	29.9
	Y/K	40.6	39.7	40.1	39.9	39.8	39.6	39.2	39.2	36.9	38.1	38.6
	P/K	12.7	12.7	13.1	12.7	13.4	12.9	12.0	11.3	10.1	11.2	11.6
United Kingdom	P/Y	33.7	32.0	31.9	31.5	32.3	32.9	30.1	29.0	30.6	31.0	30.1
	Y/K	40.3	39.2	33.8	38.3	39.6	41.7	40.2	38.2	37.9	39.1	38.2
	P/K	13.6	12.5	12.4	12.2	12.8	13.7	12.1	11.1	11.6	12.1	11.8
Australia	P/Y	25.9	25.8	27.5	30.4	30.9	29.1	27.6	28.0	34.9	35.2	34.4
Denmark	P/Y	42.1	41.5	42.9	43.4	45.8	47.4	46.1	46.3	44.5	45.0	43.7
Netherlands	P/Y	45.8	43.5	42.5	40.3	43.3	44.2	40.4	38.8	36.5	37.1	36.8

		1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Canada	P/Y	33.1	31.2	32.3	32.0	30.2	31.2	33.3	34.0	34.8	33.3	31.2
	Y/K	44.1	43.3	45.0	44.8	41.5	41.0	42.7	45.2	44.5	40.6	40.6
	P/K	14.6	13.5	14.5	14.4	12.5	12.8	13.8	15.3	15.5	13.5	12.7
United States	P/Y	29.1	27.6	27.5	25.6	23.5	25.0	26.1	25.6	23.8	27.0	28.6
	Y/K	94.5	89.0	89.2	85.6	76.5	74.4	78.0	80.7	76.1	71.9	76.3
	P/K	27.5	24.5	24.6	21.9	18.0	18.6	20.4	20.7	18.1	18.4	22.0
Japan	P/Y	48.0	43.7	50.8	50.8	50.4	47.8	45.6	42.5	39.5	40.3	
	Y/K	55.5	49.5	62.3	61.2	61.4	57.7	55.1	52.8	45.6	45.2	
	P/K	26.6	29.6	31.7	31.4	30.9	27.6	25.1	22.4	18.0	18.2	
Germany	P/Y	33.4	34.9	35.8	35.1	32.5	30.8	28.6	27.1	27.2	25.5	26.4
	Y/K	53.9	48.6	52.6	53.6	52.7	50.0	48.7	50.0	49.3	46.0	47.9
	P/K	17.0	16.9	19.3	18.8	17.1	15.4	13.9	13.6	13.4	11.7	12.7
Italy	P/Y	35.8	33.9	34.5	34.1	31.6	28.8	29.3	29.4	28.2	22.1	
	Y/K	28.5	30.2	29.7	30.5	32.3	30.6	30.8				
	P/K	10.2	10.2	10.3	10.5	10.2	8.8	9.0				
Sweden	P/Y	28.1	30.1	29.9	30.1	33.0	28.4	28.0	34.1	38.4	30.5	25.6
	Y/K	37.4	36.9	37.4	38.1	39.9	36.2	35.4	35.7	38.2	37.2	35.9
	P/K	10.5	10.4	10.9	11.5	13.2	10.3	9.9	12.1	14.7	11.4	9.2
United Kingdom	P/Y	28.0	28.5	28.4	27.5	24.6	25.0	25.8	22.8	18.9	16.0	16.7
	Y/K	37.9	36.4	36.6	36.5	35.8	34.6	33.3	32.3	29.6	28.3	26.5
	P/K	10.6	10.4	10.4	10.1	8.8	9.6	6.5	7.4	5.5	4.5	4.4
Australia	P/Y	33.8	33.5	33.9	34.6	33.4	31.6	29.5	31.0	28.0	22.5	
Denmark	P/Y	41.7	41.5	41.8	41.1	40.0	40.0	40.3	39.1	34.2	34.4	
Netherlands	P/Y	35.1	34.8	34.8	36.4	35.8	34.3	35.7	34.9	35.7	35.8	

P= Gross operating surplus. Y= Gross value added. K= Gross capital stock

Source: "Profits and Rates of Return", T.P.Hill, OECD, Paris, 1975

What structural changes have occured in industrial capitalist societies which are behind the falling rates of profit and the consequent decline of industrial dynamism?

A sound theory of the present economic crisis does not yet exist. So we have to start from those bits and pieces of a crisis theory which seem to be rather well established. [25]

To start with, let us focus on four factors: [26]

- The development of global factor productivities;
- Changes in the demand structure, based on substantial modifications of consumption patterns;
- Structural changes of the labour market; and
- Structural changes in the role of the state.

1.2.2. Factors Behind the Profit Squeeze - a Highly Simplified Model [27/]

Let us assume that the rate of profit in industrial production P/K, where P represents all profits made in industry and K is invested capital, is basically determined by the following six variables:

w = the wage level

e = price levels of energy and natural resources and costs of "externalities" [28/]

t = the tax burden

d_i = growth of internal demand

d_e = growth of demand for the country' exports

i = contribution of innovation to productivity of fixed capital Q/K where Q is the volume of industrial production.

We now present some hypotheses about how each of these six basic variables is supposed to change. We assume that w, e and t will significantly increase, that d_i and d_e will considerably decline and that also i will decline.

If we then break down the rate of profit P/K into P/Q · Q/K, it can be seen that due to the hypothetical changes in the basic variables, each of these components moves towards a drop in the rate of profit to be reaped in industrial production. In fact, rising w and t cause a decline of P, i.e. the share of the economic surplus available for profits, thus reducing P/Q. Rising e in turn increases K and thus reduces Q/K. Further, declining $d_i + d_e$ cause a decrease in the use of installed productive capacity that exerts a downward pressure on Q/K. Finally, with a decreasing capacity of innovation to increase the productivity of fixed investment, Q/K is falling per definition.

Overall, the productivity of capital Q/K would clearly decline. This could be interpreted to mean that productivity growth has been lower than the increases in the ratio of capital to labour.

Thus, in the framework of our very simplified model, we can conclude that a transition towards a vicious circle of growth and productivity would occur,

- if wage increases significantly exceed productivity;

- if falling growth rates lead to declining rates of productivity increase and to a decreasing use of existing capacities;

- if, due to rising barriers to international trade and investment, the dynamic effects of expanding world market integration cannot anymore be reaped;

- and, finally, if the process of innovation is slowing down and producing decreasing returns in terms of productivity improvments for major factors of production.

In other words, our simplified model contains in a nutshell the message which extensive controversies on "the puzzling drop in productivity" [29/] have tried to convey, sometimes in a rather confusing manner.

In what follows we will see that in reality our basic va[illegible]bles behave in a very similar manner to what we assumed, [illegible]gh of course their movements have been part of an extremely complex interplay of a much broader range of economic, social and political factors. [30/]

1.2.3. Major Structural Changes Underlying the Crisis

Any analysis trying to capture the logic underlying the falling rate of profit will have to start from the following five major structural changes which have been emerging in major OECD countries since the mid-1960s:
- rising unit labour costs;
- changes in the cost structure;
- the sharpening fiscal crisis of the state;

- demand stagnation, particularly for former growth industries;
- intensifying world market competition.

(a) Rising unit labour costs

Real wages and particularly real unit labour costs have significantly increased, particularly the indirect ones (social security contribution, payments for time off, negotiated benefits in kind, etc.). 31/

This was basically due to the fact that the once easy access to cheap, sufficiently skilled and docile labour increasingly gave way to a labour shortage, particularly for certain key industries and for certain classes of skills. This transition from a labour surplus to a labour shortage did not occur by chance. It is the logical outcome of the prevailing post-war "industrial growth model".

By and large, this mode of industrial growth and restructuring turned out to have much too high labour requirements. This is an important point for the later argumentation of this report, so let me quote two pieces of evidence:

- First, overall employment in the manufacturing sector expanded during the 1950s and the first half of the 1960s, and the most rapidly growing branches, i.e. chemicals and engineering, have been those which showed the greatest growth of employment. 32/
- Second, one of the two key "growth industries", the engineering sector and particularly the capital goods industries, continuously displayed a labour absorptive capacity substantially higher than industry's average. This is due to the fact that its capital intensity has been significantly lower than the industry average. In fact, a study of the Economic Commission for Europe has shown that, if the average for industry in general is defined as 100, than the production of electrical and non-electrical machinery in major European countries has a level fluctuating roughly between 60 and 80. 33/

It is this relatively lower capital intensity of capital goods production which has meant that this strategically important sector had to require an increasing share of industrial employment.

Table 1.3. documents trends in labour requirements of the capital goods sector in major OECD countries.

Table 1.3. Growing Labour Requirements of the Capital Goods Sector in Major OECD Countries

$\left(\frac{\text{employment in the capital goods sector}}{\text{overall industrial employment}}, \text{ in } \%\right)$

	1963	1973	1977
(1) Japan	38		44.6
(2) U.S.	38.1		41.2
(3) FRG	- [a]	46.7	47.2

[a] Earlier figures would not be comparable due to a change in the classification system in 1973

Source: Figures are taken from OECD - "The Impact of the Newly Industrializing Countries on Production and Trade in Manufactures", Paris, 1979, p. 43

Overall, the share of the engineering branch in total manufacturing employment has been significantly increasing, reaching a level of approximately 40% in 1977. 34/ In addition, the engineering industries and again particularly the machinery and equipment branches have been the only industrial sectors with significant increases in their employment shares between 1963 and 1976. 35/

It was this shift to a labour shortage in the classical locations of industrial production which allowed the trade unions to strengthen their bargaining position and which gave rise to the "reformist" social policies prevailing especially in some Western Europen countries between the mid-1960s and the beginning of the 1970s, with the result that the increase of real wages began to exceed the growth of productivity. 36/

Table 1.4. shows the consequent increase of real unit labour costs in manufacturing for major OECD countries. 37/

Table 1.4. Rising Unit Labour Costs [a] in Manufacturing for Major OECD Countries [b], 1963 - 1976
(average annual growth rates, in %)

1963-70	3.3
1970-73	6.2
1973-76	9.8

a)= adjusted for changes in effective exchange rates

b)= average for Canada, the US, Japan, France, the FRG, Italy, the UK, and weighted by 1970 exports of manufactures

Source: Adapted from table 22 of OECD - "The Impact of the Newly Industrializing Countries on Production and Trade in Manufactures", Paris, 1979

(b) Changes in the cost structure

Significant changes have been taking place in the cost structure of industrial production and labour costs are no longer the only major concern. First of all, there has been the abrupt, and probably irreversible, shift upward in real energy prices, resulting in an increased search for alternatives to crude oil, and for methods of conserving energy. Similar developments have occured, at least till 1977, in the costs of certain raw materials, for instance phosphates and various non-ferrous metals. Further, viewed from a capitalist perspective, environmental and social regulations of industrial production meant additional costs. 38/ In fact, as Barnett has shown, 39/ the costs of those measures needed simply to keep at a constant level the environmental changes and the health hazards for the labour force, characteristic for the prevailing mode of industrial production, have reached already astronomic dimensions.

In addition, the cost structure of firms has become increasingly rigid, as the proportion of fixed costs, including interest and wages, that do not decrease with a fall in production, has significantly increased. This has been due basically to two developments:

- Changing patterns of industrial financing, with the recourse to external funding increasing in importance, which in turn increased debt levels of firms;

- The increasing interventions of social and labour legislation and the growing pressure exerted by trade unions to increase job stability.

With the transition to industrial stagnation and in the context of oligopolistic competition this increasing rigidity of corporate cost structure has led to a chain effect of rising costs leading to rising prices which, in turn, determine the increase in wages which, in order to keep real standards of living, had to exceed productivity growth.

In other words, the declining scope for pricing policy due to the increasing rigidity of corporate cost structure further contributed to the vicious circle of industrial stagnation and monetary inflation, called stagflation. 40/

(c) The sharpening fiscal crisis of the state

During the industrial boom period, the domiant modes of state intervention in major OECD countries have been considerably changing. Public expenditures have been increasing, public recepts declining, and the consequent fiscal crisis has meant that, overall, the state has become increasingly less capable to create the preconditions for and to guarantee sustained growth. [41] In addition, this meant a decline in the state's capacity to neutralize and counter the unequalizing effects of market-led growth on specific income groups, sectors and regions, together with a weakening of its capacity for crisis management.

Underlying this intensifying fiscal crisis have been various developments:

First of all, public expenditures geared to non-productive uses, in particular to welfare and military purposes have been significantly increasing, with the result that a growing part of the economic surplus has been taken away from capital formation.

Second, rising public expenditures associated with the expansion of government interventions and other public sector activities have increased the relative tax burden to such levels that neo-conservative fiscal doctrines found easy ground for counter-vailing campaigns, the socalled "tax revolts". [42]

Third, as a result of the growing concentration and internationalization of some leading industrial, commercial and financial capital groups, their capacity for evading at least partially tax payment via global transfer pricing techniques and through technical and geographic relocation has dramatically increased, [43] further adding to a reduction of government receipts.

Fourth, concerning public investment, the increasing importance of investment outlays for welfare and military purposes has meant that the already low productivity of capital prevailing in public sector investments has further declined, [44] thus adding to the already explosive growth of public expenditures.

All of these aforementioned developments have dramatically increased public sector debt levels in major OECD countries, with the result that the state is increasingly running into difficulties to found r+d outlays geared to the development of new basic innovations. [45] In addition, growing public sector debt adds considerably further pressure to the already fairly intensive inflationary processes.

(d) Demand stagnation, particularly for former growth industries

With regard to demand, probably the most significant changes relate to consumption demand: strong saturation trends for major durable consumption goods, such as cars, TVs and watches, and qualitative changes, such as a new preference for reliability and quality and for new products and services related to health, education, leisure and energy-saving.

A case in point would be the dramatic erosion of demand for cars in major OECD countries.

Table 1.5. gives the trend estimates of demand, both for commercial vehicles and passenger cars, as developed by the OECD-Interfutures project. This table is based on the assumption that by 1990 car demand in major OECD countries will have reached limits of saturation; from then onwards new demand will have to come from COMECON countries, NICs and OPEC countries.

Table 1.5. Trends of demand in the car industry

(i) Share of the various regions in growth of world stock of motor vehicles (%)

Region	Passenger cars		Commercial vehicles	
	1960/1976	1976/2000	1950/1976	1976/2000
OECD developed countries	83	31	72	35
Less developed European countries	4	8	3	4
Eastern countries	5	25	9	17
Rest of the world	8	36	16	44
World total	100	100	100	100

(ii) Total demand for passenger cars

Region	Number (thousands) 1974	Percentage of world demand	Number (thousands) 2000	Percentage of world demand	Percentage of replacement demand in 1990
North America	11273	41.0	13500	23.7	84.8
Western Europe	9498	34.6	14900	26.1	87.8
Japan	2670	9.7	4400	7.7	84.3
World	27477	100	57000	100	75.0

(iii) Demand for commercial vehicles (millions)

Region	1976	2000
North America	28.4	43.0
Western Europe	10.5	26.0
Japan	10.9	16.0
World	67.1	164.0

Source: OECD-Interfutures – "Facing the Future. . .", Table 59, p. 354.

In addition, also the second major growth industry of the post-war industrial growth pattern, i.e. bulk chemicals based on petrochemical feedstocks, is confronted with significant reductions in demand. This would apply in particular for fertilizers, fibres and plastics and other synthetics substituting natural products. [46]

(e) Intensifying world market competition

Amidst a sharpening world economic crisis, private firms based in OECD countries are facing increasing difficulties to open up new markets and to further internationalize industrial production and finance. In a growing number of world market segments, competition tends to become increasingly intense and new forms of cut-throat competition and neo-protectionist regulations are rapidly emerging. We have shown elsewhere [47] that the dominant concern remains intra-OECD rivalry which gives rise to ever new rounds of a global technological race and that competition between major OECD based firms is now encompassing even the remotest corners of the world economy. In addition, cost competition from prodcution sites in some NICs and COMECON countries has also gained in importance, but still remains restricted to a handful of industrial sectors and here again to products and stages of production which overall are characterized by a low-value added and by a still relatively low technological complexity. [48]

The upsurge of barriers to global market penetration and a further internationalization of industrial production and finance occurs at a moment when the pressure both for private firms based in and governments of major OECD countries to expand the world market integration of their industrial production, trade and finance has been dramatically increasing. For instance, for a growing variety of market segments, private firms based in the OECD region are faced with stagnating and even declining demand and thus do not have much choice but to try by practically any means to open up new markets abroad.

In addition, major economies like for instance the FRG have reached already very high levels of dependence on expanding exports and worldwide sourcing networks and this would apply particularly for their key industrial sectors. 49/

In other words, the pressure to expand world market integration of industrial production, finance and trade is a logical outcome of the "industrial growth model" which has evolved after the second world war in major OECD countries. What is new today is that the scope for crisis management via global economic projection, which has worked so well during the 1960s and the first years of the 1970s,has become extremely narrow today.

1.3 Crisis, Innovation and Industrial Restructuring - Some Preliminary Conclusions

Since the end of the 1960s, a profound economic crisis has been building up in practically all economies of the OECD region. Its indicators are all too familiar: stagnating private investment, falling rates of productivity growth, the increasing fragmentation of the labour market and the decline of real wages, the consequent pressure on state expenditures, particularly welfare-related expenditures, the worsening fiscal crisis, and, in a sense reflecting all of these various developments, the increasing rates of unemployment and of inflation.

More than ever since the 1930s, Western societies are experiencing a retrogression of living standards and major social unrest would seem to be imminent.[50/]

In addition, what is new about the present crisis, is its global nature: simultaneously it hits countries and regions with widely diverging socio-economic structures and it does so on a truly world-wide scale.

This means that the scope for overcoming the crisis in the context of a national economy has become extremely narrow, even for a country like the US.

Add to this that, as in any crisis of a society, major economic actors are loosing their confidence in established patterns of anti-crisis management. In fact, the social consensus on how government intervention should be organized to counter the economic crisis has been rapidly withering away in practically all societies of the OECD region, with the probable exception of Japan (how long?). In a situation, where much more public intervention and other forms of social control over market forces would have been needed to stem the tide of the economic crisis and where the selectivity and coherence of these interventions should be improved, the very opposite seems to occur: a powerful movement towards the disengagement of the state from economic regulation seems to be under way, aiming at the re-establishment of a 19th century-type laisser-faire capitalism. [51/]

Besides its extreme manifestations in the UK and in the US, this movement, under the pressure of the deteriorating fiscal crisis, has already started to spill over to practically all other OECD countries with the possible exception of the new government in France. In other words, in a situation where concerted policies of immediate crisis management and long-term structural change would be needed, the institutional and instrumental foundations for such policies are being increasingly undermined.

This is the situation in which we have to analyze the interplay of innovation and industrial restructuring. The key question is what type of conditions should prevail if innovation is to induce a process of transition to new growth patterns?

In the final analysis, the rythm and the forms of technological change depend as much on the underlying social and economic structure and the actors involved as on the availability of innovations. In a period of crisis, the dominant economic circuits and social relations need to undergo a profound change. In other words, innovation and industrial restructuring are confronted with the need to converge structural changes in production and consumption in such a way that new forms of coherence can be established between the prevailing modes of production, the industrial organization, and the prevailing patterns of wage formation and income generation. It should be remembered that after the Big Depression of the 1930s it took nearly three decades to establish this kind of dynamic coherence between patterns of production, wage formation and consumption patterns which have been one of the basic factors underlying the post-war growth period.[52/]

Today, however large may be the potential for applying available technical innovations, the problem seems to be much more one of social innovation. Whether or not Western societies will be able to make available new product and process technologies at the right time and at sufficiently low cost, is indeed a crucial issue. In addition, however, four major challenges would have to be met: [53/]

- Will it be possible to avoid a transition to a cumulative crisis guaranteeing minimum levels of real income?

- Will it be possible to define in a new way the time spent on labour and its contents?

- Will it be possible to reformulate a viable doctrine for public intervention underlying any type of crisis management and industrial restructuring?

- And finally, will it be possible to increase the degree of social consensus on what type of innovation should be promoted and how should it be linked to production and consumption?

CHAPTER 2.

THE CRISIS OF SEMICONDUCTOR MANUFACTURING - FROM THE CHIP SHORTAGE OF 1979 TO DEMAND STAGNATION AND PROFIT SQUEEZE

2. The Crisis of Semiconductor Manufacturing - From the Chip Shortage of 1979 to Demand Stagnation and Profit Squeeze

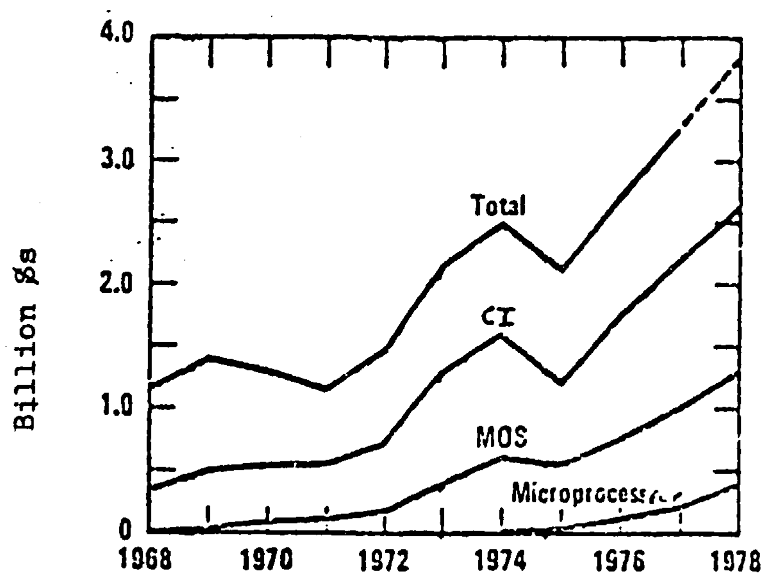
2.1. An Industry Highly Vulnerable to the Economic Crisis

2.1.1. The Myth of a Crisis-Resistant Industry

Because of its high growth and increasing pervasiveness, it has become fashionable to view the electronics industry as crisis-resistant. But this is clearly a misleading belief. In fact, this industry, and particularly semiconductor manufacturing, have turned out to be highly vulnerable to cyclical ups and downs, and even more so to the underlying structural crisis. Annual variations in demand, and consequently also in production, of 10 to 20% are assumed to be "normal" in this industry.

Figure 2.1. and table 2.1. give a picture of annual fluctuations in production and demand for the US and France.

Fig. 2.1. Annual Fluctuations in Semiconductor Production in the US, 1968 - 1978



Source: Chase, P.S. et al - "Trends in Components", Stanford Research Institute, 1975, p. 13

Table 2.1. Demand for Semiconductors in France - Annual Fluctuations, 1970 - 1976 (million francs)

1969	1970	1971	1972	1973	1974	1975	1976
577	677	557	701	1046	1475	1183	1407

Source: Usine Nouvelle, April 1976, quoted from: Truel, February, 1980, p.59.

What is behind these fluctuations is a built-in gap between supply and demand - periods of chip shortage alternate with periods of demand stagnation and consequently surplus production.

2.1.2. The Semiconductor Crisis Cycle - A Simplified Model

The following highly simplified model identifies some basic factors conditioning these wide fluctuations. Three periods can be discerned:

I) Periods of chip shortage

They induce users of electronic devices to pile up surplus inventories. 1/ Producers on the other hand tend to invest heavily in new production lines and the development of new devices.

II) The transition to demand stagnation, surplus production and profit squeeze

When the new production lines get on stream and the new products are about to emerge on the markets, demand growth turns out to lag behind the original projections. The relative decline of demand growth is basically due to the following factors: the already mentioned surplus inventories; the fact that it turns out to be much more burdensome and costly than originally projected to expand the applications of microelectronic devices to industrial products and processes; the accelerating speed of technological obsolescence; and, last but not least, the overall impact of a general economic crisis.

III) The way back to a new chip shortage

Demand stagnation and profit squeeze usually induce firms to cut r+d outlays and investment to lay off workers and, to some degree, also trained personnel, and to phase out unprofitable product lines. In other words, the foundations for a new chip shortage are laid.

Reality is of course much more complex. The interrelations for instance between the various types of product families and product generations are highly complex and are undergoing rapid change; further, it makes a difference whether products are related in a complementary or substitutive manner. More importantly, firms do not act in a homogenous manner; newcomers for instance like the Japanese firms after 1974/75 tend to take a more aggressive position and thus would not immediately adapt their r+d and production capacities to any decline in demand. Some of these developments, i.e. the interaction between crisis and industrial restructuring, are reviewed now more in detail.

2.2. The Chip Shortage of 1979

During 1979 and the first half of 1980 the semiconductor industry could no longer keep up with expanding demand. Even big user firms like NCR (=National Cash Register) and Data General were hit by this shortage of chips. [2]

What are the factors behind this chip shortage? First of all it is the logical outcome of the reaction of major US semiconductor firms to the crisis of 1974/75. Then, US firms, in trying to adapt to stagnating demand, faltering prices and the concomitant profit squeeze, cut back on investment, r+d outlays and laid off a significant part of their research teams and skilled personnel. [3] With demand taking off at a much faster rate than expected, these firms only two years later were in the somewhat paradoxical situation of being unable to build up in time sufficient productive capacities, let alone to hire skilled personnel. The Japanese firms which through aggressive pricing policies during 1979 were beginning to increase their market shares, especially for mass-produced memory chips, still did not have sufficient production capacities to compensate for this increasing gap between growth of demand and supply.

In addition, three structural factors did play a role:

- monopsonistic trends on open semiconductor markets;

- the dramatically rising fixed capital requirements of semiconductor production;

- the insufficient and declining profitability and increasing problems to find investment capital.

2.2.1. Monopsonistic Trends on Open Semiconductor Markets

During the last years, some of the largest users of semiconductors which traditionally relied almost exclusively on captive production, have been forced to buy chips on the open market. This is due on the one hand to the unexpected demand surge for end products, for instance computers. On the other hand, internal semiconductor production facilities have been running increasingly into problems.

Take for instance IBM. Because of a demand boom for its computers, IBM since 1971 has become a major purchaser of chips on the open market. By the end of 1979, informed estimates put IBM's 1980 open market needs at 25 million-30 million 16 kRAMs which amounts to half the industry's 1979 production of that kind of chips. 4/

The number of large users purchasing chips on the open market is likely to increase permanently. According to Dataquest, the number of companies using more than $ 100 million worth of chips a year has increased from one to seven since 1976 and will reach 17 by the end of 1981. 5/ This has important consequences for industries now designing chip-based products. For them, the lesson of the 1979 chip shortage has been that, even for huge demand volumes, they cannot be sure to steer clear of difficulties to secure regular chip supply. For instance, even the US car industry had some difficulty during 1979 in persuading semiconductor firms to bid for its business.

2.2.2. The Dramatically Rising Fixed Capital Requirements

In the late 1960s, a basic semiconductor-making facility could be built for about $ 2 million. Today, it would cost at least $50 million - and probably very much more.

This has had basically two effects:

- Increasing barriers to entry, with the effect that during the 1970s only three new firms were started in the United States.

- Increasing financial burdens for the established firms. In 1978 for instance, and again in 1979, fixed capital spending has been increased by 50% so that fixed investment represented 16% of total sales.

Basically, a radical change of the economics of producing semiconductors is taking place. We will take up this issue more in detail. 6/

2.2.3. Insufficient and Declining Profitability and Problems to Find Investment Capital

At least till 1979, the semiconductor industry was not earning enough profit to finance its own phenomenal growth. According to the US based broker firm Merrill Lynch, from 1975 to 1979 the industry has suffered a 31% fall in its average return on equity funds and an 18% decline in pretax profit margins. 7/

During 1979 at least, this falling profit rate had the result that venture capital kept avoiding the semiconductor industry. Instead, it was put in firms applying chips or looking for entirely new sectors such as biotechnology to exploit.

Beginning of 1980, it seemed unlikely that the US semiconductor industry which at that time supplied over 60% of the world market, could expand capacity to keep pace with demand. This would mean that user industries, particularly those outside the big established oligopolies like for instance the car industry, would be forced to take a much more conservative view on decisions to launch chip-based products.

Then, the prevailing perception was that for the first time, the price of microelectronics circuits could become an issue. During 1979 in fact the shortages have been increasingly reflected in semiconductor prices. Their long-term decline was abruptly stopped. For some products, prices have actually risen by 15-20%. 8/

In summarizing the outcome of the 1979 chip shortage in March 1980, The Economist stated: "In theory, this (=price increase, D.E.) should provide the inducement needed to expand capital investment at a sufficient rate to abolish the shortages. But it will not, because there is an even more fundamental shortage than that of capital - a shortage of skilled people. This will incidentally frustrate the ambitions of Europe to fill the gap in the market being left by the US and Japan." 9/

2.3. Demand Stagnation and Profit Squeeze - Some Underlying Factors

2.3.1. Some Basic Facts

Since the last quarter of 1980, manufacturers of microchips are clearly feeling the impact of the current world economic crisis. These firms, which have been used to extremely dynamic demand much in excess of existing capacities, very high growth rates of turnover and first class profit margins, are all of a sudden faced with demand stagnation, ferocious price wars, dramatically rising cost burdens and with a very significant reduction of profit margins. Already a process of adapting existing production capacities, and of re-shaping corporate strategies and structures is under way, ranging from periodic short-term plant shut-downs and reduced work schedules, to massive lay-offs of personnel and the pulling out from unprofitable product lines.

Of immediate importance for manufacturers of semiconductors is the fact that, starting from the second half of 1980, the electronics industry in general is again in for a new crisis. According to the 1981 World Market Forecast of the renowned trade journal Electronics, [10] the "... economic outlook ranges from poor (in Europe), to confused (in the U.S.), to so-so (in Japan). Electronics growth rates are generally expected to be flat or to slow, but as usual, there are silver linings. Computers and peripheral equipment, for example, will chalk up substantial gains in all three major markets." The Electronics survey then predicted a 12% increase for total equipment consumption from $ 150 billion to $ 168 billion. In the meantime, the sagging worldwide economy, coupled with the tight monetary policies, particularly of the new US administration, have rendered these projections completely obsolete and even the more dynamic sectors of electronics equipment like computers and peripheral equipment, are increasingly running into difficulties. The crisis of the electronic equipment sector is bound to be reflected in the semiconductor business.

Particularly hard hit are the makers of "mass market" chips like Texas Instruments, Intel, Mostek and National Semiconductor.

Take, for instance, the market for 16 K RAM chips used in almost every product in which a microprocessor is to be found. Here a ferocious price war has been sparked off, basically due to a combination of two factors: the enormous excess capacity which has come on stream since the beginning of 1980, together with the demand stagnation for chips in practically all major application areas except the military sector, mini-computers and telecommunications. In February 1980 for instance the average price of a 16 K RAM was $ 5.38 and by February 1981 it was $ 3.82 according to the U.S. Semiconductor Industry Association (SIA). But in June 1981 no one would expect to pay more than $ 1.50 for it.[11/]

In order to understand what happened we need to analyse more in detail the following questions:

- what are the factors behind the emergence of enormous excess capacities?

- what are the causes for the dramatically rising cost burden of semiconductor manufacturing, particularly with regard to LSI and VLSI chips?

- what has been the impact of the world economic crisis on chip demand in major application sectors?

2.3.2. Factors Conditioning Excess Capacities

Today's excess capacity, particularly for mass-produced, non-customized chips which go into a diverse range of products from computers to pocket calculators and electronic games like Space Invaders, was installed by the leading US and Japanese semiconductor firms, primarily in reaction to the great shortage of micro-chips between 1976 and the middle of 1980.

At the time of the last slump in the semiconductor industry in 1975 all the US companies slashed capital investment programmes and staffing levels and this left them unable to meet the boom in demand when the market picked up again.

The result was that, when the boom came, it was mainly the Japanese firms who, because they had kept increasing r+d and production capacities, particularly for 16 K RAMs, were able to react. While Japanese sales in the key US markets were minimal in 1975, in 1981 they were estimated at 7% by the SIA. But for certain products it is much higher. For instance, the Japanese now have 40% of the market for 16 K RAMs which are consumed in great quantities by computer makers.[12/] There are considerable fears in the US that the Japanese will have an even bigger share of the next generation of memory chip, the 64 K, which can store 4 times as much information as the 16 K. Figure 5.2. shows that in October 1980, estimates on the Japanese share of the 64 K RAM market ranged from 40% to 60%.[13/]

This in turn has led US manufacturers, particularly the leading ones, to devise a two-pronged counter-vailing strategy:

- All of them rushed to invest heavily in modernized production facilities dedicated to mass produced non-customized chips such that economies of scale could be pushed to the extreme which would make it possible to counter the aggressive pricing policy of Japanese firms.

- All of them invested in r+d and the procurement of state-of-the-art equipment in order to be the first to bring to the market new generations of increasingly miniaturized and powerful chips.

2.3.3. Causes Underlying the Increasing Cost Burden

This leads us to our second question, i.e. the causes underlying the dramatically increasing cost burden of semiconductor manufacturing. The accelerating technological race caused by the aforementioned conflicting corporate strategies has meant that as each generation of equipment gets more expensive, it also becomes obsolete much more rapidly.

A recent study by the US Semiconductor Industrial Association (SIA) for instance found that the average US semiconductor company has to spend 28% of sales revenue on investment and research.[14/]

It is important to note that according to the same report the R+D element has remained more or less constant throughout the last decade at 7% of sales. In other words, it is safe to assume that the increasing cost burden will not be matched by an increasingly strong innovative capacity. Without such an improved innovative capacity, however, the industry will hardly be able to cut through the Gordian Knot of demand stagnation and profit squeeze, by developing new devices, applications and most important of all, by designing much more cost-efficient processes.

The rising cost burden is due primarily to a tremendous increase of capital investment which has risen from 12% of sales revenue in 1970 to 21% in 1981. Finally, the accelerating speed of obsolescence can be gathered from the fact that the average age of installed equipment to make the chips has been falling steadily to 4.4 years, 12% less than in 1975.[15/]

2.3.4. The Impact on Chip Demand

With regard to demand it is not so much that demand has fallen, rather that its previously phenomenal growth has slowed down. And this hurts the manufacturers because they are totally geared to expanding at growth rates of 25%, 30% or more, which have been normal for most of the 1970s. Furthermore, they need the growth to finance the ever greater cost of developing new generations of products that cram even more electronic components like transistors c. to a chip.

Take for instance computer manufacturers. They still absorb vast quantities of micro-chips, but a number of these firms are running increasingly into problems, like Burroughs in the US, ICL in Britain and CII-Honeywell-Bull in France. Still computers remain a growth area, particularly for the makers of mini-computers like Nixdorf in the FRG and Digital Equipment in the US. However, some companies are delaying their purchases of more expensive systems. There has been also a significant destocking of components.

Besides computers, there will be two other areas were demand will probably remain fairly strong, although it may not grow as fast as the chip makers would like.

There is no doubt a huge demand potential in telecommunications, and this potential would grow even further once the converging of telecommunications and informatics will gather momentum.

With regard to military spending, the Reagan Administration has been outspoken in its intentions to initiate a huge increase in outlays for military hardware and R+D. Yet, it remains to be seen to what degree it will be politically feasible to implement this militarization programme. After all, defence intellectuals from the RAND corporation and other think-tanks have rightly pointed out that due to supply rigidities most of these expenditures will probably result in a re-heating of inflation rather than in fuelling the demands for avionics and other military -related electronic devices. 16/

Hardest hit by demand stagnation have been consumer products containing electronics, from TVs and radios, hi-fi equipment and video to sophisticated washing machines and micro-chip controlled hair-dryers. This would apply especially to Western Europe -- witness for instance the growing difficulties of Philips with its still dominant consumer products-orientation. 17/

2.3.5. Potential Future Growth Areas for Applications

But what about possible future trends in applications?

Semiconductor manufacturers claim that, however bad their present situation, there are a number of areas which will bring massive growth and justify the current investments in increased capacity.

Five future growth areas for applications are usually mentioned:

- Office automation which is expected to become one of the major growth areas as big companies install sophisticated communications and data-processing equipment.

- Huge programmes to establish telecommunications networks in developing countries, particularly in OPEC countries and NICs, and programmes to revamp existing telecommunications networks, particularly in Western Europe.

- The car industry, both with regard to the computerization of the end product (for instance, computerized engine control systems) and with regard to expanding the scope for robotization and flexible machining systems.

- Industrial applications in general, but particularly robots and industrial control systems.
- Finally, consumption-oriented applications are still expected to grow but at a much slower rate as originally expected. In fact, most industrial analysts would admit today that in the context of the present crisis, were growing unemployment and falling real incomes have already considerably reduced effective demand for a great variety of non-essential goods and services, the scope for spending more on electronic gadgets will tend to decrease rather than to increase. This is in striking contrast to the euphoric expectations which dominated public discussions hardly two years when slogans like "The computer will soon put the US Library of Congress into every home" and "L'informatisation de la Société", were still taken very much at face value. 18/

All said and done, the question is not whether a huge potential for applying microelectronics-related innovations exists. Rather it is the impact of the present economic crisis on the behaviour of the social actors involved in these various areas and it is with regard to this question that practically no-one can give a sound answer. This has been aptly put by one semiconductor manufacturer quoted by Financial Times:[19/] "We can see the light at the end of the tunnel alright, but we still can't make out how long the tunnel is yet".

2.3.6. Crisis and Corporate Strategy - The Case of Texas Instruments

The impact of the present crisis of chip manufacturing on major US firms has been considerable. In addition, the scope for counter-vailing corporate strategies would seem to have been fairly reduced.

Take for instance Texas Instruments,[20/] the world's largest vendor of micro-chips. Despite a $ 100 million increase in sales to $1.06 billion, this company, during the first quarter of 1981, reported a 32% drop in net profits in comparison to the first quarter of 1980, i.e. from $50.3 million to $34.2 million. The counter-measures taken by Texas Instruments' management were swift and far-reaching indeed: reduced work schedules for over 10% of its employees have been in effect since the beginning of 1981 Since end of May 1981, Texas Instruments is starting to cut its US labour force by 2800, i.e. by 3%, and will phase out a number of production activities both in components manufacture and applications. In addition, there are plans to reduce and reshuffle considerably the company's global labour force. Activities to be phased out include liquid crystal displays, magnetic bubble memories, plasma panel displays, Tiscos' distribution operations in the US, appliance electronics and selected lines of low-margin discrete semiconductors. In addition, the company intends to begin a phase-out of digital watch operations, in order to withdraw from this business.

Probably of greatest significance is the decision to axe bubble memories.[21/] Texas Instruments in fact had a major share in this industry. By industry estimates, it ranks second to Hitachi as a supplier of bubbles, holding 27% of the world market. Its sudden decision to back away from bubble memories has greatly upset their customers - makers of data terminals, instruments and small computer systems - and severely shaken confidence in the future of bubble memories.

According to insiders quoted in the Financial Times,[22/] Texas Instruments did not have much choice left. Given its emphasis on the broad range of diversified activities based on a strategy to build up industrial synergism through planned forward integration, the sudden fall in profits meant that " ... the company simply did not have the resources to continue development work in every field."

In other words, the Texas Instruments strategy of broad yet balanced diversification based on forward integration, which originally was developed to protect the company against the vagaries of the economic cycles, in the context of the present crisis turns out to increase rather than to decrease the company's vulnerability.[23/]

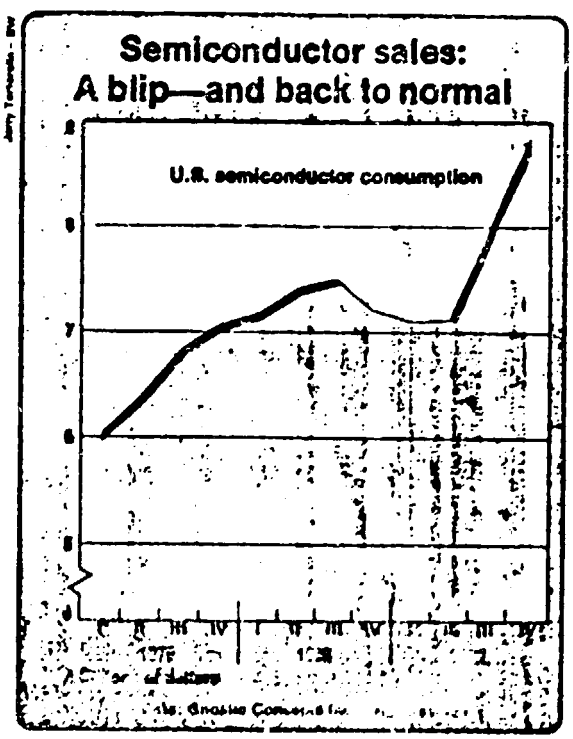
2.4. Perspectives for the Future

2.4.1. Conflicting Projections

Projection on future trends in the worldwide semiconductore market differ considerably, even for the relatively short perspective of the next two years. We will document this by quoting three different projections which have been made public within a period of no more than one year, i.e. between July 1980 and July 1981. We have deliberately quoted three of the most renowned sources in order to indicate that even the most serious attempts to project future trends in chip demand are based on very unsafe grounds.

Figure 2.2. presents estimates of Gnostic Concepts Inc., a leading US semiconductor consultant firm. In July 1980 it assumed that the crisis would be over in the second quarter of 1981 and that from then on, consumption would be "back to normal", i.e. rise nearly exponentially.

Fig. 2.2.



Source: Business Week, 21 July 1980

A market study of Mackintosh Consultants Inc., published in October 1980[24] correctly predicted that a chip shortage would not becomé a problem, at least during 1981. In fact, because of heavy investment during 1980 in chip production facilities and the recession of 1981, considerable surplus capacities have been piling up.

Consequently, Mackintosh Consultants predicted that, in 1981, the growth rate of investment in chip production facilities would be considerably reduced. (Mackintosh estimate = -6%) This then would mean that in 1982, a chip shortage again would be highly probable. Based on this assumption, Mackintosh projects for the period 1982 - 1985 an average per annum growth rate of chip production capacities of 42%.

Let us finally take a statement by Ben Rosen, a leading semiconductor industry analyst and editor of the renowned Rosen Research Inc. Newsletter of New York,at the recent annual meeting of the American Electronics Association (AEA), in Santa Clara/California, July 1981.

Its major message is that the crisis of the semiconductor industry will probably continue well into 1982.

According to Rosen, the US electronics industry will be down 4% and world-wide electronics business down 5% for 1981. The second quarter of 1981 would be flat like the first quarter, and the third quarter would turn down. Rosen expects a gradual upturn in the fourth quarter in the US, but Europe "is still a desaster". He sees the German IC business turning up again in mid-1982 and the US market getting back to a "healthy"20% growth rate in 1982. [25]

2.4.2. A Ferocious Price War

In contrast to the crisis of 1974/75, the present one has not been primarily caused by a slump in unit demand, but by a ferocious price war leading to massive price reductions. In fact, some of the most important customers of IC companies are doing very well, and this would relate particularly to telecommunications, military applications and non-mainframe computers.

The real issue is the ever more intensive battle for market shares in this industry which still is expected to have a very high growth potential in the long term. According to Rosen for instance, world-wide growth rates of semiconductor production could be expected to return to 30% a year starting from mid-1983. [26/]

It is this global competition for market shares which has led firms to increase production capacities very rapidly and at practically any cost - with the result that since the second half of 1980 enormous overcapacities have been piling up. In the words of Keith Chappel, managing director of Intel's UK operations: "The global pattern this year (=1981, D.E.) has been a steady rise in unit sales but with overcapacity driving prices through the floor." [27/] Add to this that Japanese firms are continuing to use cut-throat price competition as their major instrument to increase their market shares, then it becomes clear why price reductions have become irresistible.

The resulting price reductions have been substantial indeed: the price of the 2716 EPROM has fallen by a factor of 9 from January 1980 till June 1981 while the 16 K RAM has gone from $ 5.50 to $ 1 over the same time. "It is impossible to make up in volume", [28/] Rosen concludes.

2.4.3. Recent Trends in the Memory Market

The introduction of VLSI circuits seem to require much more time than originally perceived. A case in point would be the protracted introduction of 64 K RAMs.

Hardly two to three years ago, around 1978/79, expectations were running high, assuming that at least by 1980 the 64 K RAMs would have already found a viable market and that highly complex standard devices would allow merchant semiconductor firms to start a new round of penetrating additional applications areas.

Yet, by mid-1981, it has turned out that all these projections have been mere wishful thinking. In fact, according to Semiconductor International [29] practically all major Japanese and US firms would seem to agree on one point: whoever would dare to come out now with this 64 K RAMs on the market would probably make a huge loss. This would be so basically for two reasons:

- First, the overall decline of demand for ICs which has been caused by the worsening world economic crisis.

- Second, due to the rapidly falling prices for 16 K RAMs, there would be no-one on the market to buy these devices, simply because four 16 K RAMs would be substantially cheaper than one 64 K device.

Semiconductor International in fact comes to a very pessimistic conclusion: transition to real mass-production of 64 K RAMs will not start to materialize before the second half of 1982 and this would apply both to Japan and the US.

2.4.4. The Forthcoming Rounds of the Semiconductor War - Changing Starting Positions of Major Competitors

The fight for the control over semiconductor world markets is becoming more intense than ever before. It is too early still to speculate which firms are going to win and which ones will be the loosers, but there are already some indications that, for the next battles to emerge, starting positions of major competitors have already substantially changed compared to their relative positions in the 1974/75 crisis. This would relate particularly to the three following issues:

- Major US merchant firms would seem to be in a somewhat better position to maintain market shares after the present slump than after the recession of the mid-1970s. Overall, US semiconductor industry has cut this time capital spending only by 10% and its work force only a few percent. This contrasts with the 1975 crisis where the industry cut capital spending by 52% and many companies cut jobs by a third.

- With regard to yields and the quality of ICs, US firms, according to Rosen at least, would seem to have somewhat improved their position with regard to Japanese firms. Rosen derives this evaluation from recent remarks by John Young president of Hewlett-Packard, who said that his company's most recent measurements showed the quality and reliability gap between Japanese and US IC suppliers was closing rapidly. Young added that HP would not be surprised to see quality and reliability of US made 16 K RAMs become equal to that of Japanese parts in the next few months. [30/]

- Finally, with regard to innovation, it would seem as if circuit innovation would be decisive for the next rounds of competition. In this area, US companies still seem to be the undisputed leaders. With regard to process technology, cMOS seems to become the most important semiconductor process for the 1980s, and it is in this area that Japanese firms have a very strong position.

CHAPTER 3.

INNOVATION AND THE CHANGING ECONOMICS OF SEMICONDUCTOR MANUFACTURING

3. Innovation and the Changing Economics of Semiconductor Manufacturing

3.1. Innovation, Structural Transformation and International Location - the Context

Since around 1975, the semiconductor industry is experiencing some major transformations, both in its internal structure and in its integration into the overall electronics industry.

In fact, the nature of its product has developed considerably: from once being an intermediate input to specific types of electronic equipment, particularly data processing equipment and military systems, semiconductors have developed into powerful subsystems which are about to be integrated in an ever increasing amount of application devices pervading into pratically every aspect of social and economic reproduction. In addition, the links between the semiconductor industry and the overall electronics industry have changed substantially. Rather than being dominated by exchange relations, technological spin-offs both from circuit design to equipment architecture and vice versa have increasingly gained in importance.

In trying to analyse these recent structural changes of the semiconductor industry, we will focus on the following three aspects:

- the interrelation between innovation and the changing economics of semiconductor manufacturing (chapter 3);

- an analysis of recent developments in the software sector, particularly the socalled software bottleneck, and some of its implications (chapter 4);

- the interaction between recent technological break-throughs and industrial restructuring (chapter 5);

- and, finally, some implications for the international restructuring of semiconductor manufacturing and for global patterns of technological dominance and dependence prevailing in this industry (chapter 6).

3.2. Trends in Electronics Technology

3.2.1. Relevance and Criteria of Selection

Identifying trends in technology is of importance for various reasons. One of them would be the need to get a clearer picture of what are the most likely changes in the market structure, and in the sectorial and geographic location patterns of the industry.

Will the emergence of new technological developments contribute to a destabilization of prevailing market structures and will it allow late-comers to enter successfully the semi-conductor field? Or will it rather lead to an increasing concentration of control over strategic assets of this industry, such that huge, highly internationalized and di-versified firms will become the dominant actors?

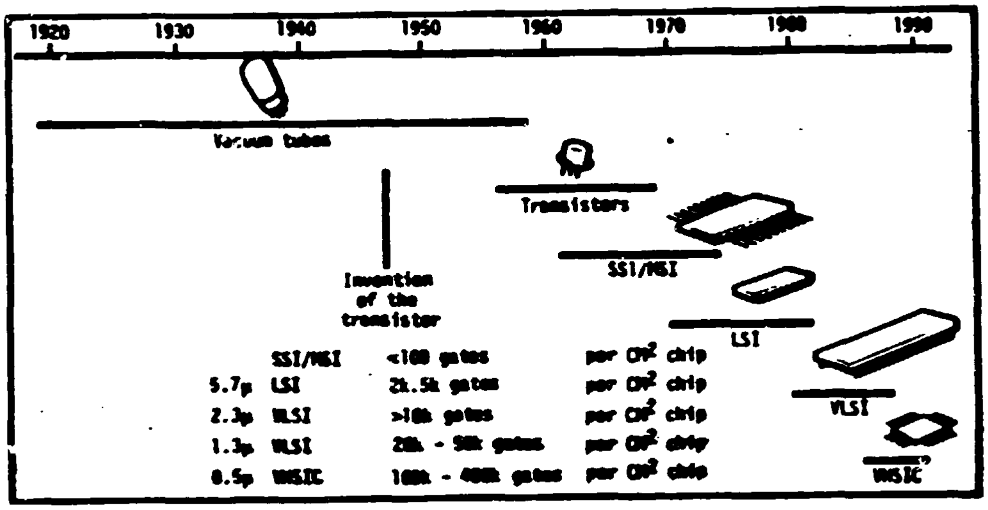
Overall, it would seem that basic changes are already underway which have hardly received a sufficient treatment in the existing literature. Take for instance market access.

Access to a specific market depends to a considerable degree on what kinds of technology are prevailing, and whether they are old or new. Thus it has been argued that to enter market segments for products using mature technologies can be extremely difficult, because of their high-volume, fiercely competitive nature. Instead, market penetration would seem to be easier for products using newly emerging and developing technologies.[1/]

There is in fact a lot of confusion on what are old and new technologies. Technological developments currently re-ceiving considerable publicity - for instance microprocessors and LSI circuits - represent the application of research ten years old or more. These are in fact areas where significant further technological advances are hardly to be expected.

Figure 3.1 presents long-term trends of technologies to design and produce microelectronic circuits. It shows that in this specific area of electronics technology a long way has been covered since the invention of the valve in the 1920s. In addition, this figure charts the massive changes that have taken place since the early days, and provides a glimpse into the future, when very high speed integrated circuits (VHSIC) are expected to dominate the market.

Figure 3.1. Long-term Trends of Electronics Technology, 1920-1990



Source: Electronics Times, No. 109, 15 January 1981, p. 23

What then are the major technological trends to be expected in electronics and particularly in the semiconductor industry?

The term "electronics technology" is a short-hand for a great variety of problems and technological approaches. Table 3.1 shows that electronics technology, by and large, can be segmented into six main areas, ranging from materials technology to applications and interface technologies.

Table 3.1. Electronics Technology - Main Areas

(1) MATERIALS:	The technology concerned with the basic raw materials consumed in fabricating electronic products (Example: Purification of raw silicon up to a purity level of 99.999 999%)
(2) COMPONENTS:	The technology concerned with a single unit which performs one electrical function
(3) SUB-SYSTEMS AND MODULES:	The technology concerned with a composite of components (or a single, multifunction unit) that performs a specific set of functions
(4) PROCESSES:	The technology - composed of both tangible fabricated products and conceptual expertise - required for the manufacture of electronic products
(5) APPLICATIONS:	The technology - primarily composed of conceptual expertise - used in the design of specific electronic products to a definedapplications market segment
(6) INTERFACE:	The technology - requiring a completely new combination of skills - concerned with the problem of interfacing electronic devices and end-user systems (capital goods or consumer goods).(Example: the technology of machine-tool controls.)

Source: Further developed from Scottish Development Agency, April 1979, p. 17

The important points to note here are:

- the great variety of knowledge required, encompassing for instance solid state physics, chemical engineering and high mathematics;
- the delineations between main areas are in a constant state of flux;
- the high degree of interdependence between the various areas of electronics technology.

In what follows we will focus on recent trends in designing and manufacturing microelectronic circuits.

According to one leading expert, the "... manufacture of large-scale integrated circuits has as its primary goal the lowest possible cost per electronic function performed. The main features of the fabrication processes adopted by the microelectronics industry can be best understood in terms of this goal. These features include the fabrication of many circuits at a time (an extraordinary example of mass production), the reduction of the circuits to the smallest possible size and the maximum simplification of the processing technology." 2/

Basically, the manufacturing of microelectronic circuits consists of four stages:

- design
- mask making
- wafer fabrication
- assembly.

The important point to note is that any firm striving to achieve systems control, should be able to master the first two stages.

Table 3.2 gives an overview of the major stages involved.

Table 3.2. Designing and Manufacturing Microelectronics Circuits - Major Stages

I. **Design**

1. Conception of a New Circuit
   - Specifying the functional characteristics of the device
   - Selecting the processing steps required to manufacture it

2. Preliminary Design
   - Estimating the size and approximate location of every circuit element
   - Computer simulation of operational characteristics

3. Final Layout
   - Determining the precise positions of the various circuit elements, by means of CAD

II. **Mask Making**

1. Generation of Optical Reticle

   (= Generating from the computer memory a complete pattern for each layer of the circuit by scanning a computer-controlled light spot across a photographic plate in the appropriate pattern)

1. Pattern Generation by Electron-Beam Lithography

   (= allows to write the pattern directly on the mask from the information stored on the computer memory; eliminates 2 photographic reduction steps)

2. Master Masks Made by Step-and-Repeat Method

3. Working-Copy Masks Made for Photolithography

III. **Wafer Fabrication**

Inputs: Photomasks, process chemicals and prepared silicon wafers (can be produced in-house or bought from sub-contractors, see stage III.1)

(1. Producing the Prepared Silicon Wafers)

- Reduction of raw silicon from its oxide, the main constituent of common sand
- Purification of raw silicon up to a purity level of 99.999 999%
- Melting (1420 °C) and adding desired impurities, known as dopants, to produce a specific type of conductivity, characterised by either positive (p type) charge carriers or negative (n type) ones
- Growing of a large single crystal
- Cutting into wafers with a thin high-speed diamond saw
- Smoothing the wafers by grinding and polishing them in an absolutely clean environment

2. Fabrication of the Integrated Circuits

2.1. Etching a pattern into an oxide

- chemical etching techniques ("Wet etching") (= films of aluminium or polycrystalline silicon are selectively removed by chemical treatment; yields large quantities of corrosive acids)
- plasma etching ("Dry etching") (= the use of hot gas to lay down or remove material from the wafer)

2.2. Lithography (= the key to microelectronic production technology, repeatedly required for the processing of any device, at least once for each layer in the finished structure)

- Photolithography
  - visual alignment techniques
  - projection alignment techniques (the image of the mask is projected onto the wafer through an optical system)
- Electron-Beam and X-ray Lithography (= allows to write the image of the mask directly on the wafer)

2.3. Selective Introduction of Dopants

Diffusion

(Silicon is heated to a temperature of ca 1000 degree C, so that impurity atoms begin to move slowly through the crystal)

Ion Implantation

(Dopant atoms are ionized, i.e. stripped of one or more of their electrons, and are accelerated to a high energy by passing them through a potential difference of tens of thousands of volts. Advantages: can be done at room temperature; doping level can be very acurately controlled)

2.4. Depositing and Patterning Thin Films
(forming the uppermost layers of integrated circuits; is of critical importance for the overall yield and performance of the circuits)

chemical-vapour deposition

(wafers are heated at around 1200 °C in a dilute atmosphere of silane, and a uniform film of polycrystalline silicon slowly forms on the surface)

low-temperature deposition

(Advantage: High temperatures can cause warping and damage to the fine features that have already been inscribed upon the wafer)

2.5. Electrical Test
(each die on the wafer is probed to determine whether it functions correctly; usually computer-aided)

IV. Assembly

1. Sectioning of the wafers into individual chips
2. Bonding the good circuits into packages
3. Connecting them to the electrodes leading out of the package by extremely fine wires, the socalled wiring
4. Sealing of the packages
5. Final Testing (the packaged circuit goes through an exhaustive series of electrical tests; except for simple devices, final testing today is in most cases automated)

With the race on to find the best way of packing more information elements on a sliver of silicon, i.e. with the transition from large scale (=LSI) to very large integrated circuits (=VLSI), three types of constraints are getting of increasing importance:

- design capacities
- software capacities
- and the tools used to fashion microelectronic circuits.

We will analyse in chapter 4 the factors conditioning recent developments in the software sector [3/] and possible future trends. On the hardware side, three major trends were of particular importance:

- a transition to new approaches to circuit design;

- recent developments in production technology;

- the increasing importance of applications technology and the consequent convergence between circuit and system design.

All of these three major trends are closely interlinked and share one common concern - the need to break through the increasingly burdensome custom chip bottleneck.

This bottleneck has become in fact an important constraint for expanding the application of microelectronic devices, particularly to information processing systems. In order to understand its importance, let us first review recent changes in the structure of demand for semiconductors and how this has been reflected in the genesis of various types of semiconductors.

3.2.2. A New Type of Market Segmentation and the Emergence of New Technological Sub-branches

For a long time, the market for semiconductors has been a relatively simple one: market size was directly related to the price elasticity of demand and to the ability of semiconductor producers to proceed with price reductions along their learning curves. On the other hand, there was a fairly unequivocal relation between the type of technology used and market segments: bipolar devices mainly went to the data processing industry, and MOS devices to consumer electronics.

During the 1970s, a new type of market segmentation has emerged which is basically due to the following developments:

- the convergence of circuit and systems design due to the increasing incorporation of systems functions on the chip;

- the increasingly complex interrelations between technology and applications, with the MOS technology in fact penetrating into most application areas;

- The increasing number of supplier firms and end users and their increasingly complex interrelations.

In order to get hold of the recent restructuring of the semiconductor markets, we start from a categorization of semiconductors, as developed by Truel. 4/ He proposes to differentiate between five types of semiconductors:
- standard devices;
- exclusive devices;
- specific devices;
- custom devices;
- microprocessors.

Standard devices are technically indifferent to the final use.

For them the compatibility between different producers is far-reaching, if not total. This would apply particularly to memories and to most of the discrete semiconductors.

Exclusive devices, like the standard devices, are technically indifferent to the final use, but are produced by just one producer,or a very small number of them, enjoying a technological monopoly. Of course, this category is the most fluid one, because the entrance of new producers could undermine the original position of "technological leadership".

Specific devices are semiconductors which can be mass produced but which can only be used in specific markets: logical circuits for the data processing or the watch industries, codecs for the telecommunications industry and semiconductors for car applications.

Custom devices are designed to respond to very particular applications, often only for one client, and are usually offered by just one firm or at least only very few. Consequently, production runs are extremely short and unit costs of production tend to be very high.

Microprocessors are circuits which can be mass-produced and used for multiple purposes, and which, because they are "programmable" could, in principle at least, be fine-tuned to the specific needs of the final user. This adaptation could be realized by the end-user himself, for instance through the use of appropriate application software. Or it could be done by the producer of the device who would then build some of the specific application requirements into the microprocessors. But the second solution, due to its very high costs in terms of additional design activities, will only be feasible at very large production runs and consequently is mainly used today in the area of car applications. On the other hand, reprogramming in reality can be much more difficult and costly than originally assumed.

due to the increasing "software bottleneck", [5] it might simply turn out that appropriate programmes will not be available, or only at a prohibitive cost. In spite of these shortcomings, general purpose microprocessors or single chip microcomputers till the beginning of 1980 have been the preferred choice over custom LSI circuits for an increasing percentage of applications. For instance, General Motors and Ford Motor Co. both choose microprocessors for million unit applications as more cost-effective than custom LSI circuits. [6]

Recently, a new type of semiconductor has emerged on the market which is also a programmable device, the so-called semi-customized devices, based on the gate array technology. We will discuss this sixth category later on in more detail.

The structure of demand for semiconductors is becoming increasingly complex and difficult to predict. There seem to be four basic trends involved which, to some extent, are overlapping or contradicting each other:

a) The market for semiconductors, overall, is undergoing a transition from a market where only a few "big shots" had to be supplied to markets with rapidly increasi g numbers of fairly heterogenous final users.

   A case in point would be the data processing industry where the emergence of seperate mini- and micro-computer industries and of a computer periphals industry has fragmented this market into hundred of firms and where the huge mainframe firms are increasing their in-house semiconductor production capacities in order to secure their own requirements.

   The same is about to happen, albeit on a much smaller scale, for the industrial electronics sector.

b) The emergence of new mass markets for standard devices, particularly in the data processing industry, due to the development of semiconductor memories, both of the RAM and ROM type. Increasingly, mass produced standard memories are also used in the other main market segments.

c) The penetration of new markets for integrated circuits, particularly the telecommunications industry and consumer electronics. A growing part of the integrated circuits used in these sectors are specific devices which have to be designed according to the very strict specifications received from the final user. This would apply for instance to the codecs used in the telecommunications sector for transforming analogous signals into numerical figures, and for the integrated circuits used in the car industry, particularly for engine control systems or for the ICs used in the watch industry.

Table 3.3 documents the increasing IC consumption of these two sectors. For the car industry alone, world-wide IC consumption in 1985 is projected to be at least $ 1 billion. 7/

Table 3.3. Sector-Specific Consumption of Integrated Circuits as a Share of Total World Demand, 1970-1985 (%)

	Telecommunications a)	Consumer Electronics
1970	5	5
1976	10	15
1985	15	25

a) =excluding military communications

Source: Figures are from Mission pour les Circuits Intégrés as quoted in: Truel, Jean-Louis - "L'industrie mondiale des semi-conducteurs", Dissertation, Université de Paris IX, Paris, February 1980, p. 226

d) The emergence of the industrial electronic sector, which previously used to consume only custom devices, as a market for memories and specific devices, like for instance interface and control circuits.

For the marketing strategies of semiconductor merchant firms, these developments had basically three consequences:

- distribution networks had to be established or improved in such a way that they could also reach medium- and small-sized users of less sophistication;

- the range of products to be offered had to be broadened;

- the emphasis on standard devices had to be even further increased.

The restructuring of demand thus has led to a considerable revision of prevailing strategies of choice of products and of marketing. This process of revision still seems to be in an experimental stage and this probably explains much of the seemingly "irrational" zig-zags of corporate strategies during the last few years.

3.2.3. The Custom Chips Bottleneck

Custom chips are generally logic chips, similar to micro-processors, but they are designed to perform specific functions. Orders for custom parts usually run into the tens of thousands or even less. Consequently, mass production seemed to be out of question - at least as long as one stuck to a specific design philosophy which assumed that chips have to be fully customized. This traditional design approach to custom circuits meant that, although they take just as much time to decide and cost as much to put into production as standard circuits, profitability was low because high costs could not be spread over long production runs. "Complex IC designs for low volume applications have always been an accountant's nightmare. The costs could not be justified most of the time." 8/ This is why chip manufacturers tended to focus on standard devices.

From a user's point of view however, standard circuits have some serious shortcomings. It is extremely difficult to operationalize them with regard to specific "user needs". It takes in fact a lot of corrective software engineering to fit them ex post to the requirements of the end user. The economic rationale underlying this distorted and extremely wasteful way of interlinking microelectronic circuit technology and end user needs has been analysed elsewhere in detail in this report. 9/ Suffice it to say here that semiconductor firms, when designing new chip generations, were only marginally concerned with end user needs. They are driven by a cut-throat competition forcing them to centre most of their activities on a frantic race to offer ever new generations of low-cost hardware. The speed of introducing new hardware has been such that semiconductor firms had no choice but to try to adapt ex post the existing software to make the new hardware applicable to user needs.

Yet, there are clear limitations to this approach. Today, the costs of applying standardized chips to highly specific applications via corrective software engineering are rapidly getting out of control. There is a growing deficit of applications software and software engineers who are able to understand interface problems and translate them under heavy time pressure into viable programmes. Further, standard chips are also uneconomic with regard to size, wastage of surplus capacity which will never be needed by most end users, and insufficient reliability.

In short, with ICs becoming increasingly complex, equipment makers' need for custom devices has been increasing dramatically. The reaction of the bigger user firms (for instance computer firms) has been to build up in-house design and production capacities for proprietary custom chips.[10/] But in most cases this has not been cost-effective.

Recently, however new approaches to attack the custom chips bottle have been emerging both in circuit and system design and in production technology. This has been due to the interplay of various factors. Two of them are of particular importance, i.e. a new design approach made possible by recent progress in computer aided design (CAD) and processing tools and some interesting adaptations of corporate strategy. In what follows I will discuss some of these issues in more detail.

3.2.4. Trends in Circuit Design

At least till the end of the 1970s, research was focussed at producers of high-volume, high-density standard circuits which can be "personalized" or programmed to perform different functions through software. Yet, this type of research focus is increasingly running into problems today.

a) Constraints inherent to the conventional design approach

There are three major constraints inherent to the conventional design approach:

- Increasing constraints to produce in an efficient manner reliable high-density circuits: a case in point would be the problems faced even by leading US semiconductor firms to develop marketable 64 K RAM devices.[11/]

- VLSI devices will have to demonstrate a cost advantage over LSI devices. Today this is becoming increasingly difficult given the price slump for major standard devices. Take for instance the problems to open up new markets for 64 K RAMs. According to Semiconductor International, [12] as prices for 16 K RAMs are driven through the floor, marketing perspectives for the new generation of 64 K RAMs are becoming extremely bleak. According to T. Atsuyoshi, Vice President of Nippon Electric Corporation (NEC): "If 64 K RAMs are brought to the market, no one will buy them, because four 16 K chips will cost less than one 64 K chip." [13]

- Increasing problems to produce devices which meet, with the help of appropriate software, the precise needs of end-user applications.

In other words, the focus on high-volume, high-density standardized devices characteristic for the 1970s, is increasingly becoming an impasse today. It is in this context that recent changes in the philosophy of circuit design, like for instance the development of semi-customized chips, based on the gate array technology, have to be analysed. Of equal importance are recent developments in the attempt to overcome the increasingly troublesome software bottleneck.

(b) Gate array technology [14]

Recently, a new programmable LSI device has been emerging which will increasingly challenge microprocessors: uncommitted, i.e. programmable, logic arrays, the socalled gate arrays. Made with low power TTL Schottky or ECL circuits, gate arrays are roughly ten times faster than microprocessors. Of immediate concern are high speed applications in information processing and communications. Computer firms for instance which want to compete with IBM's 4300 machines, are increasingly requiring gate arrays.

The term "gate array" refers to a technique for producing complex microelectronic circuits quickly and cheaply. It has been pioneered eight years ago by Ferranti and was then called uncommitted logic arrays (ULAs).

Until very recently it has been a truly marginal technological paradigm. But today experts would agree that the 1980s will go down in electronics history as the decade of the gate array. 15/

The gate array concept is simple; standard chips are mass-produced containing a selection of logic gates and other basic circuit elements, omitting only the final inter-connection layer(s). The secret lies in the fact that chips are built up layer by layer. All the logic elements (called "gates" because of the way they pass or obstruct electronic signals) can be fabricated in the lower layers, leaving only a last layer or two of metal to make the vital connection between the gates. As long as the final interconnection pattern is not specified, the chip remains uncommitted or programmable. It is that final pattern of connections which determines what the chip will do. So the customer simply specifies the final layer on an otherwise standard chip defining the particular interconnect pattern specific to his application. Then a suitable mask is produced and final metallization applied.

In short, a new type of integrated circuit has been created, the semi-customized chip: it can be mass-produced with a standardized arrangement of gates, but without the final circuit connections between the gates that determine how the chip functions. Experts further agree that gate arrays could solve the problem of designing increasingly complex circuity - and ensuring that this is done cost-effectively and that it works. In fact, this new technology in addition to improving dramatically product and process technology, could also "revolutionize" the economics of chip design.

There are two issues involved:

First, to make the step from the orthodox design concept of fully customized chips to the much more flexible design concept of semi-customized chips based on gate array technology. There is general agreement that this in fact will lead to significant reductions in design lead time and costs. Experts of Texas Instruments for instance suggest that to design a fully customized chip of medium complexity, say between 500 and 1000 logic elements in density, could take up to a year and cost up to US $ 250,000 - and then it might not work first time. 16/ An additional assumption would be that design would be done by hand. 17/ By comparison, they claim that to design semi-customized chips would take them as little as 14 weeks and cost US $ 40,000. Ferranti, after eight years' experience in this area quotes even significantly lower design costs within a roughly similar design lead time: 16 to 18 weeks and £ 3,000 for a 500 gate circuit.

In other words, the transition from fully to semi-customized chips will clearly pay off.

The second issue concerns the design technique and instruments and the way of organizing the design process. On this issue opinions clearly diverge, especially with regard to the speed of change needed to secure cost-efficient design.

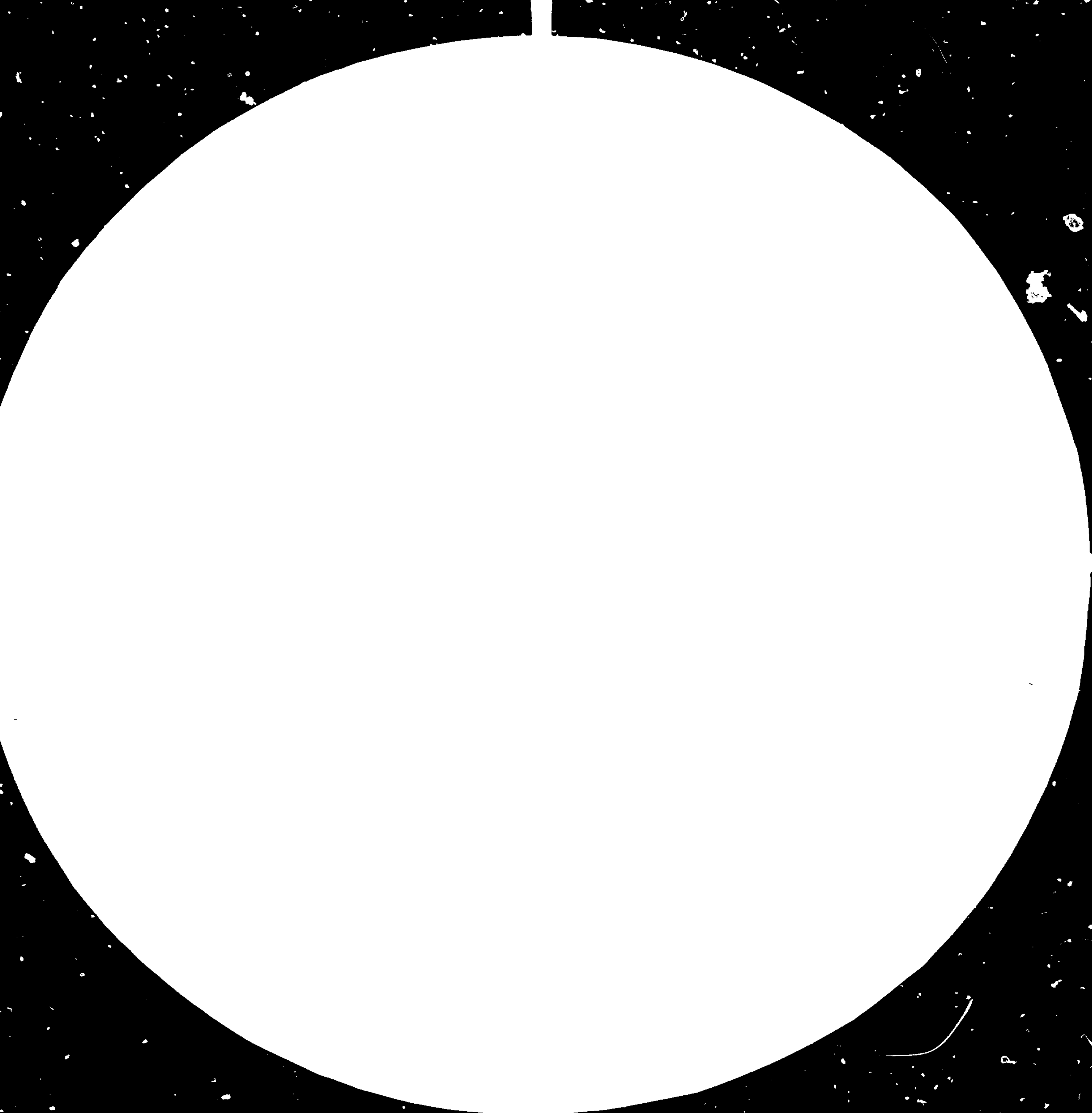
Let us first describe the objective problem: with increasing complexity of gate arrays, the disadvantages of conventional design techniques and instruments ("Manual Design Methods") might rapidly become a new bottleneck. The main reason would be that with highly trained and lavishly paid engineers it could become increasingly difficult to retain the fast design cycle time and low development costs. With design cycle time over-stretched and developments costs soaring, it would hardly be possible to realize a market penetration pricing policy, i.e. aggressive price reductions following the "learning-cost curve". Nor would it be possible for captive producers to secure cost-efficient in-house production.

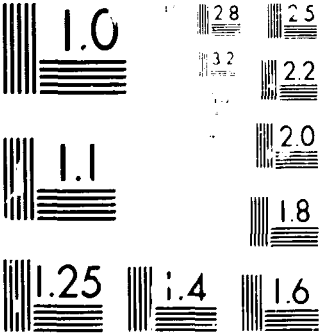
It is no surprise that both Texas Instruments and IBM subscribe to this position and stress the need to "revolutionize" prevailing modes of design. The design approach of Texas Instruments for instance underlines the superiority of automatic interconnection routing in the reduction of design lead times. Using a sophisticated software package to determine automatically the placing of circuit elements and the interconnect patterns, Texas Instruments claims to need about 8 weeks to build up the necessary computer files which describe the hardware elements and the transfer function of the device. Another week would then be required to run the autorouting package on the 5 IBM 3033s at the Dallas, Texas, computer center. Overall design lead time from inception to samples would be 12 to 14 weeks and maximum chip utilization would be 76% (for the A540 gate array) and 84% (for the 1008 gate array). 18/

A completely different design approach is taken by Ferranti, the pioneer of gate array technology. Ferranti claims that manual design methods aided by computer techniques to test consistency and produce mask making tapes, are perfectely adequate and more economical for today's gate arrays. Ferranti's manual design methods give consistently better chip utilization factors: from 85 to 90% over the last 5 years. 19/ Consequently, Ferranti is able to sell its 1,000 gate circuits for Ł 2.50 each whereas original price quotations (February 1981) for Texas Instruments' new arrays, which are comparable to Ferranti's in complexity but outdo them in speed, range from Ł 10 - Ł 25 each. Asked for the reason for Ferranti's superiority in performance, David Grundy, Chief Engineer of Ferranti, claims that "... people are still better than computers at the kind of pattern recognition needed to design an efficient array interconnection pattern." 20/

Ferranti's design approach might be valuable today but will it also be tomorrow? For instance, Ferranti admits that as complexities and array sizes increase still further, it will have little choice but to take advantage of computerized methods. In fact, it has recently spent more than Ł 1 million on computer equipment for this purpose.

There is reason to doubt whether firms the size of Ferranti or even smaller, for instance the newly founded LSI Logic Corp., 21/ will be able to survive in this market. Giants like




1.0
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1.6

IBM and Texas Instruments are already heavily engaged in devicing strategies which would dramatically increase the "barriers to entry" and the "cost of survival" for medium and small scale firms. Fully integrated automatic layout systems require extremely high capital outlays and IBM and probably also Texas Instruments are already about to connect these integrated automated systems directly with an electronic beam machine (minimum unit costs for such a machine in 1980 exceeded US $ 2 million)[22/] which writes the final connection patterns on the wafer. In other words, it is difficult to see how medium sized firms like Ferranti, whatever their original technological strength, let alone newcomers like LSI Logic, would ever be able to break this new constraint of interlinking directly design and production via new computer aid systems.[23/]

3.2.5. Recent Developments in Production Technology

a) Conditioning factors and major areas of change

Changes in production technology are becoming of increasing importance. In fact, Booz, Allen and Hamilton in their influential study on how to develop an electronics industry in Scotland even go as far as to claim: "Process technology holds the key to major advances in microelectronics."[24/]

The major driving force behind recent changes in manufacturing technology has been the reduction of the direct labour content of the product. This statement is backed by the findings of a recent OECD study on the electronics industry which has been based on interviews with scientists, technologists and managers in leading firms and research institutions.[25/]

The study found that "product and process innovations resulting from r+d activities in the electronic sector have mainly resulted in savings on labour costs rather than in a reduction of energy or material costs."[26/] Consequently, "...capital costs were increasing as a proportion of total production costs; and ..., at least in manufacturing, labour costs formed a declining proportion." 27/ For the semiconductor industry in particular "...it was felt that: 'in the last five years the rate of increase of labour productivity has increased' and that there has perhaps been a tendency to over-invest in labour-saving process innovation." 28/

Four main areas of changes in production technology can be discerned:

- the use of new lithographic techniques
- the introduction of new processes for wafer fabrication
- the rapid proliferation of automation into all stages of production, including chip assembly
- the introduction of new production technologies in application areas and the consequent convergence of process and product technology.

Each of these changes could have important implications for the economics of semiconductor manufacturing and thus are likely to induce major realignments in the structure of this industry, the strategies and organizational patterns of major firms involved and in the prevailing patterns of international location.

We will trace out later on in detail some of these implications. But first we will discuss each of these four major types of changes in production technology.

Overall, we will see that, due to the frantic race to squeeze more logic on tiny silicon chips, the first generation of chip making equipment, first introduced less than ten years ago, is already becoming obsolete. Consequently the pressure to introduce a new generation of semi-automatic and extremely expensive equipment is becoming all-pervasive.

b) Changes in lithographic techniques

Changes in lithographic techniques center on generating resolution of individual features with dimensions less than one micron. Conventional optical photolithography cannot achieve these dimensions - new lithographic techniques such as electron beam and eventually X-ray techniques offer a significant improvement over current photolithographic methods. Electron-beam systems for instance can print much smaller circuit details on a wafer, more acurately than optical systems.

Yet, the new lithographic techniques require extremely expensive equipment and thus are not yet profitable to use. This is the basic message of a recent study by Mackintosh Consultants on the semiconductor micro-lithography equipment and materials sector. [29] According to this study, the following generations of lithographic equipment can be discerned:

- Earliest techniques used photographic masks in contact with the wafer surface to produce the circuit pattern. Called contact aligners, this type of equipment today is mainly used for discrete semiconductors.

- The move in recent years has been to projection aligners where mask and silicon surface are seperated and now to direct step-on-wafer techniques, the socalled wafer steppers, where each circuit pattern for each chip is impressed separately onto the wafer surface (each wafer yields 300 or more individual chips).

Contact aligners, projection aligners and wafer steppers all belong to the family of optical semiconductor equipment used to imprint circuit patterns on the silicon surface.

There are two other types of equipment, more sophisticated but also more expensive - X-ray equipment and electron beam machines.

Many semiconductor firms are looking ahead to the time when electron beam machines can be used to write directly on the silicon surface guided by a pattern locked in the memory of an over-seeing computer. This technique is already used for complex chips where it can reduce the time taken to generate a circuit from 20 or more hours to 60 minutes. But, as the Mackintosh report points out: "So far, a viable market for direct-write electron beam systems has failed to emerge. Currently three machines are in use at IBM, generally believed to be assigned to semi-production or development circumstances for very low volume circuits where the usual development of masks is not practical. Wafer throughput is extremely low and product costs are extremely high. While there are several electron beam equipment companies developing products for direct-write production purposes, a viable machine with practical wafer throughputs is not expected to be available until the 1982-85 period". 30/

Even then, Mackintosh goes on to say, prices of these machines will be such, i.e. around $ 200.000 and more, that market volume will hardly surpass $ 2 million p.a., i.e. roughly 10 machines per year.

For X-ray equipment, on the other hand, the scope for reducing the cost of writing small features on a chip seems to be somewhat greater.

Yet, the real market growth will lie with the optical equipment manufactureres like Cobilt and Casper (contact aligners), Perkin-Elmer and Cobilt (projection aligners) and GCA, Electromask, Ultratech, Canon, Hitachi, Philips and Censor (wafer steppers). The market for wafer steppers alone, according to Mackintosh, should be $ 929 million a year by 1985.

Overall, Mackintosh International suggests that a growth of 43% annually can be expected in the worldwide market for the optical equipment. Table 3.4 summarizes the major results of the Mackintosh study.

Table 3.4. Worldwide Optical Semiconductor Equipment Market. Summary by Equipment Type, 1980-1985

	$ millions 1980	1981	1985	Percent change 80/81	81/85*
Contact Aligners (Discrete Devices)	4.6	5.2	7.2	13	8
Projection Aligners (Group I ICs)	56	85	164	52	18
Projection Aligners (Group II ICs)	70	100	117	43	4
Wafer Steppers (Group II ICs)	75	133	929	77	63
TOTALS	206	323	1,217	57	39

* Average annual compound percent change.

Source: Mackintosh International - "Semiconductor Microlithography Equipment and Materials Outlook to 1985", London, June 1981, quoted from: Cane, Alan - "Growth expected to be in optical equipment market", Financial Times, 8 June 1981

c) New processes for wafer fabrication

Of particular importance for recent changes in process technology for wafer fabrication are new low temperature deposition processes and plasma etching.

Low temperature deposition processes avoid the very high temperatures, typically around 1200 degrees C, that are normally required. The advantage of low temperature operation is that there is no damage to the wafer. High temperatures can cause warping and damage to the fine features that have already been inscribed upon the wafer. As device intensities increase, this damage becomes critical.

Plasma etching, or the use of hot gas to lay down or remove material from the wafer, replaces "wet" processes using chemical baths. Plasma etching, during which unwanted areas are removed from the wafer surface, has several advantages over chemical processes. It is practically essential for VLSI devices since the chemical baths cannot be very accurately controlled. Plasma etching is also safer as it avoids the messy business of dipping wafers into dangerous chemicals.

Other new processes for wafer fabrication include ion implantation and laser annealing. 31/

d) The proliferation of automation

One of the most important developments in semiconductor production technology is the rapid proliferation of automation into practically all stages of production, including chip assembly.

A good test case for the state-of-the-arts in mid-1981 of automating semiconductor production would seem to be the plans announced by Nippon Electric Corporation of Japan (NEC) in July 1981 to build a $ 100 million semiconductor plant in Roseville, near Sacramento/California. This plant would use the most advanced and highly automated equipment for the production of ICs by a merchant supplier in the US. It will be equipped with the very latest in wafer fabrication, assembly and test equipments and will have a through-put of 75,000 to 80,000 wafers per month when it becomes fully operational in 1985. NEC says that it will make very large-scale integrated circuits - memories, microprocessors and gate arrays - i.e. the most sophisticated products available on the market. First products from the factory will be 64 K dynamic RAMs, the building blocks for large computer memory stores. By 1984 - 85 it is expected that the plant will be able to turn out the next generation of very large-scale integrated circuits which will include 256 K dynamic RAMs and advanced microprocessors. NEC also plans to produce Read Only Memories (ROM), another important element of computer memories. According to NEC's executive vice-president for the US, Charles Wood, NEC will make 128 K and 256 K ROMs at the new plant.

The NEC project indicates to what degree automation will affect semiconductor production in the years to come. According to Handel Jones of Gnostic Concepts, a market research company with close ties to NEC and other Japanese companies, the degree of automation at the NEC factory will be higher than that in any other semiconductor plant anywhere in the world with the single exception of some of IBM's wafer fabrication lines. 32/

But the most important novelty would be that automation would also cover the traditional bottleneck of semiconductor production - the assembly stage at which finished chips are put into packages and bonded to the output pins that plug the integrated circuit into a circuit board. Automation of assembly will substantially reduce the required work force at the IC plant.

Projected employment figures for the plant are only 200 persons when the plant opens, rising to 600 people working in the three shifts when it is working at full capacity. According to industry experts, typical employment figures for a plant with similar through-put might be expected to be closer to 1,500. Additional evidence on the scope for worker's replacement through transition towards automated bonding can be gathered from the experience of Electronic Arrays, the Silicon Valley based subsidiary of NEC which recently has introduced automated bonding devices at its Mountain View plant. One worker, using the automated equipment replaces now 30 manual bonding employees. 33/

Automating semiconductor assembly has become today an established practice with major semiconductor firms. This would relate to both merchant firms and captive producers. In fact, each of the major US semiconductor manufacturers has today plans underway to build new, highly automated assembly facilities in the US.

The rationale usually quoted for this move towards automated assembly is the need to speed up assembly in order to be able to react in a flexible manner to market fluctuations and the need to improve the yield of good devices. Equally significant, training requirements can be substantially reduced. According to Electronics [34/] it takes only two weeks to train a machine operator to work at automated bonding equipment, while it normally takes about three months for a worker to become competent at manual bonding.

For NEC, an additional motivation seems to have played a very important role: the distrust of all Japanese firms with regard to the US labour force. By automating semiconductor production to such a high degree the Japanese now feel that they can avoid the problems of employee management in the US.

e) The transition towards automated assembly

According to a recent study by Mackintosh Consultants,[35/] the the worldwide market for assembly equipment and materials will experience a rapid expansion during the next five years.

Table 3.5 resumes market growth projections for major types of equipment.

Table 3.5. Market Growth Projections for Major Types of Assembly Equipment, 1980-1985

Years / Type of Equipment	1980 (mio $)	1985	CAAGR[a)] (%)
(1) Lead-Bonding Equipment	70	183	21
-Thermocompressive wire bonders	Have the greatest market share		
-Gang bonder equipment		15	50
(2) Die-Seperation	17	43	20
(3) Die-Attachment	12	28	18
(4) Packaging Equipment	61	78	5
-molding presses	-drastically declining markets		
-flat-plate-aperture molds	-significantly increasing markets, but still of relatively small volume		

a) CAAGR= compound average annual growth rate

Source: Figures are taken from "Semiconductor Assemoly Equipment and Materials Outlook - 1985", Mackintosh Publications Ltd., Darmstadt, June 198[illegible], quoted from Blick durch die Wirtschaft, 13 July 1981, p. 7

Except for packaging equipment, average annual growth rates of demand are expected to be very high, ranging from 18% for die-attachment equipment to 50% for gang bonder equipment. The low growth rate for packaging equipment, which has already experienced high growth rates during the last years, would seem to be due basically to the drastically declining market for molding presses which the rapidly increasing demand for flat-plate-aperture-molds is not yet able to compensate.

For all major types of assembly equipment, the Mackintosh report predicts increasingly high levels of automation, increasing operation speeds, and significantly improved yields. This would apply particularly to bonding equipment and to die-separation equipment where fully integrated lines are now available on the market.

Thus, the Mackintosh report would seem to indicate that the trend towards automating chip assembly is continuing unabated by the present crisis of the semiconductor industry.

f) <u>Changes of manufacturing technology in application areas</u>

Examples of the introduction of new manufacturing technologies in application areas include:

- the automatic insertion of components and modules onto PCBs (Printed Circuit Boards) in the TV industry;
- computer-driven wire wrapping, which is claimed to be a more reliable and efficient method than solder for wire/pin connections;
- computerized test and measurement equipment.

The new emphasis on process technology has already started to influence basic design approaches. In fact, a convergence of process and product technology is taking place: products are being engineered and re-engineered in order to be applicable to given process technologies and the once clearly delineated interface between design engineering and production engineering has become blurred. It is this convergence of process and product technology which probably has contributed much to the aforementioned recent breakthrough in designing and producing semi-customized chips. In addition, it documents the increasing importance of applications technology.

3.2.6. The Increasing Importance of Application Technology [36]

a) Options for increasing application orientation

Due to increasingly tough market constraints, semiconductor firms can not anymore say: "We will be building a million or four million bits of memory on a chip, if anyone wants such a thing...."[37] - and hope that a market will develop. Instead, innovation and production have to be increasingly geared to end-user needs.

There are two possibilities to achieve this goal: either through a customization of standard ICs by software engineers or by integrating user needs into device and system design.

The reorientation of innovation towards customer needs is going to have dramatic consequences for the structure of the industry. If the first route is chosen, then this would mean that increasingly the bulk of the value-added would be reaped in the software sector.

The second route, on the other hand, would mean that the weight of IC producers would increase. Yet, in order to be able to reap the benefits and control this route to user-orientation, IC producers would have to pursue a strategy of forward integration into equipment, systems and consumer electronics.

Both these developments would increase in turn the pressure for computer, telecommunications and consumer electronics firms to initiate strategies of backward integration into IC design and manufacturing, in order not to loose control over end-user markets.

The result could well be a blurring of the traditional lines of segmentation running through the industry and this could have a considerable impact on the economics of production and demand. In other words, new trends in innovation are bound to lead to a considerable restructuring of prevailing patterns of "industrial organization" and this in turn will have a considerable impact on corporate structure and strategy.

Some implications for the software sector of this type of interaction between innovation and industrial restructuring will be discussed in detail in chapter 4. So let us concentrate here on the implications for circuit and systems design and their consequences for industrial restructuring.

b) The convergence between circuit and system design - the pressure to increase technical and industrial synergism

The convergence of circuit and system design which is one of the most important structural changes in the whole electronic sector, is taking place on two levels:

First, the design of circuits has to take increasingly into account the application requirements of end-users. Cases in point would be specific devices like codecs, programmable devices like microprocessors and gate arrays, and firmware, particularly that designed into EPROMs.

Second, the design of systems is increasingly conditioned by the type of integrated circuits available. In the extreme case this could lead to a design approach where systems would be designed around ICs. In addition, this could induce a product design philosophy to emerge where products would be conceived as "black boxes" [38/] to be adapted to specific end-user needs through appropriate software or firmware.

This convergence of circuit and system design and the growing importance of software development in this process has important consequences for patterns of allocation and division of labour within the electronics industry. This would apply particularly to specific and programmable devices, and much less so for standard devices like RAMs.

Much more than ever before the focus is now on reaping the benefits of technical and industrial synergism through developing new forms of coordination between circuit and system design and software development. In order to realize these synergetic effects, not only a permanent flow of inter-sectorial transfer of technology and feedback informations would be required, but also a considerable reshuffling of prevailing sectorial and geographic location patterns.

In other words, new patterns of vertical integration and/or disintegration are already about to develop in the electronics industry and we should expect significant changes in the prevailing patterns of international location.

3.3. The Changing Economics of Semiconductor Manufacturing

Due to the aforementioned recent technological developments, the economics of semiconductor manufacturing have recently experienced significant changes. In fact, changes in production cost have been the major issue. There are three aspects involved:

- significant changes in the overall cost structure;

- changing skill requirements; and

- the dramatic increase in the costs of market entrance.

3.3.1. Significant Changes in the Overall Cost Structure

We have already shown that the reduction of labour costs has been the major driving force for innovations in manufacturing technology. [39/]

According to Truel[40/] this has already caused the share of direct labour costs in overall costs of production to fall from 46.7% in 1963 to 30.2% in 1976.

This relative fall of labour costs has been particular prominent for chip assembly costs, due to the increasing use of automatic bonding equipment.[41/]

In addition, with the growing complexity of the circuit, the importance of assembly costs tends to decline.[42/] This is in fact one of the established basic laws of the economics of semiconductor manufacturing. Robert N. Noyce, Vice Chairman of Intel and one of the industry pioneers, adds: "The most cost-efficient design is a compromise between high assembly costs (which are incurred at low levels of integration) and high scrapping costs (which are incurred at high levels of integration)." [43/] This statement would seem to imply in fact that for high levels of circuit integration, offshore assembly was never a really pressing issue.

Table 3.6 documents how the importance of assembly costs decreases with growing circuit complexity. In fact, the relative decrease of labour costs for assembly operations from 33 to 4% is a dramatic one indeed.

Table 3.6. Circuit Complexity and Changing Cost Structure

Type of Circuits / Cost Categories	Discrete Semiconductors or Simple Integrated Circuits Value ($)	(%)	Complex Integrated Circuits Value ($)	(%)
Cost of the chip	0.015	10	1.00	29
Cost of the capsule	0.050	33	0.50	15
Labour costs for assembly operations	0.050	33	0.15	4
Test	0.020	13	0.75	22
Rejects	0.015	10	1.00	29
	0.150	100	3.40	100

Source: Adapted from: U.S. Department of Commerce - "A Report on the U.S. Semiconductor Industry", Washington, D.C., Government Publications Office, September 1979

3.3.2. Changing Skill Requirements

In order to realize the aforementioned technological developments, the classical patterns of division of labour between the various disciplines of electronic or computer engineering, metallurgy, physics and chemistry do not suffice anymore. In fact, these previously separate specialities have to be increasingly converged and in particular knowledge of interface problems will become of increasing importance.

The future of some of the main innovations in manufacturing technology for instance will depend upon a mixture of physics, chemistry and metallurgy expertise for successful implementation of these technical advances.

This would apply even more so for circuit design. The role of the electronics engineer, with regard to the required qualifications and experience, will become increasingly that of a systems designer with a high working knowledge of the needs of the end-user applications and less of a detailed knowledge of the discrete circuit interconnections. The software content of the product can be expected to increase dramatically requiring many more software or "firmware" engineers than are now used in product development. Overall, the impact of the pure scientist should decrease during the next five to ten years as the industry will shift focus from laboratory/ process research to product/application design.

Changes in high-level skill requirements have led to siderable shortages, particularly for design engineer... for application programmers.

Of all the job categories, the task of the electronics design engineer has undergone the most rapid change in recent years. According to the OECD study on the electronics industry, "... one firm replied 'What we need is bright engineers who can work in a team of 20-30 people and who can design a chip which both uses the equivalent of one million transistors and does something useful'." 44/

The shortage of application programmers is felt to be even more disturbing and has led to what has been called the "software bottleneck". 45/ The OECD study for instance reports that "...at one European manufacturer they hoped, within the next 2 - 3 years to produce 'foolproof' high-level programming languages to increase the productivity of programmers and lower the skill requirements for applications programmers." 46/ As will be shown later, this kind of statement indicates perhaps more the increasing frustration and perplexity of the industry, and could hardly be taken as a serious projection of what would become feasible in the foreseeable future.

Changes of similar importance are to be expected for the established patterns of skill requirements in production. According to the OECD study, "...all interviewees were unanimous in agreeing that the nature of jobs and the pattern of skill requirements had undergone considerable changes in the last decade. In the semiconductor manufacturing process, firms reported that skill requirements were rapidly reducing; that the production of LSI chips (and thus of whole electronic systems) was increasingly resembling a chemical process operation. The equipment manufacturers remarked that 'manual' skills were being replaced by 'computer operating' skills and that circuit designers were being replaced by writers of software as digital ICs (and, in particular, microprocessors) became the dominant design element."

The study concludes that "... the general pattern of job structures seems to reflect a polarization of skill requirements with a replacement of 'semi-skilled' production workers by highly skilled design, test, and inspection personnel and a number of unskilled machine operators. Many firms remarked that this polarization of skills was masked by the export of unskilled jobs to offshore assembly operations, so that the net effect of technical change appeared to be a trend towards fewer and more highly skilled jobs in domestic operations." 47/

In addition, a shift of personnel from manufacturing work into training, service, and sales activities has taken place, particularly in firms engaged in equipment manufacture.

This huge conversion of skills is increasingly becoming a major problem, particularly for the computer industry. According to the OECD study again, "... the amount of money allocated to 'in-house' retraining was, in all the firms interviewed, high (at one large computer manufacturer training accounted for 4% of sales)." 48/ Only the retraining of production workers to work in maintenance jobs in the service sector was felt to be "relatively unproblematic".

3.3.3. The Dramatic Increase in the Costs of Market Entrance

Till about 1975, the costs of entering the semiconductor industry were relatively low: access to technology was fairly easy, first, because basic research then was the driving force behind the product and process innovations, and second, due to the high mobility of researchers and engineers. 49/

In addition, semiconductor manufacturing used to be a relatively labour-intensive business, and equipment costs still were relatively low. Consequently, the minimum requirements of capital for entering this industry were moderate: National Semiconductor in 1967 entered business with $ 1 million, and Intel two years later needed hardly $ 3 million.

In the meantime, costs of entering the semiconductor industry have dramatically increased. According to Robert N. Noyce, competing in VLSI markets "...implies the willingness to risk at least $ 50 million to $ 100 million a year in capital, plus another $ 50 million to $ 100 million a year in r+d cost." 50/ In other words, with less than $ 100 million it is impossible today to enter the VLSI market.

It was P. Lamond, Vice-Chairman of National Semiconductor, who put the problem into a nutshell: "In the semiconductor industry you once needed 50 cents of investment capital to generate 2 dollars of annual sales. Today, you have to invest 1 dollar in order to generate just 1 additional dollar of sales." 51/

3.3.4. Factors Underlying the Increasing Cost Burden of Semiconductor Manufacturing

The huge cost increase of designing and manufacturing state-of-the-arts semiconductors and particularly of very-large-scale-integrated circuits was due to a variety of factors.

Of particular importance are:

- the decreasing importance of basic research and the increasing weight of design and mask making;
- the increasing importance of firmware;
- rising budget requirements for circuit development;
- the expansion of new and rigid forms of technological protectionism;
- and, finally, the soaring costs of equipment used to make semiconductors.

(a) The decreasing importance of basic research and the increasing weight of design and mask making

Today, the logic conception of a new design consisting of at least tens of thousands of functions and its graphic representation would be impossible without using extremely expensive CAD systems. In addition, huge teams of highly qualified designers are needed, and a lot of time is required to complete the task of circuit design and lay-out, particularly for very complex VLSI circuits. 52/

(b) The increasing importance of firmware

Increasingly, integrated circuits are designed to include a growing part of the software which, once wired into the circuit, is then called firmware. This capacity to store programmes permanently on a chip has been significantly increased due to the emergence of the so-called EPROMs (= Electrically Programmable Read Only Memory) which are dead memories where information stored can be extinguished electrically and which then can be reprogrammed. This means that in the design stage, software engineers have become of increasing importance and are matching now the requirements of solid state physicists. According to Truel, 53/ research on microprocessors today requires approximately four software engineers for every hardware engineer.

(c) Rising budget requirements for circuit development

As a consequence of (a) and (b), the budgets needed for developing a new circuit family have very much increased. US semiconductor manufacturers for instance claim to need today at least a couple of million dollars to develop just one product family.

The increasing cost burden of r+d has been documented by the OECD study: "... in almost every case r+d costs were rising faster than inflation". This was basically "... due to the relative labour intensity of such activities and the fact that rises in wage costs in most OECD countries had at least kept pace with rates in inflation". 54/

Table 3.7 shows that in 1978 the cost burden of r+d in the semiconductor industry by far exceeded the average of high-technology industries, let alone the overall average of US industry.

Table 3.7. The Cost Burden of R+D in the US, 1978

	R+D outlays as percentage of sales (%)	R+D outlays as percentage of profits (%)
National average	1.9	43.4
High-technology average	4.0	65.4
Aerospace	3.7	93.0
Electronics (general)	2.6	56.1
Data processing	6.0	54.8
Instruments	3.9	69.9
Semiconductor	5.8	102.3
Telecommunications	1.9	16.1

Source: Figures are taken from "R+D is a Shrinking Resource", Electronics, 17 January 1980, p. 83 where date from Standard&Poor's are quoted.

(d) The expansion of new and rigid forms of a technological protectionism

Access to technology for newcomers has become increasingly difficult due to the expansion of new and rigid forms of technological protectionism.

This trend towards increasing technological protectionism among the established semiconductor merchant firms clearly shows up in the aforementioned OECD study: "The US semiconductor firms (interviewed for this survey, D.E.) perceived an increased need to protect internal innovations as a defense against the formation of new firms in the component business by engineers leaving the established firms." Consequently, "...they had tended to patent less in relation to activity in recent years, not only because of the increasing significance of software, but also as an attempt to keep more 'trade secrets'". 55/

(e) The soaring costs of equipment used to make semiconductors

Finally, the costs of equipment needed to produce state-of-the-arts semiconductors and particularly VLSI circuits have soared up rapidly.

Overall, the cost burden of equipment used to make semiconductors has increased in price by a factor of between 4 and 20 times since 1967.[56] "Firms were certain that such trends would continue in future; that the manufacture of the next generations of integrated circuits would require ever greater levels of capital investment." [57]

Table 3.8 for instance documents the increase of capital equipment cost for a wafer fabrication facility.

Table 3.8. Costs of Capital Equipment Needed to Set Up a Wafer-Fabrication Facility (million $)

Year	Cost (million $)
1967	0,5
1979	10,0
mid-1980s	34[a)]

a) Electronique Actualité, 15 December 1978, expects an even bigger increase till the mid-80s to around $ 50 million.

Sources: Handel H. Jones, Vice President of Gnostic Concepts, quoted from: Business Week, 3 December 1979 and Electronique Actualité, 15 December 1978.

The table shows that from the mid-1960s till the late 1970s, capital equipment costs for wafer fabrication in fact experienced a twentifold increase and during the five years starting from 1980 another three to fivefold increase is to be expected.

Cost increases have been particularly rapid for the following types of equipment:

- Electron beam and X-ray lithographic devices;

- Equipment needed for mask-making;

- Computer aided design facilities for total VLSI circuit pattern generation;

- High speed computer-based test equipment;

- Improved crystal pullers and refiners to produce "zero-defect" material;

- Wafer processing equipment such as ion implanters, processing furnaces etc.

The unit costs of equipment needed for mask-making for instance increased from $300,000 in 1975 to a minimum of $2.5 million in 1978 and it will probably run up to around $7 million in 1982.[58/]

Table 3.9 presents some additional information on recent trends in semiconductor equipment prices.

Table 3.9. Recent Trends in Prices of Semiconductor Equipment ($)

	average prices 1976 ($)	average prices 1980 ($)
(1) Wafer exposure equipment	44,000	345,000
(2) Electron-beam microlithography system		2 million
(3) Assembly equipment	8,000	20,000
(4) Projection mask aligner (Perkin-Elmer)		230,000 (240,000[a)])
(5) Automatic Testing Equipment		ca.500,000

a) =Price quotation from Wall Street Journal, 3 October 1980

Source: Figures are taken from "Semiconductor Equipment takes on its own Glow", Business Week, 1 December 1980

As a result of these huge price increases, equipment costs today represent approximately 10% of chip production expenses. 59/ According to John R. Welty, head of Motorola's semiconductor group, "...we are shifting from what has been a fairly labour-intensive business into a capital-intensive business". 60/

Tables 3.10 and 3.11 give evidence of this dramatic increase in the capital intensity of semiconductor manufacturing.

Table 3.10. The Increasing Fixed Capital Intensity of Chip Production, 1979-1985

	1979	1985	1979 - 85
(1) Average costs of capital equipment needed to set up a wafer-fabrication facility (mill. $)	10	34	
(2) Global expenditure on equipment for chip production (billion $)	1.1	5.6.	p.a. average growth rate = 31%
(3) Average growth rate of investment costs per $ of annual sales			8%

Sources: (1) Handel H. Jones, Vice-President, Gnostic Concepts, quoted from Business Week, 3 December 1979
(2) + (3) Mackintosh International, Inc. , op. cit

Table 3.11. Capital Expenditures in the Semiconductor Industry, as a Share of Sales, 1975-1985 (average shares in %)

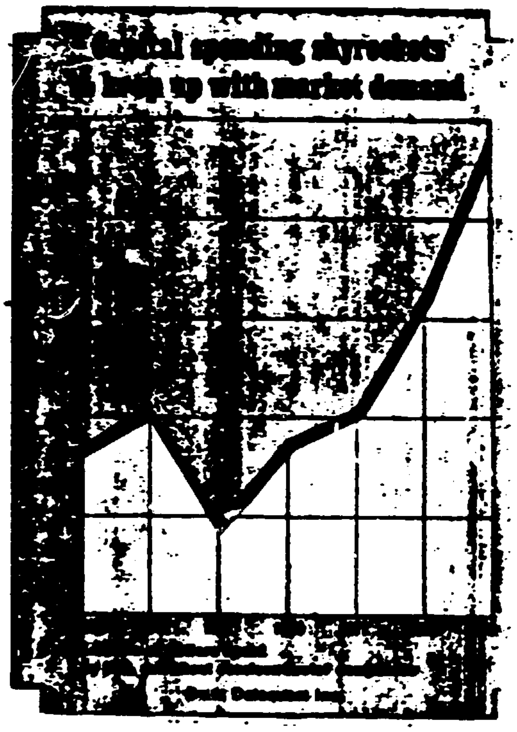
1975	10
1980 1/	16
1985 1/	20

1/ = 1980 estimates.

Source: Figures are from the investment firm Morgan Stanley, quoted from: French, Michael B. - "The Semiconductor Industry: An Overview", Datamation, April 1980, p. 164

Figure 3.2 documents the rapid increase of capital outlays by US merchant semiconductor companies, particularly since 1977.

Figure 3.2.



Source: Business Week, 3 December 1979

In what follows, we will take up in detail some implications of recent changes in the economics of semiconductor manufacturing for corporate structure and strategy and will put them into the wider context of structural change pertaining to the semiconductor and to the overall electronics industry.

CHAPTER 4.

THE SOFTWARE SECTOR - CONDITIONING FACTORS AND POSSIBLE FUTURE TRENDS [1/]

4. The Software Sector - Conditioning Factors and Possible Future Trends

4.1. The Concept of Software and Some Major Issues

Trends in the software area are of crucial importance for understanding the scope and constraints of applying micro-electronics-related innovations to industrial products and processes. To start with, we have to be clear about what we talk. Definitions of software differ considerably. This reflects the great variety of functions software is supposed to fulfil. But what is the common purpose and what is it that constitutes the difference to hardware?

According to one leading expert, software should be defined "...to include programmes that modify computer hardware and extend its function beyond the general purpose digital computer. Software includes, but is not limited to control programmes, executive supervisors, teleprocessing and communications monitors, application programmes, programming aides, languages,etc. Software could be delivered as a product, with or without large- or small-scale hardware, as a service through a time-sharing network, as one of the value-added components in a facilities management arrangement etc. I am defining software in the broadest sense possible, . I I do so because the current market place requires it." 2/

The first lesson to be drawn from this definition is that the software market is nothing less than a homogeneous market. On the contrary, market segmentation is the name of the game. This has important implications which we shall discuss later on in detail. Suffice it to say here that one should be very careful to avoid rapid over-generalizations.

In addition, it should be noted that, due to the lack of sound information, this chapter deliberately left out recent developments in firmware engineering, i.e., the wiring of programmes into micro-electronic circuits. Consequently, the following analysis is still of a very tentative nature and is basically meant to document the need for more in-depth follow-on research 2a/.

This chapter discusses some factors conditioning the structure of the software market and strategies of major groups of firms involved. Further, it analyses some causes underlying the socalled software bottleneck and identifies possible future trends, particularly in applications packages and software development systems. Finally, recent changes in corporate strategy and possible future impacts on market structure and industrial restructuring are discussed.

My basic assumption is that the spread of applications for microelectronic devices depends critically on the available capacities to develop, operate and maintain software, particularly applications software. When we talk about microelectronics-related innovations and industrial restructuring, we always have to keep in mind that there is an overall shortage of programming capability in relation to the rapidly growing population of installed computers (mainframe, mini and micro) and that this applies in particular for programmers capable of devising machine codes for microsystems. This shortage of programs needed to run computers and microelectronic programmable devices, the socalled software bottleneck, is in fact becoming an increasingly important constraint for attempts to expand the reach of microelectronic applications beyond its traditional confines. Thus, analysing the software market might help us to understand better why the microchip has been so "unexpectedly slow" 3/ to become that all pervasive force as predicted by the most renowned forecasts since more than 10 years.

The purpose of this chapteris to identify the actors involved in the development, production and maintenance of software and to point out that, although market segmentation is traditionally high in the software sector, trends towards an increasing concentration and globalisation have recently gathered momentum. I would argue in fact that any attempts to analyse or forecast future application patterns of microelectronics and their impact on international restructuring in industry should be based on a careful evaluation of these recent structural changes of the software market. This would help to ensure that policy formulation and implementation would not be roped into ephemeral projects, but would selectively focus on a few strategic areas of attack and support.

4.2. The Emergence of a Separate Software Sector

In order to understand today's problems of software engineering, we need to analyse the structure of the software industry.

A first question would concern its origins and how this industry relates to other parts of the information processing sector.

4.2.1. The Origins

There are three actors involved in information processing:
- The hardware manufacturer/provider;
- The software manufacturer/provider;
- The end user.

Originally, these three different functions were united in one and the same person, or at least were part of the same team. The man with a computing problem (the end user) built a machine (thereby becoming a hardware provider), then modified it to accomplish his specific task (creating software).

With the emergence of the computer industry, the end user (the man with the computing problem) was seperated out of the equation. Software was provided by either the hardware manufacturer or by an in-house programming force which the end user hired specifically for this purpose.

Viewed from the end user's perspective, this type of arrangement had three basic shortcomings:

First, neither of the two groups of software producers were sufficiently acquainted and in tune with the end user's needs so that needs and software hardly ever intermeshed completely. In other words, it took a long time and it cost a lot to bring software sufficiently close to end user needs and one never knew whether the system really would work, let alone whether it would be able to incorporate necessary adaptations over time.

Second, because of the high wages of programmers, the cost burden of software development and engineering was rapidly increasing to very high levels. That is why both end users and hardware manufacturers had some common interest in reducing the role of highly paid programmers and in displacing them as far as possible by other arrangements.

Third, it did not take end users too long to realize that software received from hardware producers always contained significant doses of built-in hardware dependencies, i.e. the need to rely on maintenance and repair services and spare parts, but also to remain loyal to the system when expanding computing capacity.

But also hardware producers had increasingly reason to feel uneasy with this arrangement. They used to give away software as part of the system price paid for the hardware, but were getting under increasing pressure to cover the tremendous costs of software development. The famous "unbundling decision" of IBM in June 1969 was the logical outcome of this concern. Some would argue that by explicitly seperating software and hardware costs, this strategic move of IBM, probably in contradiction to the then prevailing motivations, did contribute considerably to the emergence of an independent software sector.

Obviously this is only part of the story. If we want to understand the causes of the present software crisis which we have shown to be one of the key constraints to the application of MRIs to industrial products and processes, we need to inquire further into the history of the software market place. Various events could be cited:

- In 1956, IBM started its independent data center which was due to a judgement by the government that required IBM to treat its Service Bureau Division as a seperate, but still wholly owned subsidiary rather than as a adjunct activity to its computer sales.

- In 1959, largely due to the military and space agencies programming needs, independent contract programming firms were first emerging. Their position was strengthened when IBM had difficulties bringing its third generation computer equipment to the market place in 1963-64.

- A further push to the development of independent software firms was due to the rise of the time-sharing industry in 1966-67.

- Finally, one would have to mention the attempts at taking end user programmes and modifying them for attempted multi-installation use, a pratice that began in 1967-68 and is notable if only for its failure rate.

4.2.2. Conditioning Factors

It is not easy to uncover the logic underlying these events. In fact, Welke is right, when he states: "...the software product market place occured not because of a grand design, a technological break-through, or the genius of anyone individual or company. It developed bit by bit and piece by piece, with form chosen only sometimes by technology, with standards dictated by economic necessity, with risk taken out of ignorance, and with the rewards sometimes going to the perverse as well as to those who just persevered." 4/

Nevertheless it seems possible to identify some common threads running through each of these events. I would propose to focus on three of them:

First, the hardware manufacturers' concern to reduce the cost burden of software development and maintenance caused not only changes in pricing policy, i.e. IBM's unbundling decision, but also the development of new modes of software production and engineering, the socalled "software packages", and of new forms of subcontracting, starting from software conversion right into the development of specific applications packages. Add to this the end users' concern to reduce or do away completely with the extremely expensive in-house programming teams, then it becomes obvious that the drive to reduce the importance of highly skilled and lavishly paid programmers was of considerable importance.

Second, with the destabilization of the established oligopoly and the intensifying technological race between hardware manufacturers, the gap between ever new generations of computer hardware on the one hand, and available software on the other, was dramatically increasing. This applies to both systems and applications software. Hardware manufacturers, for reasons we will analyse later on more in detail, were unable to cope with this problem and thus had no choice but to accept and sometimes to even actively promote the emergence of independent software firms.

Third, firms interested in gaining access to the larger information and services market place, soon realized that software could serve as the ideal entry level business. The reasons are fairly evident:

- The relatively low barriers to entry. Compared with starting a hardware company, for instance, software requires little initial investment. Today, a minimum entry cost would be

$ 500 .-0 which, in addition to initial investment, would include costs due to the need for product differentiation and competition, for incorporating data base design and new communications requirements.

- The high rate of return and very attractive profit margins, particularly with multiple sales of software packages. In other words, software is still widely perceived,and probably rightly so, as a "get-rich-quick business".

- The great diversity of software requirements and the consequent segmentation of the market place almost precludes domination by any one firm. The software market has so many needs and demands which furthermore are undergoing rapid change, that the small firm can easily carve a niche. Attempts to homogenize effectively the software market for the sake of subordinating it to oligopolistic control, are of course under way, but still they have a long way to go.

4.3. Trends in the Market Structure

Market segmentation has been an important characteristic of the software sector. At first sight at least, it would seem as if very narrow limits exist for a homogenization of this market and thus for attempts to increase concentration of control.

Yet, closer analysis shows that reality is much more complex and that the software sector is undergoing significant change. Particularly in certain strategic areas, like "basic systems packages" and "software development systems", the prevailing trend points to an increasing concentration and globalization.

4.3.1. Software - a Part of Computer Services

Fig. 4.1. indicates that software is part of computer services.

Fig. 4.1. The Computer Services Industry

Computer Services

Data Services

- Network Information Services (NIS) (refers to any connection of the computer with a terminal located remotely)
- Batch Services (work is carried in by hand or by courier to the computer, for instance payroll)
- Facilities Management (FM) (first-time installation of a computer, usually on a turn-key basis, or transition from one computer system to another)
- Software Products (software that has been written and marketed as a standard package to do a specific job)
- Software Services (contract programming)

Support Services (=operations that are not directly related to data processing)

- Education (training of programmers etc.)
- Third Party Leasing
- Used Computer Equipment
- Third Party Maintenance

Source: Based on industry reviews in electronics trade journals, particularly on: Roach, William R. and Jung, David C. - "Spending for Software and Services", in: Datamation, March 1975

Market data on the computer services industry are only available since 1960. It was estimated that computer services revenues for the United States in that year reached barely $115 million (see table 4.1.). Twelve years later this market had grown to $4.3 billion.

Tab. 4.1. US Computer Services Markets, 1960-1972

Computer Service Sector	DP Expenditure Basis (Millions of Dollars)				Average Annual Growth Rate (1967-71) %	Average Annual Growth Rate (1971-72) %
	1960	1967	1971	1972		
Data Services						
Facilities Management	—	110	645	800	56	24
Network Information Services	—[1]	45	430	600	77	39
Software	50	200	467	700[3]	24	49
Batch Services	50[2]	500	650	800	7	23
Total Data Services	—	855	2,192	2,900	27	32
Support Services						
Education	—	60	50	—	—	—
Third Party Leasing	—	50	775	—	99	—
Used Computer Equipment	—	25	225	—	74	—
Third Party Maintenance	—	3	45	—	97	—
Total Support Services	—	138	1,095	1,400	68	27
TOTAL	115	993	3,287	4,300	35	30

1) Primarily geared to DoD, NASA and large aerospace companies

2) Services offered by around 300 - 400 small, local service bureau operators

3) Software products = $ 300.million; software services = $ 400 million

Source: Figures are taken from: Roach, W.R. and Jung, D.C. - "Spending for Software and Services", in: Datamation, March 1975, p. 54

Concerning software, estimates for 1960 would put them roughly at $ 50 million which then was almost exclusively dedicated to the military and space complex. Twelve years later, in 1972, the market value of all non-captive software was $ 700 million, where software products, defined as software that has been written and marketed as a standard package to do a specific job, were still the smaller part and consisted of approximately $ 300 million. End of 1979, the independent software product industry in the United States has developed into a $ 1 billion - plus business with 1,400 vendors, 8,000 products and more than 30,000 users. (See table 4.2.). In other words, software packages have turned out to be the most dynamic of all computer services.

Tab. 4.2. The Independent Software Product Industry 1/ in the U.S., 1969-1980

	1969	1975	1979	1980 2/
(1) Annual sales ($ millions)	25	400	1,000	1,400
(2) Number of vendors of large scale software product			1,400	
(3) Number of products			> 8,000	
(4) Number of users			> 30,000	

1/These figures do not include or reflect the volume of business done by IBM or other computer mainframe manufacturers

2/November 1980 - estimate

Figures are taken from: Welke, Larry (President, International Computer Programs, Inc., the Indianapolis/USA software information service company) - "The Origins of Software", in: Datamation, December 1980

4.3.2. Types of Market Segmentation

Most software firms are specialized in a segment of the market, whether a hardware manufacturer (IBM and IBM compatible systems), an industry or a type of application.

There are two exceptions to this rule:

- Firms active in "systems software" would usually cover more than one industry;

- A few of the bigger firms, mostly affiliates of major corporations, which strive to develop what they call "a full portfolio of software product offerings".

But overall, market segmentation is the dominant characteristic. This reflects the fact that possibilities to homogenize software are still very limited, particularly in applications software. The statement by James A. Unnerstall, General Manager of Indiana Standards' Informations Services Department, reflects an experience common to practically all industries: "The probability of your programme fitting another company's system up front is practically zero." 5/
In fact, taking a programme that was tailored for one company's operations and revising it for general use requires an enormous investment, a figure that can exceed the original cost of the software. 6/

Table 4.3. presents one aspect of the present degree of market segmentation, i.e. the split between large scale equipment and mini- and microcomputer markets. 7/

Tab. 4.3. The Segmentation of the Software Market - Large Scale versus Mini and Microcomputer Equipment

Large Scale Equipment	↔ Mini and Microcomputer
- Absorbs the majority of software outlays, but hardware markets are approaching saturation limits	-Still a minority market, but large growth potential
- The great majority of this market is geared to IBM machines and IBM compatible peripherals and CPUs	-Because of great variety of hardware suppliers, exclusive orientation of software firms to a specific hardware firm or a group of products is seldom
- Consolidated patterns of competition and cooperation	-Rules of the game yet to be established, cutthroat competition dominant
- High profit margins per sale; software is usually leased or licensed, not sold	-Due to aggressive pricing policy (market penetration prices), profit margins per sales are low
- Established rules for securing maintenance and technical support services and for pricing them (maintenance fee normally ranges between 12 and 15% p.a. of the basic lease price)	-Deterioriating supply of maintenance and technical support services; no established rules for pricing them
- Highly sophisticated users; cost burden of software production high, but still under control	-Mostly unsophisticated users; to write easy to use programs is more difficult and thus more costly and time-consuming
- A global market, at least within the dominant economic blocks of the world economy (USA, Japan, Greater EEC, South East Asia and China, Latin America)	-A great variety of local rather than a national market

There are other types of segmentation. Two of them are of particular importance:

- Basic versus non-basic systems;
- Individually tailored software versus software packages.

Basic systems is a short-hand for describing those software systems which are experiencing very high demand. They include:

- Hardware utilization/performance measurement and accounting systems;

- Payroll and personnel information systems;

- Financial planning and profit analysis programmes;

- Project management and control systems;

- General accounting and integrated financial reporting systems.

It is on these basic systems that the greatest part of pre- ly available programming capacities are focussing. The e of the game in software business is specialization on a few fast-growth systems, the capacity to develop and market commercially attractive software packages and to guarantee reliable technical support.

4.3.3. Software Packages

Software packages are systems which have been developed to overcome the shortage of skilled manpower, especially programmers. Software packages are increasingly used by banks, insurance companies, but also by manufacturing firms. According to a recent American Bankers Association review for instance, in 1981 more than half of all software in US banks was provided in package form. 8/

In manufacturing firms, although use of software packages is increasing, limitations to a wide-range application of packages still seem to be **considerable.** 9/ In absolute terms, this market is of considerable importance. In the United States for instance, users of information processing systems spent about $ 2.5 billion for software packages (excluding contract software) in 1979. About two-thirds of this went to the computer manufacturers and one-third to the independent software industry. 10/

There are two types of software packages: application packages and packaged systems programmes.

Application packages include, in order of sales volumes presently realized in the US: general ledger packages, payroll and personnel records. For these basic management functions, reprogramming becomes a periodic necessity. The traditional approach would have been to delegate this job to in-house programming teams or to subcontract to independent programmers. Yet even for big firms, the costs of this approach rapidly became prohibitive. So why not buy a package instead? Of course, very small user firms getting their first computers never had any professional programmers, at most they might have hired a couple of part-time ones. Without packages (or systems so easy to use that professional training is unnecessary), the small user could have never considered a computer at all.

Manufacturing packages, on the other hand, with fewer sales so far, seem to have a **considerable** growth potential in the **future** 11/ for instance to test, measuring and analytical instruments, and to industrial electronic equipment such as motor controls, numerical controls, inspection systems, sequence controls, but also to robots and semiconductor production equipment.

Packaged systems programmes include data base managers and data dictionaries, programme development aids and schedules, and protocol translators that permit interlinking of computer systems and terminal complexes (including word processors) from various vendors.

The largest independent companies in the package business are all primarily producers of systems programmes. Demand for system packages is huge and is bound to increase: Very few users would even think of preparing their own systems programmes any more, and the computer manufacturers can satisfy only a majority (at best) of the diverse **demands** of their customers.

Further, new opportunities for systems programmes keep appearing which means that systems packages will continue to be an essential component of the software market.

4.3.4. Identifying the Actors

We have seen that software originates from the computer services market and that it has experienced rapid growth, particularly in one form, i.e. as software packages. Who are the actors engaged in this increasingly important segment of the information processing industry?

In a first step, let us analyse some figures on users and vendors of computer services. Table 4.4. and table 4.5. summarize information available for the first half of the 1970s. 12/

Tab. 4.4. Computer Services - Users and Vendors, around 1974

Users: Size and Type	Users: Services required (in order of priority)	Users: Market Shares (%)	Vendors: Type	Vendors: Market Share (%)
(1) Small 1)	NIS, batch	15	(1) Independent Vendors	>80
(2) Medium 2)	NIS, FM, software	25	- Dedicated computer service vendors	
(3) Large 3)	FM, software, NIS, support	50	- Banks providing computer services	
(4) Government	Software, FM, support	10	- Data processing spin-offs of big corporations (for instance Boeing Computer Services)	
			- Other vendors, including CPA and common carriers subsidiaries	
			(2) Computer Manufacturers	
			(3) Government Agencies	

1) =company with less than $ 15 million annual revenue

2) =between $ 15 and $ 150 million

3) over $ 150 million

Source: Figures are taken from: Roach, William R. and Jung, David C. - "Spending for Software and Services", in: Datamation, March 1975

Tab. 4.5. Major Service Firms [1] U.S. Revenues ($ Millions)

	1972	1973	% Growth
IBM	248	355	43%
Control Data Corp.	132	156	18%
Computer Sciences Corp.	119	135	13%
Boeing Computer Services	115	125	9%
McDonnell Douglas Automation Co.	109	121	10%
Electronic Data Systems	103	118	16%
Automatic Data Processing	70	100	43%

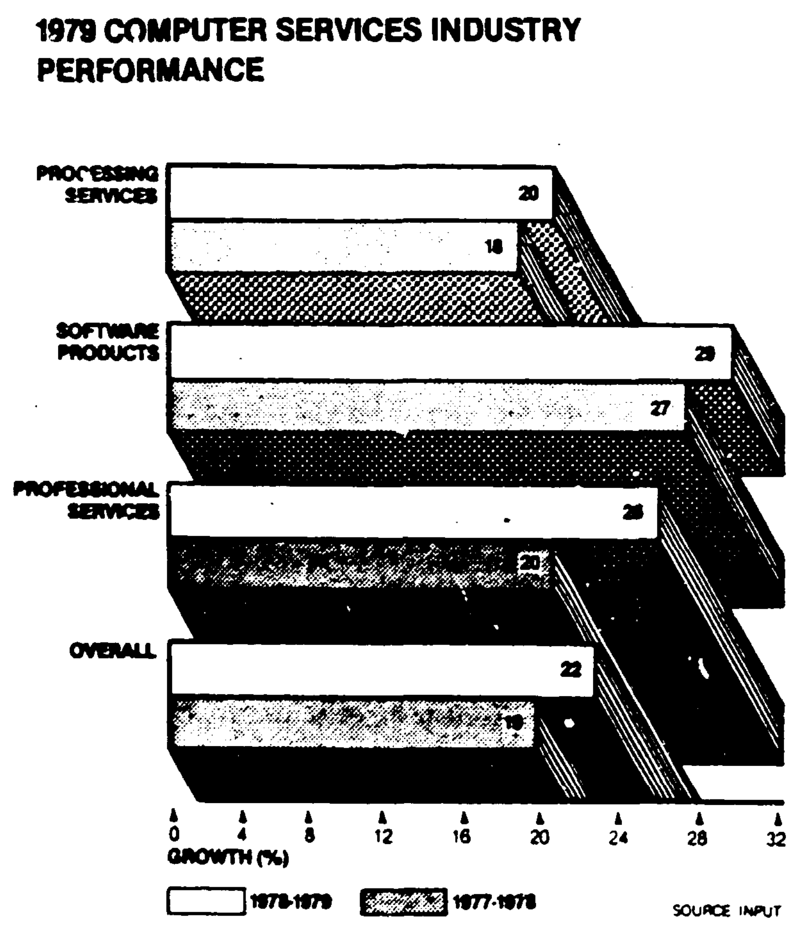
[1] Computer service companies which topped $ 100 million in 1973. Total of computer service firms in 1973: 1700. Over 2/3 of them or 1200 firms had revenues of less than $ 2 million per year.

Source: Figures are taken from: Roach, W.R. and Jung, D.C. - "Spending for Software and Services", in: Datamation, March 1975, p. 55

Historically, the computer services industry has been very decentralized, consisting mostly of small or medium size vendors offering data processing services within a local area. In 1973, for example, of the 1,600 to 1,700 service vendors in the United States, over two-third, or 1,200 firms, had revenues of less than $ 2 million per year. In addition, only seven vendors had revenues of more than $ 100 million.

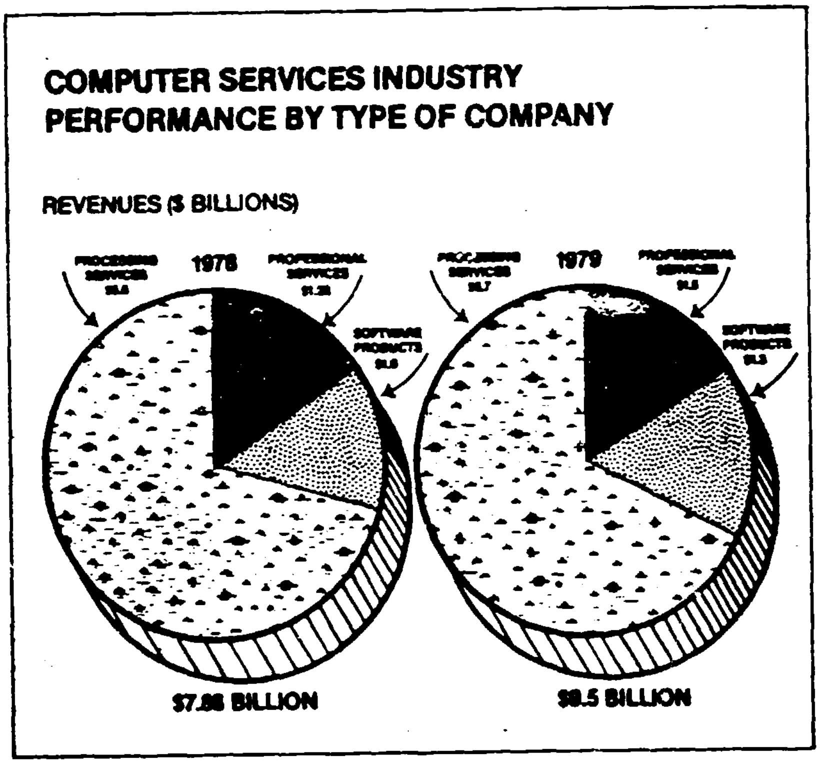
During the last years however, the computer services market, and particularly the software product market is undergoing rapid change. The odds are that large, independent service companies such as Electronic Data Systems, Automatic Data Processing, and Optimum Systems, together with spin-off vendors of multinational corporations will gain increasing importance. Add to this IBM which is still by far the largest services vendor, mostly in software, and it will become clear that, in analogy to earlier developments in the hardware sector, computer services will increasingly become a worldwide business. Three factors have been behind this trend towards concentration and globalization: the development of communication-based remote computing systems in the late 1960s, the growing importance of software packages , particularly applications packages, and the implementation of a maintenance contract as part of the business deal. 13/ Figures 4.2. and 4.3. give a picture of the U.S. computer services industry in 1979. It can be seen that the software products industry, although still by far the smallest part of the business, is experiencing very high growth rates, much in excess of the overall growth rates for the computer services industry.

Fig. 4.2. US Computer Services Industry Growth Rates, 1977-1979



Source: Input Inc. Figures, as quoted in: "Bucking the System", Datamation, July 1980, p. 51

Fig. 4.3. Computer Services Industry - Share of Activities, 1978-1979



Source: Input Inc. Figures, as quoted in: "Bucking the System", Datamation, July 1981, p. 51

That moves towards increasing concentration have recently gathered momentum has been documented in a recent study of Broadview Associates, a US financial consulting firm. 13a/ For the US computer services industry the study found in fact a sudden upsurge of acquisition and merger activities. The report identified 107 mergers and acquisitions valued at a total of $ 671 million in the industry during 1979. The 10 largest transactions accounted for $ 487 million, 73% of the whole sum paid, although they represented but 9% of the number of transactions. In the five-year period from 1975, the number of acquisitions of computer services companies has shown an 168% increase, which, according to Broadview Associates, made computer services the leading acquisition-prone industry in 1979.

Table 4.6. indicates the structure of the US software supply in 1980. It is obvious that IBM and other data processing firms, by the sheer volume of their software revenues, dominate the market. On the other hand, relatively small and specialized independent software suppliers **have been able to** survive.

<u>Tab. 4.6. "The Structure of the US Software Supply, 1980"</u>

10 LARGEST U.S. SOFTWARE SUPPLIERS

	1980 rank	Total corporate revenue ($m)	% software revenue	1980 software revenue ($m)
1 Management Science America, Inc.	43	$52	92%	$48
2 Cincom Systems, Inc.	49	$37	92%	$34
3 Policy Management Systems	44	$46	70%	$32
4 Pansophic Systems, Inc.	54	$31	100%	$31
5 Applied Data Research, Inc.	52	$37	78%	$29
6 American Management Systems, Inc.	40	$59	49%	$29
7 Software AG of North America, Inc.	58	$28	93%	$26
8 Computer Associates, Inc.	62	$25	100%	$25
9 Kirchman Corporation	53	$32	59%	$19
10 Cullinane Corporation	80	$18	100%	$18

10 LARGEST U.S. FIRMS WITH SP&S

	1980 rank	SP&S revenue (millions)	% of total corporate revenue	Total corporate revenue (millions)
1 International Business Machines	1	$1,835	7%	$26,213
2 TRW Inc.	8	$ 425	9%	$ 4,984
3 Honeywell Inc.	14	$ 295	4%	$ 4,925
4 Sperry Corporation	9	$ 383	8%	$ 4,785
5 Litton Industries, Inc.	85	$ 17	0%	$ 4,247
6 Control Data Corporation	2	$1,036	27%	$ 3,800
7 NCR Corporation	3	$ 598	18%	$ 3,322
8 Hewlett-Packard Company	11	$ 305	10%	$ 3,099
9 Burroughs Corporation	5	$ 580	20%	$ 2,902
10 Digital Equipment Corporation	4	$ 589	25%	$ 2,368

Source: Cane, Alan - "Package Software set for Boom", <u>Financial Times</u>, 13 May 1981

Overall, market trends suggest that the bigger companies will swallow up some of their rivals but that there will still be a place for small firms specializing in market niches. This would apply particularly to applications software where intimate knowledge of the application concerned is required and difficult to acquire by huge highly centralized firms. According to the <u>Financial Times</u>, "... no single company can encompass even a small proportion of all the necessary expertise. Even the mighty IBM has made it a practice of picking up the best software written by, or for, its customers." 14/

4.4. The Software Bottleneck - Relevance and Underlying Causes

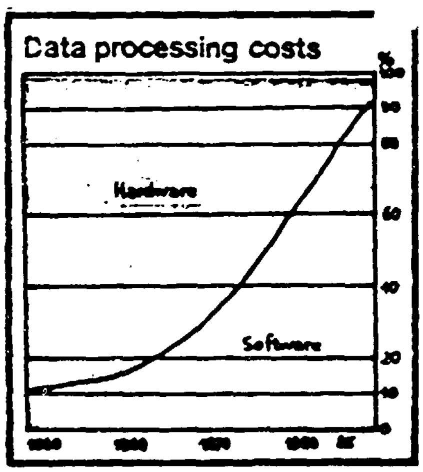
According to Martin A. Goetz, Director of the Software Products Division of Applied Data Research Inc. of Princeton, New Jersey, more than $ 100 billion has been spent around the world since the mid-1950s computerizing and automating production of goods and services.[14a] An essential prerequisite for running these computerization schemes efficiently is the availability of adequate and cost-effective software.

4.4.1. The Increasing Software Cost Burden - Some Basic Figures

Yet, the costs of developing, operating and maintaining software have been dramatically increasing, particularly sinde the end of the 1970s. This has led to what analysts of the information processing sector have become used to call the software bottleneck. This means that both semiconductor and systems firms, but also end user firms are having increasing difficulties to find adequate software at reasonable cost.

Fig. 4.4. and Tab. 4.7. indicate the order of magnitude of the increasing software cost burden.

Fig. 4.4.



Sources: Boehm, Datamation, quoted from: The Economist, March 1, 1980

Tab. .. The Increasing Costs of Developing, Operating and Maintaining Software

(1) In computer users' budgets, the proportion of expenditure for rented or purchased hardware has fallen rapidly with the introduction of microelectronics, while software costs are increasing.

(a) The findings of the Siemens study[1)]

	Average share of outlays for software in computer users' overall budget (%)
1955	5-10
1970	> 50
1985[2)]	≈ 90

(b) Trends in the U.S. Air Force computer budget[3)]

	Expenditure for software / Overall computer budget (%)
1970	20
1980	80
1985[2)]	90

(2) Costs of producing software are rapidly outpacing costs of producing microelectronic hardware

Example: The production of a program line costs on average about 10 dollars, which is considerably higher than the unit costs of state of the art microprocessors [4)]

(3) Outlays for software absorb an increasing part of the r&d expenditures of both computer and semiconductor firms

Example: For major components manufacturers, software absorbed over 50% of r&d expenditure in 1980. In the mid-1980s, this figure is expected to rise as high as 80% [5)]

(4) Outlays for software maintenance account for a growing part of of the user firms' maintenance budget

Industry estimates: 50 - 80% [6)]

1) Figures are taken from an unpublished Siemens study, quoted in: "Softwareprobleme behindern den Fortschritt der Computertechnologie", Blick durch die Wirtschaft, 6 March 1981, p.4

2) estimate

3) Figures are quoted from: Lamborghini, B. - "The Enterprise: A Mechanism to Transfer Microelectronic Innovation into Society". op.cit, p. 7

4) Software production cost figure is taken from McCracken, David - "The Changing Face of Applications Programming", Datamation, November 1978. Price quotations for 8-bit microprocessors, all of which are considerably below $ 10 can be found in: "Gate Arrays. A Special Report", Electronics, 25 September 1980, p.146

5) Figures are taken from Lamborghini, B., op.cit.

6) Various issues of Datamation

4.4.2. The Relevance

Software constraints are one of the most serious bottlenecks for the diffusion of microelectronics. There are three major concerns:

- The growing gap between hardware and programme preparation technologies which means that hardware development and the capacity to write systems and applications programmes are increasingly de-synchronized. It is estimated for instance that the latter is growing by 18% p.a., which is several percentage points slower than the rate at which computers are being installed. 15/

- The dramatically increasing shortage of software experts. According to Lamborghini, in 1980 the US demand for computer programmers exceeded the supply by at least 50,000 16/ and experts would agree that this gap is bound to increase further. Siemens, for instance, in 1980 had to spread its recruitment net all over the world to fill in the 2,800 posts required for software experts. 17/ **Similar figures have** been **quoted for IBM and Burroughs.** It would be interesting to contrast this shortage of experts within the OECD region with figures on the brain drain of software experts originating from developing countries, and particularly from some NICs. Casual evidence on Singapore, Malaysia, India, Brazil and Mexico would seem to indicate that the proportion of programmers and systems analysts originating from the Third World in the software teams of major OECD-based electronics firms is already considerably increasing. The same would seem to apply for systems houses and computer service firms. 18/

- The structural limitations for increasing productivity in software development and engineering (including maintenance and reconversion). In hardware production, economies of scale and automated mass production are possible which allows firms to reduce significantly costs. Software production on the other hand still defies a systematic application of the instruments of socalled "scientific management".

According to Lamborghini, head of the economic research department at Olivetti, it is "...still mainly the work of craftsmen, especially based on the individual skills of analysts and programmers. The job of writing software is extremely labour-intensive." 19/

This insufficient control over the process of software production has very negative consequences not only for the software firms themselves, but also for hardware manufacturers and end user firms. For all firms active in developing and applying microelectronic circuits its means a growing burden of software costs which are in fact rapidly coming close to critical levels.

Finally, a much more fundamental concern has been voiced by one of the leading computer scientists, Joe Weizenbaum of MIT. 20/ He points out that although reductions in hardware cost and size, coupled with increases in operating speeds, have increased substantially the amount of problems which computer systems could theoretically tackle, a software 'threshold' may well have been crossed. In the early days of computer programming, one person usually devised and wrote a whole computer system. But with growing complexity of computer architecture and programs, the one-man approach increasingly gave way to team programming. This in turn means that "a computer system suffers the onslaught of many people... As a consequence there are many systems for which there is no theory and no team of people who understand the whole thing."

4.4.3. Some Underlying Causes

The crucial factor seems to be the marketing strategies of the hardware suppliers. In a situation where established oligopolies became destabilized, competition centred on a frantic race to offer new and low-cost hardware. The speed of introducing new hardware is such that hardware producers (computer or components firms) could only try to adapt ex post the existing software. In other words, most of the expenditures on software engineering had to be geared to software maintenance and adaptation.

Take for instance Siemens.

According to Anton Peisel, member of the board of directors of this company, up to 80% of the company's software capacity, i.e. of the highly trained personnel capable of writing computer programmes, have to occupy themselves with software maintenance and adaptation. In other words, 80% of Siemens' software labour force has to repair the faults of the past, whereas only 20% are able to focus on the development of new software. This shows that the insufficient growth of productivity in software engineering, rather than being caused by purely technical reasons, is probably mainly due to this very particular way of organizing the software labour process. According to Joachim Schweim, managing director of SCS Scientific Control System GmbH, Hamburg, "...a firm which is forced to apply permanently more than 80% of its personnel capacities to software adaptation and conversion and which can realize new applications programmes only under extreme time pressure, will simply be unable to develop basic and long-term strategies." 21/

But why is it so difficult to get rid of this seemingly "irrational" structure of the software sector?

There are basically six reasons :

First, economic incentives to overcome the software bottleneck are hardly existing. In fact, a great variety of actors is drawing heavy profits from the present situation. Take for example the Federal Republic of Germany. Hardware firms during the last years were able to earn approximately DM 825 million annually for this type of software repair. In addition, DM 444 million have flown to a rapidly increasing number of software houses (approximately 100 - 200), programming bureaus (ca. 1500 - 1800) and management consultants in the area of data processing (approximately 600). [22/]

A *second* major reason is the increasing scarcity of adequately skilled persons, where scarcity is of course a relative concept, related to certain wage levels which firms are willing to pay.

Third, the transition from software engineering as an art to software engineering as "big applied science" is still very much in its early stage, with all the inherent inconsistencies and malfunctions.

Fourth, problems related to the organization of the data processing activities in user firms. For the relatively small number of sophisticated user firms the main problem would seem to be to devise policies of transition from organizational patterns designed around central data processing departments to those based on distributed data processing (DDP) and database management. This in itself is a very difficult process, full of trade-offs and contradictions. But the real problems are with the huge majority of medium- and small-sized firms. These firms are hardly able to implement integrated data processing systems. Rather, they are under strong and probably even increasing pressure to apply very partial solutions, socalled island solutions. One basic reason would be that financial constraints and the need to avoid cashflow problems force these firms to take a step-by-step approach rather than to risk a quantum jump in investment. The other side of the coin of this incremental approach is obvious: a proliferation of gaps and inconsistencies between hardware and software.

Fifth, the growing gap in the speed of obsolescence between hardware and software. According to Gudrun Bäumel from Diebold Deutschland Gmbh, three quarters of the presently used applications software is much older than the hardware on which it is used. 23/ This would apply both to its design and its technique of programme realization. There are two underlying causes:

- The insufficient back-up documentation for and flexibility of existing software;
- The experience that it takes a very long time to implement new applications software effectively and that very high cost overruns are the rule. This experience of deficient software introduction is bluntly stated by the head of a leading German bank's computer centre: "The old programmes are running now at least with a relatively low amount of failure, but do we really know whether the new programmes would ever run?" 24/

Finally, a sixth reason would consist of the inconsistencies and frequent changes pertaining to corporate philosophy and strategy due to changing pressures in the world market and the progression of the capital investment cycle.

4.5. Perspectives for the Future

For the software sector, it is extremely difficult to assess future perspectives. Whether or not the software bottleneck will be overcome, depends mainly on two factors:

- the availability of effective counter-strategies;

- and the impact on industrial restructuring and thus on patterns of control over strategic assets.

4.5.1. Counter-Strategies

The costs of the software bottleneck are such that attempts to overcome it are pursued with high priority. Basically five different counter-strategies can be discerned:

- Attempts to reorganize the production of software.

- Attempts to supply standardized software packages and turn-key systems, i.e. non-flexible systems where the user cannot modify programmes.

- Attempts to wire standard programmes into the hardware of computers and thereby, in theory, mass-produce the software which in this case is called firmware.

- The proliferation of independent software houses.

- International subcontracting with regard to programme reconversion and applications software.

Expectations are running high. Yet it seems that none of these approaches still has been able to overcome the two most basic problems:

- The dependence of programming work on the creativity of highly paid individuals whose activity defies quantitative measurement and therefore control

- Software to a large extent has to be individually tailored to the needs of each customer.

4.5.2. The Failure of Attempts to Reorganize the Production of Software

According to one leading expert, "...the programming of computer applications is about to turn a corner. After 25 years of writing programmes in languages like FORTRAN and COBOL, in which we have to tell the computer h o w t o d o what we want, we are now on the verge of being able to tell the computer only w h a t w e w a n t, then let i t figure out h o w. A change in method which will have a profound impact on the computer industry is a long-needed response to the 'software crisis' that has plagued us for years." 25/ Of particular importance are attempts to increase the use of high-level languages (for instance Ada) which are expected to enable programmers to write software faster. New programming languages which promise to make computers easily accessable to all come up regularly - and equally regularly fail to make any impact on the professional data processing world. A recent example would be APL which is being commercialized by the American software house STSC (=Scientific Time-Sharing Corporation). According to the Financial Times, STSC claims that it would take only one quarter of the time to develop applications programmes using APL than other languages - the competition includes COBOL, PL 1 and BASIC. But there is a price to be paid of course: all that simplicity for the user means lots of software behind the scenes - the production of APL requires very complex software and software development systems. The quoted cash price for APL is about £ 20,000 - or £ 750 a month on lease. 26/

The same would apply to attempts to "taylorize" programming through segregation of tasks and devicing patterns of division of labour between programmers, the socalled "structured programming". 27/ Finally attempts to adapt CAD (=Computer Aid Design) techniques to software development, have recently gained increasing prominence. 28/

Overall, these attempts to reorganize the development and production of software seem to have led to a considerable reduction of programming time and complexity. Further, flexibility has been increased, as has the ability to respond to requirements not anticipated in detail when the application was first programmed. Finally, the time needed for maintenance programming has also been considerably reduced.

Yet despite of these improvements, there is still a long way to go to cover the productivity gap between hardware and software development. The productivity for instance of today's programmers is no more than two or three times the productivity of programmers a quarter century ago. In the same period, the price/performance ratio of the computer hardware has improved by a factor of perhaps a million. In addition, programming tasks are getting harder. To quote McCracken again: "As we learn how to solve one class of applications, we tackle harder ones. The software problem is therefore a rolling crisis." He concludes: "In a word, the rate of improvement in programming productivity... is just too slow to keep up with the demand for new applications." 29/

4.5. Implications for Industrial Restructuring

The aforementioned changes in the software sector will increasingly condition corporate strategies. This would first apply to the information processing sector itself, but later on it would increasingly spread over to a growing number of industrial user sectors.

Corporate strategies would be affected in various ways. Two aspects of particular importance are attempts to restructure the firm in terms of product, organization and vertical integration and strategies of sectorial and geographic redeployment.

One school of thought purports that the decentralization of software production could play a significant role in this process. The proliferation of small software houses which are able to produce software at costs lower than the internal costs of the systems manufacturers could become an important factor for a new round of destabilizing the dominant oligopolistic structures. In other words, trends in the software sector, according to this view, could contribute to a process of vertical disintegration of huge highly diversified electronics firms and thus counter at least so some degree the powerful moves towards increasing concentration. 30/

Software strategies related to microcomputers would seem to be a case in point. The microcomputer industry is clearly among the most dynamic industries in the electronic sector. Competition which is getting more and more fierce, will increasingly center on the development of software strategies. 31/ Actors involved in this competition are computer manufacturers with in-house software development capacities and independent software houses active in the area of microcomputers.

Increasingly, the market success of a particular microcomputer system depends on the availability of good software and reliable documentation. Most of the first-class software originates today from independent software houses. This trend seems to continue and most hardware producers prefer to procure software from independent software houses.

Take for instance IBM. Since the introduction of its personal computer in August 1981, [32/] IBM has contracted with independent software houses in the U.S. to adapt two widely-used operating systems for use on its microcomputer. IBM is also experimenting with some unconventional tactics. In an unprecendented move, the computer giant has opened up, at least selectively, the software market for its system. It is encouraging users to develop applications packages for the machine and offering to publish those which it approves. To get the ball rolling, IBM employees are being offered incentives to purchase the machine and develop software in their spare time. The company obviously expects that this approach will help to build up a large library of application software for the machine - at relatively low cost and under tight control of IBM.

On the other hand, competition between major software producers is becoming increasingly intense and thus moves to increasing concentration are bound to multiply. This applies to all the major market segments, i.e. operating systems, languages, compilers and application packages.

With regard to operating systems, the name of the game is standardization. For 8-bit microcomputers for instance, the CP/M-system software of Digital Research has become the de facto standard. For 16-bit system software, the fight has just started and Creative Strategies International (CSI) [33/] expects that the dominant firms will have established their position during the next two years. Actors involved include Digital Research, Micro Soft Inc., Bell Labs., Onyx, Cromemco and others.

Our own position would be that it is probably too early to predict the final outcome. After all, developments in the software sector cannot be analysed in isolation from the dialectics of forward and backward integration which is increasingly becoming the dominant characteristic of the overall electronics industry. With the growing pervasiveness of microelectronic devices, these battles over strategic assets and markets will increasingly spill over to sectors outside the traditional confines of the electro-mechanical industry, with the result that predictions will become even more difficult. 34/

4.5.4. The Concentration and Globalization of Control

In the final analysis, I would expect trends towards an increasing concentration and globalization of control over strategic assets to prevail also in the software market. This expectation is based on four factors:

- the rising cost burden of designing, engineering and maintaining software;
- the huge cost of developing appropriate high-level languages;
- basic limitations to the software package approach;
- the need to expand in-house application teams.

During the forthcoming new rounds of office automation and computerization of production, the importance of software will further increase. For firms intending to apply microelectronics-related innovation, the question of how to procure, control and maintain cost-effective system and application software will become of increasing importance.

Firms wishing to acquire dominant positions in the software sector, are ultimately confronted with four key conditions of success:

a) The development of new modes of computerizing the design, engineering and maintenance of software, particularly application software. In other words, new programming tools are required which are based on new, more powerful CAD systems which allow for inter-active programming. It is through this new applications development tools that it would be possible to reduce the time needed to develop applications programmes, and in addition to reduce development and maintenance costs. This last point, i.e. the reduction of the number of personnel that has to be allocated to software maintenance, is of crucial importance, because it would allow to dedicate a higher proportion of the highly paid software personnel to the development of new applications.

b) The development of high-level languages embedded in inter-active development systems which would allow to reduce the applications development effort by as much as 80 - 90% and the maintenance effort by up to 95%. 35/

According to Goetz, 36/ high-level programming will reach much higher levels than was achieved in the 1960s and 1970s with languages as COBOL and PL/I. There are two reasons for these new productivity gains

- First, the inter-active programming at a terminal permits the computer to prompt, show and help the user in many new and innovative ways. Immediate use of feed-back and examination of results using new high-level languages and commands can significantly reduce the programming effort.
- Second, high-level statements that elimate inputs/outputs statements interacting with the data dictionary, and that provide for structured logic and non-procedural statements (that is, definition of reports), can reduce significantly the overall effort required for applications development, maintenance and enhancement.

c) Integrated management of data base systems. Most companies need more than a data base administrator; they need a complete department that controls the use and modification of data within the corporation.

One major reason is that applications packages will hardly ever be able to fill the need for the majority of applications that will eventually be computerized within a corporation. Therefore, the in-house development of computerized applications will continue to play an important role to meet unique company requirements which cannot be satisfied by an applications package. According to Goetz "...the use of data base management systems and software development tools associated with these applications provides the most effective solution for most individual companies that have complex operations shared among departments and divisions." 37/

d) Sufficient investment in high-quality technical personnel. In other words, whatever progress will be made in software packages and in the miniaturization of hardware, micro-electronics-based automation systems can hardly be effectively implemented without the active participation of an "elite corps of high-technology engineers building computerized application systems". 38/

To conclude, the software market which is of strategic importance for the future growth of microelectronic applications is still characterised by relatively low barriers to entry and a fairly wide-ranging heterogenity of firms involved. At present cost-price ratios, subcontracting arrangements with independent software houses and computer service companies are attractive - at least for certain types of software activities. Yet the economies of desiguing, engineering and maintaining software, particularly of applications software, are rapidly causing a considerable increase of barriers to entry. Consequently, trends towards an increasing concentration and globalization are bound to multiply also in this industry.

CHAPTER 5.

THE INTERACTION BETWEEN RECENT TECHNOLOGICAL BREAKTHROUGHS AND INDUSTRIAL RESTRUCTURING

5. The Interaction between Recent Technological Breakthroughs and Industrial Restructuring

5.1. Implications for Corporate Structure and Strategy

We have seen that due to recent technological developments, the economics of designing and manufacturing semiconductors have been subordinated to a radical change. A branch which used to be characterized by a relatively high labour intensity, today experiences sky-rocketing capital outlays and a dramatic upsurge in capital intensity.

In addition, the combined effect of demand stagnation and profit squeeze and the semiconductor industry's high vulnerability to any economic recession has made this industry less attractive as an investment opportunity. In other words, the semiconductor business is increasingly running into problems of capital formation and investment. It is in this context that we have to discuss implications for corporate structure and strategy.

5.1.1. The Search for New Modes to Finance Growth

At the same time as costs rise, product life cycles are becoming shorter and shorter. In other words, a faster recovery of increasingly huge investment sums is required which puts increasing strain on the financial capacities of semiconductor firms.

We have already documented the increasing cost burden of capital expenditure and how this has increased the profit squeeze for major semiconductor merchant firms. 1/ The important point is that both trends are not just short-term ones, but seem to be closely related to long-term structural change, i.e. a radical transformation of the economics of semiconductor manufacturing.

In fact, the crucial issue is that the cost of new production and test equipment is rising faster than profits even for the industry's leaders. George Heilmeier for instance, vice president for r+d at Texas Instruments, recently observed that with investment costs of a complete new manufacturing line today running up to $ 40 million, even a firm like Texas Instruments would have to be increasingly selective about new markets. [2/] In other words the changing economics of semiconductor manufacturing might impose increasingly narrow limitations to strategies of innovation and market penetration. According to Datamation: "Industry leaders have warned that unless firms are able to improve their profit margins, very few of them will be able to effort the development and capital equipment cost to produce state-of-the-art VLSI circuits." [3/]

How to finance growth has indeed become a dominant concern among major semiconductor firms, particularly US merchant firms, and established doctrines of innovation and production management and marketing are being increasingly questioned.

In principle, there are three possible approaches to an increase of profits and thus to reestablishing the capacity of semiconductor firms to generate internally the increasing funds needed for capital formation:

- they could try to manipulate prices;
- they could attempt to lower costs through improved productivity;
- or, finally, they could take recourse to a cutting-back of production.

(a) The traditional approach: focus on yield improvement and learning curve pricing

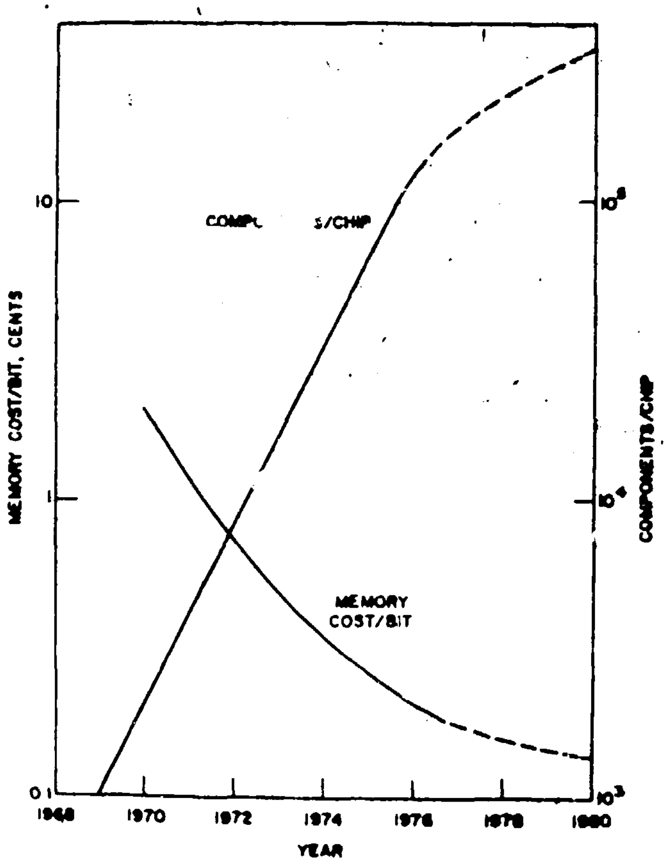
Traditionally, the industry has been characterized by an aggressive market penetration pricing strategy, called "learning curve pricing" [4/] which was made possible by the persistent and rapid decline in the cost of a given electronic function. In fact, the cost of a given electronic function has been declining even more rapidly than the cost of integrated circuits, since the complexity of the circuits has been dramatically increasing, as their price has decreased.

For example, the cost per bit (binary digit) of random-access memory has declined an average of 35% per year since 1970, when the major growth in the adoption of semiconductor memory elements got under way.

The principal cost determinant for semiconductor is yield, i.e. the amount of devices per wafer that passes final testing. [5/]

Figure 5.1. shows the ability to pack electronic components on a single chip (die) while maintaining acceptable yields. The number of components per chip has been doubling every year [6] and in the near term is expected to continue doubling every 2 years or less. At the same time, the cost per function (in this case, per bit of memory) has been declining rapidly. It is this combination of increased functional complexity and decreased functional cost that is expected to cause rapid proliferation of electronics into many formerly nonelectronic areas. [7]

Figure 5.1. Trends in the Cost and Level of Integration in Monolithic Circuits



Source: Wise, Kensall D. et al - "Microcomputer: A Technology Forecast and Assessment to the Year 2000", John Wiley & Sons, New York, 1980, p. 13

It is due to this tremendous decrease of functional cost that prices for electronic components since the development of the integrated circuit have experienced a more than hundredfold decline. This in turn has allowed the semiconductor industry to double output annually over an extended number of years. According to Robert N. Noyce, vice president of Intel Corp., this has meant that rather "... than serving a market that grows only in pace with the gross national product or the population, the industry has served a proliferating market of ever-broadening applications. As each new application consumes more microelectronic devices, more experience has been gained, leading to further cost reductions, which in turn have opened up even wider markets for the devices." 8/

"Learning curve pricing", perhaps the most important management innovation of the semiconductor industry, today is running into increasing problems.

Traditionally, as semiconductor firms learned how to improve their yields, these "learning-by-doing" effects, which go along with increasing output, would be reflected in significant price reductions. Radical price cuts in turn stimulated new markets and volume-related reductions in manufacturing costs. Thus, by driving down unit prices, vendors sold much more and ultimately made higher real profits. Major US semiconductor firms, such as Texas Instruments, Motorola and Intel have been pioneering this type of pricing policy. Japanese firms were soon to join this game, particularly for 4K and later on for 16 K RAMs.

Yet, as we have already shown, recent structural changes in the industry are increasingly obstructing this "learning cost curve" approach. This was true even as long as demand for most semiconductors exceeded supply and immediate sales were usually assured. Today, in a situation of demand stagnation, these constraints have become even more serious.

As complexity - measured in chip size and number of processing steps - goes up, so does the yield uncertainty. One day yields are good, the next day yields are disasterous. Each manufacturer hopes to sell devices at a price sufficiently high to generate a target revenue per wafer in order to cover costs, profit margin, and yield uncertainties.

In fact, as the state-of-the-art in RAMs, ROMs and EPROMs went from 4 K to 64 K, price reductions, fuelled by an increasingly aggressive Japanese competition, continued to cause market expansion, but because of significantly rising costs of production, actual net profits as a percentage of sales shrank considerably. In other words, prevailing sales prices did not generate any more sufficient revenue per wafer. Thus, semiconductor firms are increasingly loosing their capacity to generate internally the increasing funds needed for growth.

(b) The defensive approach: cutting back production

In 1979, major US semiconductor firms clearly chose the last of the three aforementioned options, i.e. cutting back production. For example, Texas Instruments, National Semiconductor and Intel were all cutting back on 4 K MOS RAM production in spite of strong user demand and lead times of up to four months. In fact, the last two firms, in late 1979, were quietly buying 4 K RAMs from Japanese firms to supply to their US customers, and to enable their own production resources to be diverted to more advanced products with better profit margins. [9] In other words, much of the 1979/1980 "chip crisis" might have also been a result of deliberate strategic choice.

In 1980, this move towards cutting back production gathered momentum, encompassing now increasingly the phasing-out of whole product groups - witness for instance the phasing-out of bubble memories by such prominent firms as Texas

Instruments, Motorola and NSC, despite the fact that each of these firms had to write off huge r&d and investment outlays. 10/

5.1.2. Transition to Cut-throat Competition - the Role of Japanese Firms

Clearly an important development of the last years has been the fact that Japanese firms were able to make significant inroads into the most dynamic market of the semiconductor industry, i.e. the market for integrated circuits. This would apply especially to memory chips, particularly 16 K RAM chips.

Obviously, the attack by Japanese firms has changed the face of the industry and obviously too the new role of Japanese firms is bound to influence the interaction between innovation and industrial restructuring. In fact, some observers are convinced that Japanese firms are already about to achieve dominance in major segments of the world semiconductor market and some go even further to predict a new "Japanese challenge" for the world computer and telecommunications markets. 11/

No doubt, Japanese firms, thanks to their aggressive strategies of selective market penetration, have set in motion a process of destabilizing US dominance in this sector. But whether this will lead to a viable multipolarization of control over strategic assets, both in semiconductor manufacturing, and in the electronics sector at large, remains to be seen.

(a) The subordinate role played by West European firms

What seems to be obvious however is that Western European firms, including Philips and Siemens, so far have played a subordinate role in this game. Due to insufficient innovative and productive capacities they have been unable to gain from the chip shortage of 1979, and are still far behind, if not falling back further, in crucial areas, such as: VLSI design capacities; the design and production of semiconductor equipment, particularly of lithographic equipment for the sub-micron range; software development and engineering techniques; and the application of CAD/CAM techniques to circuit design.[12] Further, with regard to production efficiency and yield per wafer, most European firms involved in semiconductor manufacturing are lagging very much behind their Japanese and even behind most of their US counterparts.

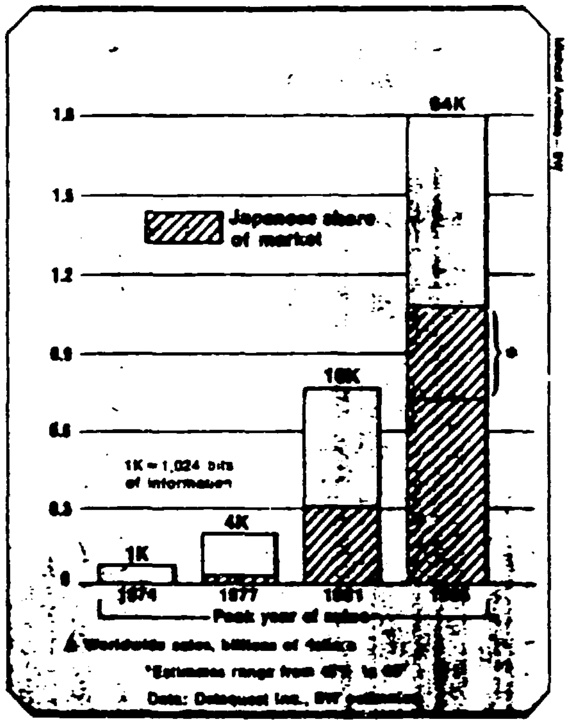
Thus, by and large, European firms are bound to play a relatively passive role in the forthcoming battles to gain control over the strategic assets of this potential key growth industry. This is in fact the conclusion drawn by a recent study on the semiconductor industry in the EEC undertaken by the Sussex European Research Center: "... a Japanese-style catch-up strategy in semiconductors would make little sense for the EEC; the Americans and the Japanese are too far ahead, and it is essential that their technology should be freely available to the European electronics industry." [13]

(b) The scope for further market penetration by Japanese firms

After the chip crisis of 1974/75, the Japanese firms, in contrast to their US counterparts, did not cut back investment and r+d outlays. On the contrary, they proceeded with their long-term strategy of capacity expansion. They were thus able to react quickly to the chip shortage of 1979. Thanks to an aggressive pricing policy they could increase their market shares considerably, so that in 1980 they were already controlling 40% of the US semiconductor market. [14]

Fig 5.2. documents the dramatic increase since 1977 of the Japanese share in the world market for memory chips. Till 1985, according to some estimates it is expected to run up to 60%.

Fig. 5.2. The World Market for Memory Chips-Trends and Structural Change, 1974 - 1985



Source: "The Chip Makers' Glamouros New Generation: the 64 K", Business Week, 6 October 1980

It remains however to be seen whether Japanese firms will be able to continue their market penetration. It seems that most projections on the development of market shares have somewhat hastily assumed that Japanese firms will be able to win the "US-Japanese semiconductor war". Yet, recent developments in the first quarter of 1981 indicate that this will not be that easy. Japanese firms owe much of their penetration success to dramatic price reductions, particularly for 16K RAM chips. The unit price for such chips which in January 1980 was quoted as $ 6, in March 1981 had already fallen to $ 2 and is declining even further. [15]

Even the most successful of the Japanese firms will hardly be able to continue with such a ferocious price competition. Furthermore, US-firms have reacted with a threat to undertake anti-dumping measures. On March 15, 1981, Nippon Electric Corp.(NEC), the biggest Japanese producer of semiconductors, stopped to export 16K RAM chips to the US market, at least the open one. [16] It further announced its intention to serve the US and the West European market increasingly from its production facilities in the United States and Ireland. This recent move of NEC indicates that Japanese firms might have to substitute market penetration from production facilities, based in the US and Ireland, for production via exports. Overall, the trend towards greater Japanese electronics exports both to the U.S. and Western Europe seems to continue unabated.

Latest figures from the Electronic Industries Association in Japan, as presented in table 5.1., underline the dynamics of Japanese semiconductor firms.

Tab.5.1. The Japanese Semiconductor Industry - Recent Trends, 1980/81 [a] (growth rates in %)

(1) Production	
- all semiconductes	36
- integrated circuits	45
(2) Exports	
- semiconductors	27
- integrated circuits	36
(3) Imports	
- semiconductors	9
- integrated circuits	6

a) =fiscal year 1980/81, from 1 April 1980 till 31 March 1981

Source: Figures are from Electronic Industries Association of Japan, as quoted in: "Japan steigert kräftig den Halbleiterexport" , Blick durch die Wirtschaft, 3 July 1981

(c) The widening US-Japanese trade gap in electronic-based products

For the U.S., recent figures of the U.S. Department of Commerce [17/] show that the trade gap of this country with Japan continues to widen in six out of eight electronic product areas.

Tab. 5.2. US Trade With Japan In Electronic-Based Products, 1975 - 1980
(millions of current dollar)

Product group		1975	1976	1977	1978	1979	1980
Telephone and telegraph equipment	I	5.6	5.1	4.4	6.3	8.1	6.6
	II	25.6	31.1	44.9	92.9	105.6	163.3
	III	-20.0	-25.0	-40.5	-86.6	-97.5	-156.7
Electronic systems and equipment (commercial, military and industrial)	I	52.8	51.1	51.6	49.2	66.4	76.9
	II	111.2	193.7	781.5	391.1	350.4	438.6
	III	-58.4	-142.6	-729.9	-341.9	-284.0	-361.7
Electronic components	I	109.1	141.9	133.0	172.3	253.4	238.2
	II	161.2	257.7	371.5	502.0	698.6	830.0
	III	-52.1	-115.8	-238.5	-329.7	-445.2	-591.8
Electronic computing equipment	I	189.3	239.5	279.5	331.1	441.1	607.3
	II	32.3	41.7	57.9	187.2	195.7	189.3
	III	+157.0	+197.8	+221.6	+143.9	+245.4	+418.0
Consumer electronics	I	22.1	28.4	25.2	37.2	55.4	61.6
	II	1,251.5	2,578.0	2,047.7	2,757.7	2,350.7	2,337.1
	III	-1,229.4	-2,549.6	-2,022.5	-2,720.5	-2,295.3	-2,275.5
Calculating and accounting machines	I	9.4	7.8	12.3	19.2	18.5	22.2
	II	180.1	229.4	240.0	338.8	300.3	373.3
	III	-170.7	-221.6	-226.7	-319.6	-281.8	-351.1
Typewriters and office machines	I	4.4	9.9	12.4	13.6	19.7	25.5
	II	100.1	162.8	203.0	190.0	226.9	256.6
	III	-95.7	-152.9	-190.6	-176.4	-207.2	-231.1
Photo-copying machines	I	4.6	6.5	14.6	13.9	16.1	17.7
	II	70.2	105.4	163.9	290.3	307.9	424.0
	III	-65.6	-98.9	-149.3	-276.4	-291.8	-406.3
Totals	I	397.2	490.2	532.9	642.7	878.7	1,056.0
	II	1,903.1	3,599.9	3,910.6	4,745.1	4,536.1	5,012.2
	III	-1,505.9	-3,109.7	-3,377.7	-4,102.4	-3,657.4	-3,956.2

Note: I = Exports
II = Imports
III = Trade balance
(+ = Surplus; - = Deficit)

Source: U.S. Department of Commerce, Bureau of Industrial Economics, adapted from table published in Hindin, Harvey J. - "Trade gap with Japan widens", Electronics, 2 June 1981, p. 102

Besides the classical deficit of consumer electronics which is worth now $ 2.3 billion, the most rapidly growing deficit took place for components and particularly semiconductors. In fact, since 1975 this deficit has increased more than tenfold! All in all, in the eight sectors charted by the Department of Commerce figures, the 1980 gap was wider than that of 1979 in six, and narrower in only two. The total 1980 trade imbalance was the second widest in six years, exceeded only by that of 1978. Even for computers where US firms used to have a safe lead, it would seem as if Japanese firms are rapidly gaining ground - whereas in 1975 the ratio for electronic computing equipment of US exports to US imports was roughly 6:1, in 1980 it had declined to just over 3:1.

(d) Towards a new "Japanese Challenge" for the world computer and telecommunications markets?

It remains to be seen however whether the new goal proclaimed by MITI for 1985, i.e. "the dominance of the world computer market" [18/] can be realized. After all, the huge Japanese electronics conglomerate are notorious for their weakness in providing software and service, let alone creative design or future-oriented basic research. This would apply, as a recent report by Electronics [19/] has shown, even to those firms which like Fujitsu, Hitachi and Nippon Electronic are mainly concerned with computers and communications. On the other hand, these firms, together with Toshiba Corp., have recently started to create specialized firms which are supposed to develop the software needed for VLSI chips. [20/] In addition, Japanese firms recently have been very active in trying to tap the pool of still relatively low-paid software engineers and systems analysts, available in the UK [21/] and have recently started to engage in the multi-pronged programme of the government of Singapore to train computer programmers. [22/] In the final analysis however, it would seem that the Japanese Science and Technology System is hardly able to cope with the problem of overcoming the software-bottleneck - at least not within such a short period.[23] It seems likely, as the Financial Times Survey[24] points out, that with the increasing spread of computer use, the demand for new software will continually outrun the supply. Thus, Japanese semiconductor firms will probably continue to rely on bringing in Americans for specialized systems development - though companies are usually quiet on this dependence.

To conclude, Japanese firms have clearly succeeded in enlargening their market shares in semiconductor world markets, particularly for mass-produced LSI standard devices. They have reached this position because they were able to outdo US competitors in quality and reliability, price and performance.

But to claim that they are about to achieve dominance in the world semiconductor markets would seem to be premature. This would apply even more so for the world computer and telecommunications markets, the two key markets of the future. There would thus seem to be some need to demystify the widely quoted "Japanese challenge", or more precisely, to reduce it to its correct dimensions.[25]

5.1.3. The Search for New Patterns of a Division of Labour Between Firms Involved in Semiconductor Manufacturing

(a) The driving forces

We have seen that in a situation of rapid structural change and of a worsening economic crisis, traditional approaches towards corporate strategy and structure cease to work sufficiently. On the other hand, a defensive approach such as cutting back production and phasing-out whole product lines is no viable solution at all to the increasing constraints facing semiconductor firms. In addition, new strategies and organizational arrangements have recently emerged, developed particularly by Japanese firms. Thus, those firms which used to dominate the world semiconductor industry practically uncontested till around 1978, i.e. basically the ten leading US firms, do not have much choice today but to look for new approaches to adapt corporate structure and strategy. It is in this context that the search for new patterns of a division of labour between firms involved in semiconductor manufacturing has recently gathered momentum, particularly in the U.S.

Basically, there are three different types of arrangements in this field:

- The first type of arrangement relates to a division of labour between unequals, i.e. mainly new forms of sub-contracting arrangements, where minor or new start-up firms step into stages of production and product ranges which the dominant firms for a variety of reasons do not want anymore to cover themselves. This would relate in particular to the upsurge of assembly subcontracting arrangements during the chip shortage of 1979/1980 where major US merchant firms engaged an increasing number of tiny firms originating in Southeast Asia, especially the Philippines. We will discuss in detail this type of subcontracting arrangement in chapter 6.

The additional two types of cooperation by and large relate to a division of labour between equals. In fact, it would seem as if they are going to engage increasingly only a small number of dominant firms.

- The <u>second</u> type of arrangement relates to new forms of subcontracting in the field of silicon foundry services. We will show that major US merchant firms recently established strong positions in this market and will discuss some of its implications.

- The <u>third</u> type of arrangement finally relates to the recent trend towards increasingly extensive inter-company cooperation. Again we will show that major US firms are involved and will identify the logic underlying this development.

Before we are going to discuss in detail the second and third approach, we should add that, from the very beginning, these new and to a large degree still experimental forms of a division of labour between semiconductor firms, have not been restricted to one particular country, e.g. the US, or one particular region, e.g. the EEC, but tended to be global in nature. In addition, these changes internal to the semiconductor industry are increasingly interlinked with the dialectic moves of forward and backward integration which are rapidly restructuring the global electronics complex (see 5.2. and 5.3.).

(b) New subcontracting arrangements in the field of "silicon foundry services"

According to recent reports from electronic consulting firms and newsletters, [26/] the semiconductor industry is just about to experience a new round of industrial restructuring which might again change considerably the economics of semiconductor manufacturing. I am talking about the recent rapid expansion of a seperate market for silicon foundry services in the US, a development which even the most intimate "connaisseurs" of this industry were unable to visualize hardly one or two years ago. According to Intel, this market in the US alone in 1981 was already worth $ 135 million and will grow to $ 680 million by 1985. [27/]

Silicon foundry services is a loosely used proxy for all kinds of manufacturing and service activities. Usually, their main focus is on wafer-fabrication, i.e. on transforming the original design, as embodied in the mask, into a silicon architecture. The name silicon foundry is derived from the fact that this was originally done primarily by means of chemical processes and heat treatment. Silicon foundry services thus can be roughly defined to exclude on the one hand IC design and mask making and on the other assembly and final testing.

In reality, an independent silicon foundry service firm would usually receive from a huge computer or telecommunications equipment manufacturer a basic design for a highly complex non-standard IC of which the equipment manufacturer wants to be sure that it cannot be purchased or copied by his competitors. Much of the detail of VLSI design is then handled by the silicon foundry service firm by means of computer aided design tools.

The essential point is that the barriers to entry into the silicon foundry services market are very high indeed - the equipment firm wants to be sure that it can get access to a great variety of complex and effective computer programmes which the silicon foundry service firm has developed in-house and used in the design of new chips, microprocessors and memories. This approach allows systems designers to draw up integrated circuits layouts without having too much concern for the details of the circuits, and thus contributes considerably to a reduction of design costs and lead time. In other words, system firms expect silicon foundry service firms to be able to offer customers some of the most advanced semiconductor processes available today, and in multiple locations so that the customer is always assured of supply.

Consequently, the range of firms which could hope to enter successfully this market for silicon foundry services is very restricted. This is in contrast to earlier expectations according to which newcomer firms and even some firms originating from offshore locations in South East Asia might be able to enter this field.

US Semiconductor Merchant Firms Enter the Stage

Three of the major US semiconductor merchant firms, i.e. Intel, Motorola and National Semiconductor seem to have already established strong positions in this market. Intel for instance in September 1981 announced that, with annual sales approaching $ 800 million, it will turn as much as 10% of its production capacity over to the new venture into silicon foundry services. The company expects the new operation to have sales of $ 100 million a year within a couple of years.

The logic underlying the emergence of this new market can be roughly described in the following way:

<u>Systems manufacturers</u>, i.e. particularly computer and telecommunications equipment firms, are under growing pressure to build systems that offer exclusive features. To do this they need non-standard electronic devices - ones that cannot be purchased or copied by their competitors. Some of the

largest <u>systems manufacturers</u> have acquired their own chip manufacturing facilities to make these parts, but with the cost of setting up a semiconductor manufacturing plant approaching $ 100 million, silicon foundries offer an attractive alternative.

<u>Semiconductor merchant firms</u> have different motivations. It would seem safe to mention at least three of them:

- <u>First</u>, the down-turn in the US economy, which has its effect upon the semiconductor market, has prompted semiconductor makers to accept foundry business as a means of keeping production lines busy. Many of the companies that are presently "filling in" with foundry business will turn it away when the economy turns up, some analysists predict.

  On the other hand, all major semiconductor merchant firms, during the last two to three years, have considerably increased their production capabilities by building new plants and increasing the yield of good chips made out of each silicon wafer. Consequently, there are huge surplus capacities existing now, particularly for mass produced standard devices, and it is very unlikely that even the most powerful economic upturn will be able to absorb their output. In other words, there would seem to be enough pressure for semiconductor merchant firms to stay in the silicon foundry services business, at least as long as the existing overcapacities have not been written off.

- <u>Second</u>, strategies to enter the silicon foundry services market might be conceived as a counter-strategy to foreign,and particularly Japanese competition. Take for instance Intel. Its move into the silicon foundry business to make custom chips marks a dramatic departure from the company's previous policy of sticking almost exclusively to high profit innovative device products. With that business now under increasing threat from Japanese competitors, Intel is switching towards a market in which close customer supplier relationships are crucial, one which is largely immune to foreign competition. The new strategic focus is aptly described by Jack Carsten, vice president and general manager of Intel's microcomputer division: "The silicon foundry operation is a major committment by Intel to the new business of marketing our state-of-the-art manufacturing ability." 28/

- Third, an additional advantage that silicon foundry services offers for semiconductor merchant firms is that it shifts design and development costs and risks to the customer. For today's highly complex chips this is a very significant investment.

Of course, these developments are so recent that it is probably too early to draw well-established conclusions. But it would seem safe to conclude that if the move of major semiconductor merchant firms into the silicon foundry services market continues, this would be just another factor adding to the increasing concentration of control over the semiconductor industry. Consequently, chances for newcomers and firms originating from offshore locations in South East Asia and other Third World areas to enter the field of designing and producing microelectronic circuits will even further deterioriate.

(c) The new trend towards inter-company co-operation

A second approach to establishing new patterns of a division of labour within the semiconductor industry brings together firms of relatively equal strength. We are talking about the new trend to establish among major firms new forms of extensive cooperation agreements. In contrast to conventional types of very selective cooperation, for instance the socalled "second sourcing" agreements, these new types of cooperation agreements have a much broader scope and tend to focus in particular on joining forces in the development and marketing of high technology devices.

A case in point would be the recent extensive cooperation agreement signed by two major US semiconductor firms, i.e. Intel Corp and Advanced Micro Devices (AMD) on 11 October 1981. [29/] According to this agreement, both firms will cooperate over the next ten years in their development and marketing of the following types of devices:

- top range 16-bit microprocessors designed by Intel;

- special peripheral parts linked to them, as designed by AMD.

In addition, AMD will allow Intel access to its bipolar processing technology which is expected to become of strategic importance for the new markets of super-fast logic circuits and telecommunication devices. [30/]

The impact of this cooperation agreement will be considerable indeed. As partners, rather then competitors, AMD and Intel will represent a major new force in the semiconductor business. Intel is the world's fourth largest manufacturer of integrated circuit 'chips' after Texas Instruments, Motorola and National Semiconductor. Sales last year were $ 855 m. AMD ranks ninth in the world with sales of over $ 300m.

The logic underlying this new trend towards inter-company cooperation centers around five basic motivations:

- First, a defensive one, i.e. to counter the impact of the economic crisis. Intel's operating earnings for instance during the first nine month of 1981 showed a decline of 82% to $ 25.5 million from $ 143.4 million in the same period in 1980. AMD did even worse: for the quarter ending September 27, 1981, it reported an 85% drop in net income from $ 7 million to $ 1 million and a 16% drop in sales.

  Obviously, the situation is such that firms have to run behind even the slightest improvement made possible by arrangements to join forces and consolidate markets.

- Second, an additional defensive motivation arises from the concern of most US semiconductor firms to fend off increasing competition from Japan. In the case of Intel's 16-bit microprocessor for instance, three Japanese companies are already producing copies of it, two of them without licence from Intel. No doubt this has calmed down Intel's earlier resistance to share technology with compatriot US firms.

- Third, companies perceive such agreements as a convenient means of sharing the rising cost burden of developing, manufacturing and marketing new microelectronic devices.

- Fourth, gaining access to markets for high technology products. For AMD this would apply for instance with regard to Intel's new generation of 16-bit microprocessors and its future successors. For Intel in turn, it means the chance to complement its product range by complementary peripherals and, as mentioned already, by access to AMD's bipolar processing technology.

- The *fifth* and last motivation relates to the conventional search for reliable second sources which particularly in the high-technology range of products requires increasingly long-term arrangements.

(d) The underlying logic

Three factors seem to have played an important role in the search for new patterns of a division of labour between firms involved in semiconductor manufacturing.

First, the need to increase economies of scale. Due to the aforementioned changes in the economics of semiconductor manufacturing economies of scale in fact are becoming of increasing importance in this industry. Today, according to industry insiders, they even exceed the weight of "learning economies".

The traditional approach to increasing economies of scale is to expand the minimum plant size. According to Truel [31/] a wafer fabrication plant, in order to be profitable, needs to produce at least 10 to 30,000 wafers per month, i.e. several million complex circuits belonging to the same family per annum. Increasing minimum plant size in turn requires an expanding turnover and thus is bound to lead to a further intensification of worldwide competition for market access.

But in an industry with a dramatically rising cost burden of r&d and investment and with an equally dramatic increase in the risks involved both in research, product development and marketing, there are clear limitations to this approach. Instead of relying on highly integrated huge plants costing up to $ 100 million today, an alternative approach would consist for instance of segmenting production in such a way that highly specialized firms would focus on specific products or stages of production, and to complement this segmentation by new forms of a branch-specific subcontracting. Thus a <u>second</u> factor would relate to the need to decrease cost burdens and the risk involved.

A <u>third</u> factor finally relates to the need to increase the flexibility of firms to react on all stages of production, i.e. in r&d, production and stock-keeping, to the ups and downs of semiconductor demand. We have seen already to what degree the semiconductor industry has been vulnerable to the economic crisis. Thus, the pressure to decrease crisis vulnerability would seem to be particularly high for this industry. Again, new forms of interfirm cooperation or subcontracting can contribute considerably to this goal.

Overall, the search for new patterns of a division of labour between firms involved in semiconductor manufacturing is an excellent example of the two-way interrelation between innovation and industrial restructuring. The availability of new technologies has changed the economics of semiconductor manufacturing. This in fact has set in motion extensive processes of restructuring the industry, by and large increasing considerably the intensity of competition. It is this increasing global competition which has been one of the major driving forces behind the recent rapid expansion of automation which, in addition to its classical applications in mask-making and wafer fabrication, is increasingly applied in design (CAD) and assembly.

Thus, the availability of new electronic technologies on the one hand has led to major changes in the economics of semiconductor manufacturing and thus was bound to lead to a considerable adaptation of corporate strategy and structure. These new types of corporate strategies in turn, centering on increasingly aggressive forms of a global competition, do have an important role to play in the ongoing process of choosing product and process technology.

5.2. The Dialectics of Forward and Backward Integration - Towards a New Semiconductor Industry of Corporate Giants?

5.2.1. Forward versus Backward Integration - Conditioning Factors, Constraints and Recent Trends

The structure of the firms active in the semiconductor industry is undergoing rapid change. The era of specialized and independent firms characteristic for the late 1950s and the early 1960s is clearly over now. New actors have become involved, the economics of semiconductor production have changed, and consequently firms were forced to test out ever new types of corporate strategy with regard to choice of product and technology, marketing and pricing, and investment allocation. Starting from their classical applications in the military and aerospace sectors, and in the data processing industry, microelectronic circuits are beginning to expand into ever new applications, and their potential for pervading into practically every sector of industrial production is tremendous. [32] Consequently, new types of economic and technological interlinkages have been emerging between the semiconductor industry and an increasing variety of industrial activities, rapidly transcending the confines of the classical electro-mechanical sector.

(a) The emergence of a "Global Electronics Sector"?

But the really important point is that the introduction of microelectronic circuits would lead to the emergence of a new type of growth industry, i.e. the global electronics complex centering around new information technologies (NIT).

Due to the considerable cost reductions for storing, processing and communicating informations and to the new scope for technological conversion, sectors which used to be disjointed,tend to be increasingly inter-linked. Overall, the trend seems to point towards an increasing monopolization and world market orientation of the electronics sector. The driving force are highly diversified electronic multinational corporations aiming at increasing the degree of their vertical integration on a global scale.

This transition towards an increasingly integrated electronics sector is a complex process, which does not preclude that for certain sectors at least, corporate strategy will lead to an increasingly vertical disintegration internal to the firm. In fact, the crucial development is the trend towards the conversion and homogenization of previously separate industries and their integration into a newly emerging electronics sector. This can take two forms:

- **an increase of the vertical integration internal to the firm**
- **the emergence of new hierachical patterns of sectoral division of labour and subcontracting.**

Finally, the importance of services in the electronic sector tends to increase. This would apply particularly to those services which are linked to the design and manufacture of semiconductors, of information processing and communication systems, and of electronic devices dedicated to the consumer. Of crucial importance in this context is the whole area of software design, engineering and maintenance.

No wonder then that these changes have been reflected in the structure of firms.

Historically, there have always been major differences between the structure of US and non-American IC companies. According to Mackintosh, in both Europe and Japan, the bulk of the current IC capability resides within vertically integrated and highly structured companies, whereas in the US - with the exception of organizations such as IBM and Western Electric - most of the IC capability, at least until a few years ago, resided in companies in which the semiconductor activity is a major part of its total industrial committment [33/].

But these sharp differences seem to become increasingly blurred and firms, irrespective of whether they originate from the components or the equipment sector, all seem to converge in their drive to complement their classical activities by means of vertical integration.

(b) Types of vertical integration

In principle, three types of vertical integration centering around microelectronic devices can be discerned:

- attempts of semiconductor manufacturers to integrate forward;

- attempts of producers of systems and final products to integrate backward;

- and attempts by outsiders to penetrate semiconductor production.

During the 1970s, all three types of vertical integration took place. Forward integration for instance, starting from the pioneering moves of Texas Instruments in 1972 into pocket calculator and watches, at one stage or another involved practically all the leading US merchant semiconductor firms and, in addition to consumption-oriented final products, tends to include now increasingly moves into information subsystems (high capacity memories, OEM micro computers and microprocessor development systems), data acquisition systems and industrial electronic equipment.

Backward integration on the other hand always used to be the guiding principle for the highly integrated electronic conglomerates of Western Europe and Japan. In addition, leading US mainframe and mini-computer firms, and also telecommunications companies are increasingly using backward integration as a means to secure sufficient in-house capacities for designing and, if necessary, for producing semiconductors, particularly specific devices and microprocessors.

Finally, the number of industry-outsiders trying to get involved in the semiconductor business has significantly increased, with General Electric, Exxon Enterprises, Schlumberger and Saint Gobain being only the most prominent cases [34/].

The question thus is not whether vertical integration has taken place but whether it is going to be a viable approach and if so what effects it will have on market structure and consequently on future patterns of innovation and international restructuring in this industry.

(c) A viable approach?

Concerning the first question, we have to differentiate between forward and backward integration. With regard to forward integration, the first "euphoria" of the early 1970s has rapidly faded away, as practically all attempts to integrate forward into consumer-oriented end products, with the exception of pocket calculators, have turned out to be commercial failures. In fact, even Texas Instruments which seem to have been the only company with a successful integration policy into electronic watches, recently began to phase out this activity. 35/

This experience in fact would seem to back up the socalled "Mackintosh General Theory of Vertical Disintegration". 36/ Mackintosh in fact is very outspoken: "...it is my view that the vogue for vertical integration is an irrelevant diversion in the long-term development of the electronics industry. We live in an age of specialization, and it has for a long time been difficult to accept that IC companies can sell watches, for example, better than the established specialists, or that the mini-computer companies, as another example, will succeed in establishing and maintaining a cost-effective semiconductor capability over the long term. ...I believe that of all the vertical integration activities - upwards and downwards - now going on in many parts of the world, only a few will turn out to be successful in the long term." 37/

This statement is probably sound - as far as it goes. But it does not go far enough - because stating that only a few firms will be able to survive strategies of forward and backward integration is hardly more than a truism. In fact, the real issue would be to identify, in an operational manner, the scope for different types of firms to proceed with such strategies or, for that matter, to switch to a strategy of vertical disintegration.

Only then would we be able to answer the most intriguing question of all: Is the semiconductor industry today experiencing just the beginnings of a new round of competitive battles, aiming at the control of strategic market segments of the electronics industry, but this time with huge, highly diversified and highly internationalized conglomerates as the main and most powerful driving forces?

5.2.2. The Recent Wave of Acquisitions and Mergers in the U.S.

Worldwide, the semiconductor industry is undergoing a process of violent restructuring and the major driving force seems to be an acceleration of vertical integration, particularly since the second half of the 1970s.

Huge, highly diversified firms have always been the dominant actors in the Japanese and the West European semiconductor industry. Their dominance is bound to increase even further as a result of the recent upsurge in both areas of government-backed programmes to develop IC design and production capacities.

In the US industry, on the other hand, vertical integration used to be low and independent semiconductor merchant firms clearly were the main actors. According to a recent study by the US Department of Commerce, by 1972 there were 96 US companies producing semiconductors and at least 217 more producing semiconductor parts. More than half of the former were specialized semiconductor houses; 37 were branches of "conglomerates"; and 9 were captive producers.[38/] Of the top 9 merchant suppliers of integrated circuits in 1975 only 3 were diversified electronics firms.[39/]

Today, a wave of investments and acquisitions has tied virtually all independent semiconductor makers to major equipment companies. Table 5.3. shows that since 1975 at least 23 important acquisitions have taken place.[40/] According to Dataquest Inc., out of 36 semiconductor startups since 1966, only 7 remained independent today.[41/] Of the top 9 merchant semiconductor firms in 1975, today 5 belong to vertically integrated conglomerates.[42/]

Tab. 5.3. Major Investments and Acquisition Moves in the U.S. Semiconductor Industry

Company	Date	Investor or Acquirer	Major Activities of Acquirer	Share (%)	Total Sum Invested (m. US $)
Advanced Micro Devices	1977	Siemens (West Germany)	Semiconductor, telecommunications, computer	20	
American Microsystems	1977	Robert Bosch (West Germany)	Automobile equipment	12,5	14
		Borg Warner (US)		12,5	
Analog Devices	1977	Standard Oil of Indiana (US)	Oil exploitation	20	
Electronic Arrays		Nippon Electric (Japan)			
Fairchild Camera	1979	Schlumberger (Netherlands Antilles)		100	397
Inmos, Inc.		National Enterprise Board (Britain)			
Interdesign		Ferranti (Britain)			
Intersil	1977	Northern Telecom (Canada)	Telecommunications	24	
Litronix		Siemens (West Germany)			
Micropower Systems		Seiko (Japan)			
Monolithic Memories		Northern Telecom (Canada)			
MOS Technology		Commodore International (US)			
Mostek	1979	United Technologies (US)	Diversified, but mainly aerospace	100	349
Precision Monolithics		Bourns (US)			
Semtech		Signal Companies (US)			
Signetics	1975	Philips (Netherlands)		100	49
Siliconix		Electronic Engineers of California (US)	Automobile equipment	24	
		Lucas Industries (Britain)			
Solid State Scientific		VDO Adolf Schindling (West Germany)	Automobile equipment	25	
Spectronics		Honeywell (US)			
Synertek		Honeywell (US)			
Unitrode		Schlumberger (Netherlands Antilles)			
Western Digital		Emerson Electric (US)			
Zilog		Exxon (US)			

Sources: Morgan Stanley Electronics Letter, Mackintosh Consultants, World Business Weekly, quoted from: Deutsch-Amerikanische Handelskammer: amerika handel (New York/Chicago), No. 2, March/April 1980; Truel, 1980a, p. 285; Siegel, 1981, p. 5

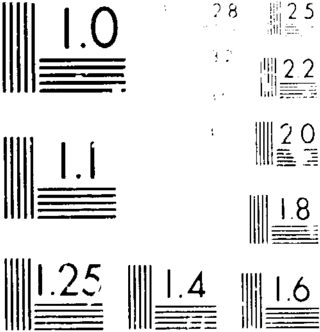
But these accelerating take-overs through Big Business are just one aspect of this move towards an increasing vertical integration. Huge firms, increasingly relying on complex integrated circuits, have in fact additional options to increase their control over the design and manufacturing of semiconductors. Many equipment companies unable or unwilling to pull off such acquisitions have made for instance substantial investments in their own internal semiconductor operations. This increasing role of captive IC producers is reflected in a projection of John D. Shea, a consultant for Integrated Circuit Engineering Corp., according to which at least one third of the complex integrated circuits produced in the mid-1980s will be built or designed by users not suppliers. 43/

Add to this the growing concentration of the users' side which means that a few big customers are in fact dominating the market. According to Daniel L. Klesken, an analyst at Dataquest, the number of companies using more than $ 100 million worth of semiconductors annually has jumped from one to seven in the last three years and will hit 17 in 1981. "By 1985," Klesken predicts, "30% of merchant production will be consumed by about 30 major users." 44/

5.2.3. The Emergence of New Start-Up Companies - Does It Indicate a Reversal of Consolidation Trends?

During the 1970s, the semiconductor industry clearly has been characterized by an increasing concentration of control over strategic assets and by a transition to more consolidated patterns of oligopolistic competition. This has been primarily due to the acquisition of independent semiconductor houses by multinational electronics firms and conglomerates. The semiconductor business, and in general the electronics sector, finally seemed to be reaching the status of a "mature" industry.

Yet, recent changes in the status of the semiconductor business seem, at first glance at least, to contradict this type of an analysis and indicate that a reversal of prevailing consolidation trends might be possible.


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

One factor of particular importance is the emerging custom chip bottleneck 45/ and the impact it is going to have on innovation and corporate strategy.

During 1980, as many as five firms have entered the U.S. semiconductor business. All of the new start-up companies plan to attack a market that has been virtually ignored by the established semiconductor firms - the custom circuits business. Until very recently, the name of the game in semiconductors has been standard parts - i.e. logic and memory devices that can be built and sold by the millions in order to drive down the price. According to J. Perkins of the venture capitalist firms Kleiner, Perkins, Claufield and Byers, "the commodities side of the business is huge and well established, but the custom needs have not been met." 46/

This is not to say that major semiconductor houses are absent from this market. Companies like Fairchild, Fujitsu, Motorola, American Microsystems (AMI), and Signetics have been major forces in the custom chip market. 47/ But up till now established producers viewed the custom business as bad business and consequently tended to down-play the importance of this market. Their main focus was on producing high performance arrays designed specifically to meet the needs of computer manufacturers who were willing to pay very high prices for these devices. But no attempts were made to expand the markets for these types of application - oriented chips.

However, the introduction of the gate array technology and the consequent possibility to produce semi-customized chips chould change all that. It could lead in fact to some significant changes in the patterns of division of labour prevailing between firms involved in semiconductor manufacturing. It increases in fact the scope for the emergence of small, highly specialized firms and of new types of subcontracting arrangements.

Take for instance the case of Micro Circuit Engineering (MCE) at Tewkesbury, Gloucestershire, a new subsidiary of Smiths Industries. To establish it will cost roughly £ 1.5 million and it will need no more than 50 employees. Yet it will produce very sophisticated uncommitted logic arrays (ULAs) to compete with such major companies as Ferranti, GEC, Plessey, Racal, General Instrument, Texas Instruments, Motorola, Fujitsu, Thompson CSF and Siemens.

The crucial point is that MCE will not process silicon. Instead, all the investment is being made at the two ends of the production process: the design of circuits and masks and the dicing, testing and packaging.

Semiconductor processing is carried out under contract by a number of semiconductor majors for MCE so that devices can be supplied in CMOS bipolar and I-squared-L technologies. These companies process only the wafers - all the testing is carried out by MCE.

MCE itself holds stocks of standard silicon wafers on to which the basic components have been processed. Circuits and masks are designed at customers' sites and at MCE. When a completed circuit layout is received the wafers can then be committed to the customer's requirements via CAD techniques, by etching off an overall metal layer to leave the required interconnections.

Whether or not this approach will be a viable one remains to be seen. An important constraint could be the very high cost of equipment and the need to write it off at a very short period. According to Ian Pearson, chief manager, MCE will "...have to achieve a 30% return on funds used in order to generate the necessary cash for re-investment in new production equipment which, due to innovation, has to be written off every three years. [48/]

With increasingly rising equipment costs and the highly cyclical nature of demand for semiconductors including ULAs it would seem safe to assume that it will be extremely difficult to sustain such high profit rates for any lengthy period. Sooner or later then one would expect that major firms will have to be involved to consolidate this very shaky position.

In addition, it remains to be seen whether gate array technologies will flourish as much in the US as they seem to do in the UK - after all, their main advantage has been to allow the relatively small markets in the UK to be tackled economically.

5.2.4. Acquisitions and Concentration - the Fate of Firms Producing Semiconductor Equipment?

Acquisitions and concentration moves are not restricted to the semiconductor industry, but are bound to spill over into some complementary industries. A case in point would be recent developments in the semiconductor equipment business.[49]

(a) The semiconductor equipment business - growth potential and structural change

On Wall Street and in the board-rooms of acquisition-minded companies, the semiconductor equipment business is beginning to be recognized as an even more attractive growth opportunity than some of its chip-making customers. Business Week[50] for instance talks of "hot prospects for a fast-growth industry."

Table 5.4. shows the world market for semiconductor production and test equipment in 1979. It can be seen that wafer processing equipment by far dominates this market, followed by test systems. Assembly equipment on the other hand still had a relatively low share, i.e. 13%. The degree of concentration prevailing today in this market segment is considerable, but not excessive: nearly 55% for the top ten firms, and more than 20% for the first two.

Tab.5.4.Worldmarket for Semiconductor Production and Test Equipment - Sales1) and Types of Equipment, 1979

(1) Top 10 Suppliers of Semiconductor Equipment

	Equipment sales ($million)	Market shares (%)	Cumulated market shares(%)
Fairchild	111.4	10,5	
Perkin-Elmer	101.2	9.6	20,1
Applied Materials	54.1	5,1	25,2
GCA	54.1	5,1	30,3
Teradyne	53.4	5,0	35,3
Varian	50.8	4,8	40,1
Tektronix	39.2	3,7	43,8
Eaton (Cutler-Hammer)	37.7	3,6	47,4
Kulicke&Soffa	37.0	3,5	50,9
Balzers	33.7	3,2	54,1
subtotal	572.6	54,1	
others	480.3	45,9	
total	1,052.9	100,0	

(2) Types of Equipment

	Sales ($ mil.)	Sales of total (%)
Waferprocessing equipment	515,9	49
Test Systems	400,1	38
Assembly	136,9	13
Total	1,052.9	100

(1) : Does not include captive sales of equipment

Source: Global Electronics Information Newsletter, No. 4, September-October, 1980, p. 7

Tab.5.5.and fig.5.3.document that the expansion of the markets for semiconductor equipment has been truly dramatic and that it is expected to accelerate even further. Yet, till the mid-1980s at least this expansion would be mainly restricted to processing and testing equipment, whereas the growth potential for assembling equipment would seem to be considerable lower.

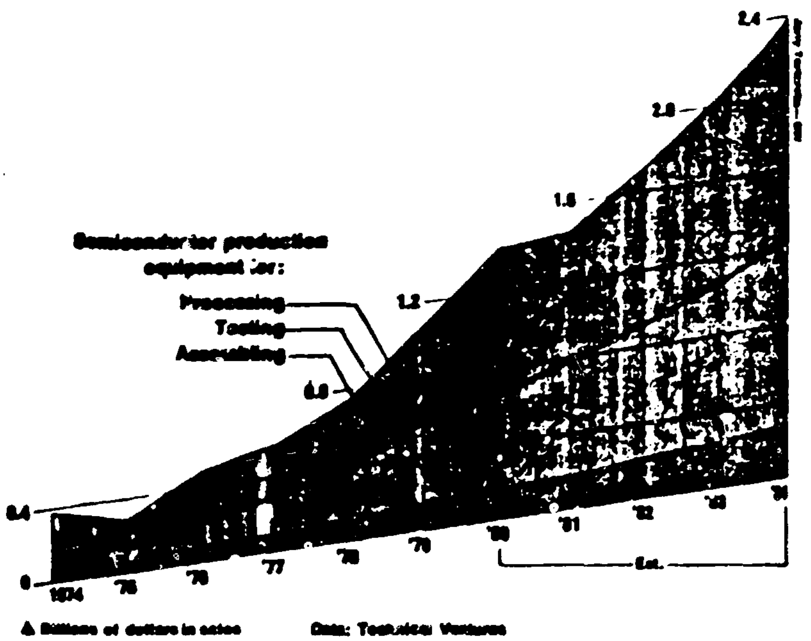
Tab.5.5. Sales of Semiconductor Equipment: 1975 - 1990 [$ bill.]

1975	: 0.3	
1979	: 1.0	+ 44% (chip sales in the same period rose by only 29%)
1980[1)]	: > 1.4	
1990[2)]	: 10.000	

1) September 1980- estimate by the US based Semiconductor Equipment and Materials Institute, cited in Wall Street Journal, 3 October 1980

2) Estimate by Willard L. Kauffman, Vice-President, Intel Corp, cited in "Semiconductor Takes on its Own Glow", Business Week, 1 December 1980

Fig.5.3. Growth Prospects for Semiconductor Production Equipment, 1974 - 1984



Source: "Semiconductor Takes on its Own Glow", Business Week, 1 December 1980, p. 98 L-E

(b) The equipment shortage and the dramatic increase in equipment cost

At least till 1982, the supply of semiconductor equipment will considerably fall short of demand. In such a situation, price is virtually secondary to obtaining delivery. In fact, according to Business Week "...the most expensive equipment is typically sought after most, since it usally offers higher productivity to justify the price." 51/ Perkin-Elmer for instance has an 18-month waiting list for an projection mask aligner that costs $ 230,000.

In other words, there is reason to believe that the equipment market will remain buoyant despite the general economic crisis because the chip makers have no choice but to invest now in order to maintain their present market shares. Furthermore, the cost of highly sophisticated equipment which is already jumping phenomenally, will continue to grow. According to Glen R. Madland, chairman of Integrated Circuit Engineering Corp. "...large manufacturers have no choice - they must automate to cut human error and improve yields. Even smaller firms serving the custom-desigded-circuit market are moving to automation to enhance processing flexibility. And no company can afford not to offer the latest, most powerful chips in its markets. Driven by such forces, the chip-making industry is rapidly approaching the point where it will take a dollar of invested capital to generate each additional dollar of sales. Equipment costs already represent 10% of chip production expenses." 52/

(c) Acquisition and concentration - trends and underlying causes

The result of the dramatic growth of semiconductor equipment sales will be no doubt a major restructuring of this sector in the 1980s - a drive toward consolidation based on a spate of buyouts and mergers.

In other words, what happened previously to independent chip manufacturers, is taking place now in the semiconductor equipment sector: a process of increasing concentration and a reshuffling of prevailing patterns of specialization, conflict and cooperation. Factors behind this drive toward increasing concentration include:

a) The growing financial problems resulting from soaring R+d costs. "As competition for qualified technical personnel heats up and as companies pour more and more money into development costs, small, undercapitalized companies are finding it increasingly difficult and risky to go it alone." (A. C. Tobey, Marketing Director, GCA Ccp.) 53/

b) The surge of captive chip producers requires new product and marketing strategies. Consuming about 30% of all fabrication equipment, this user group constitutes the fastest-growing market segment for semiconductor equipment. Furthermore, it constitutes a stable, financially strong outlet more immune to the economic cycles that affect merchant chip makers. To serve this changing market, the equipment builders are formulating new strategies and it is already obvious that small independent firms will hardly be able to survive.

c) The prospect of growing competition from Japanese firms. According to **Electronics** 54/ there are already signs that U.S.-based producers of semiconductor production equipment are loosing their dominant position in the Japanese market. Consequently, a number of U.S. companies are setting up sales offices or manufacturing plants, wholly or jointly owned, in Japan. Kulicke and Soffa, for instance, established a Tokyo office to service its wire bonding equipment. TRE semiconductor has announced a joint venture with Tokyo Electron to manufacture wafer steppers and microlithographic equipment. Applied Materials is "opening regional sales and service centers and is planning a $ 4 million design center." And GCA and Perkin-Elmer already operate successful Japanese subsidiaries.[55/]

Tab. 5.6. documents recent acquisition moves by the top ten makers of semiconductor equipment. It shows that 6 out of 10 firms undertook such acquisition moves and that 2 of them, General Signal and Eaton were especially active.

Tab. 5.6. Acquisition Moves by the Top Ten Makers of Semiconductor Equipment

Acquiring company (1979 sales)	Company acquired
Schlumberger ($ 111 million)	Membrain (1978) Fairchild Test Systems (1979)
Perkin-Elmer ($ 101 million)	Etec (1979)
Applied Materials ($ 54 million)	Ion Implantation of Lintott Engineering (1980)
GCA Corp. ($ 54 million)	
Teradyne ($ 53 million)	
Varian Associates ($ 51 million)	Extrion (1975) Speciality Metals&Alloys (1978)
General Signal ($ 46 million)	Tempress (1977) Kynetics (1980) Electron Beam Microfabrication (1980) Kayex (1980)
Tektronix ($ 39 million)	
Eaton ($ 38 million)	Kasper Instruments (1978) Davis & Wilder (1978) Nova Associates (1980) Macrodata (1978) Pacific Reliability (1978)
Kulicke & Soffa Industries ($ 37 million)	

Source: "Semiconductor Equipment Takes on its Own Glow", Business Week, 1 December 1980, p. 98 N-E

5.3. Who Will Dominate the Electronics Complex? Recent Moves by Major Actors

5.3.1. Patterns of Technological Spin-Offs - Who Will Control Them and Benefit from Them?

The introduction of microelectronics-related innovations is bound to lead to a major structural reshuffling of established modes of industrial production. One immediate effect would be a restructuring within the electronics complex itself.

Industrial restructuring always has important consequences for patterns of hierarchical control. In other words, introducing new technology which causes major changes in the ways and means of producing industrial products will touch upon established power relations in industry. On the other hand, choice of technology and the speed of applying them also depends on which actors (coalition of actors) are dominant in the constitution of these new patterns of industrial production and are thus able to reap the major benefits from the new growth industries.

(a) The "electronics complex"

On a first level, we will focus on the evolving new patterns of conflict and cooperation between major firms involved in the constitution of the electronics complex.

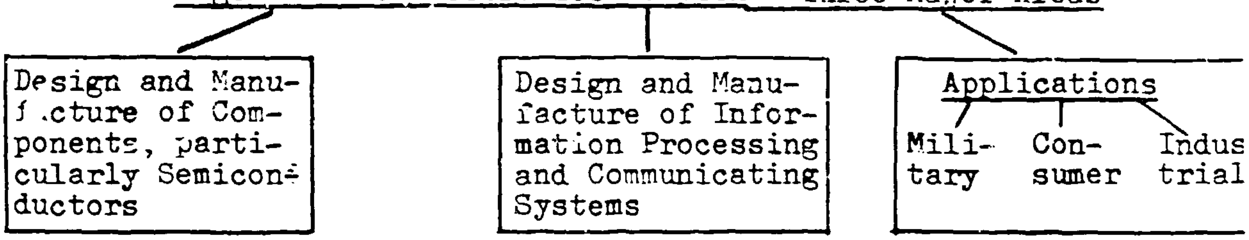
Fig. 5.4. shows that three blocks of actors are of interest:

- actors involved in the design and manufacture of electronic components, particularly semiconductors;

- actors involved in the design and manufacture of information processing and communicating systems ("telematics"), i.e. firms active in computers, office equipment and telecommunications;

- actors active in the application of electronic devices and subsystems which include industrial, consumer and military applications.

Fig.5.4. The Electronics Complex - Three Major Areas



Let us first focus on interrelations between the first two groups of actors, that is basically semiconductor, computer and telecommunication firms. Which firms or coalition of firms are going to benefit most from the introduction of microelectronics-related innovations?

(b) A typology of firms involved in the information processing sector

There are three types of firms involved:

- companies mainly active in the computer field and whose vertical integration in production is relatively high (for example IBM);

- companies coming from mechanical or electromechanical production sectors, f.i. office machinery or electrical equipment goods, and converting to electronic technology (for example Olivetti and Siemens);

- companies with a high degree of applicative specialization, mainly in software and service activities.

Obviously, for each type of firm, the impact of microelectronics-related innovations will differ considerably.

(c) Consequences for industrial restructuring in the information processing sector

Four types of consequences are of particular importance for industrial restructuring in the information processing sector:

- First, a restructuring of firms with regard to size, organizational structure and strategy.(We will discuss this aspect in chapter 5.3.2.)

- Second, the emergence of new patterns of specialization and thus of conflict and cooperation between firms. (We will discuss this aspect in (d) and (e))

Further, two additional consequences can be discerned:

- Third. barriers to access to technology might considerably change. For hardware technology for instance, particularly for microcomputer and equipment available on the OEM submarkets, these barriers obviously have been weakened, whereas access to software, particularly to applications software, to the design of new systems architecture and data handling networks has become increasingly restricted.

  The implications for corporate strategy and structure are obvious: major information processing firms tend to turn their attention to systems applications, to the design of new architectures and data processing networks.

- Fourth, the emergence of new patterns of an international division of labour in information processing and telematics. New patterns of cooperation and conflict will rapidly emerge. On the one hand, more emphasis will be placed on agreements, mergers, joint ventures between component, information processing and telecommunication companies, on a worldwide scale. On the other hand, however, conflicts will intensify, and the increasing interventions of government procurement markets and government agencies are already about to change the rules of the game. Take for instance the leading Japanese firms which, backed by MITI and based on their new technological capabilities derived from the government-promoted VLSI programme, [56] aim at concentrating an increasing share of world hardware production in their country.

(d) Semiconductor versus system firms: the changing balance

We have already seen that there is a battle going on between some firms, primarily located in the US and Japan, and to a lesser degree in the FRG, the Netherlands, France and the Scandinavian countries, on who is going to dominate the emerging global electronics sector. We have also seen that the outcome of this battle will depend strongly on which firms are capable of controlling most of the technological spin-offs from microelectronics.

If we confront on the one hand semiconductor firms and system firms, i.e. firms engaged in the computer and telecommunications business, on the other, which side is going to survive and what new patterns of "cumulative hierarchical control" [57] are likely to emerge?

There are two opposing interpretations: On the one hand there are those who would claim that it will be the semiconductor firms who will be able to reap most of the benefits resulting both from technological spin-offs and new applications. This would be so basically because of the increasing integration of systems characteristics into microelectronic circuits which would increasingly transform them into electronic sub-systems and systems.

Take for instance the position of Truel.[58] His basic hypothesis presented in a study published in January 1980 was that a couple of major semiconductor firms, particularly those originating from the US, will be able to reap most of the benefits resulting both from technological spin-offs and new applications. He points out correctly that the introduction of microelectronics-related innovations and the consequent constitution of an electronics complex has been characterized by two basic structural trends:

- Semiconductor and especially LSI circuits and microprocessors are not anymore just electronic inputs, but are about to become subsystems and systems on their own.

- Technological spin-offs are becoming much more important for the interaction between the various sections of the global electronics sector than exchange relations.

It is the first point which we would like to illustrate more in detail because of its potential for throwing upside down some of the basic structural relations prevailing today in the information process sector. Take for instance the development of a socalled "micromainframe" by Intel Corp. This development of a "micromainframe", i.e. a 32 bit processor called Intel 432 is an essential element of Intel's strategy.[59] Intel claims that this micromainframe could cover applications which are at present the exclusive realm of medium-sized mainframe computers.

According to industry observers, micromainframes, because of higher reliability and much lower costs, might be in a good position to increasingly substitute for conventional mainframes. This would mean that component firms could reap a significant part of the benefits to be expected from the booming informatics market.

Intel managers purport in fact that the new 32-bit microprocessor is so powerful that it could become the "brains" for such currently unavailable products as office workstations that can 'understand' human speech, and industrial robots that 'recognize' the parts on an assembly line. Leslie L. Vadast, senior vice-president at Intel, expects new applications to emerge rapidly ("At least half of the applications that will exist in 5 or 10 years, we can't even imagine today") and that new companies, and even new industries, will spring up to build new end products using these superchips.[60/]

Whether or not these high expectations will materialize, depends of course on the effective costs of using these micromainframes. Intel quotes the price for the Intel 432/100 as $ 3.900.[61/] This would cover hardware, software and documentation. Yet, this price is based on the assumption that the Intel strategy of reducing the most important cost element, i.e. software costs, will work. The Intel approach consists of 2 elements:

- the use of the high-level programme language Ada which allows for modular planning;
- the integration of software elements into the chip structure, by designing socalled object-oriented structures.[62/]

It remains of course to be seen whether Intel's optimistic assumptions can be realized. In any case, the micromainframes would have 2 additional comparative advantages:

- users could increase their computing capacity without having to change software;
- the reliability would be significantly improved through the use of a tandem structure.[63/]

However important this transformation of chips into microelectronic subsystems and systems might be, it is an altogether different point to conclude, as Truel does, that due to these structural changes induced by microelectronics-related innovations, semiconductor firms by and large would be on the winners' side.

However plausible this conclusion might have seemed to be, reality did not follow this course and has in fact vigorously falsified Truel's prediction. It turned out in fact that the game is much more complex and that actors and firms which had a relatively low profile during the first years of the semiconductor industry, are about to increasingly penetrate this sector through backward integration and thus to acquire strategic control. We have shown that this would apply for instance to established highly diversified multinationals like General Electric or Exxon Enterprises, but also to relatively small multinational firms specialized in extremely profitable market niches, like Schlumberger which is mainly active in the oil exploration services. Further, we have also seen that, at least in the U.S., there has been a growing influence of "Big" Venture Capital and of industrial manufacturing systems firms.

(e) Towards radical structural changes of firms engaged in information processing

According to Lamborghini and Antonelli, [64/] two factors impose radical structural changes on firms engaged in information processing:

First, the dramatically increasing risk in r+d and product planning.

The risk of failure is high, because firms in designing new systems had to forecast the future availability of new micro-circuits which could then be integrated into the systems. With the growing degree of integration and complexity of micro-circuits, this unpredictability is even further increasing. The same applies even more so with regard to forecasting of the availability dates of software.

The strategic consequence is obvious: Systems and equipment manufacturers tend to make use of several supply sources for micro-circuits and software to reduce the risks of a delay in availibility. This would apply even to the large companies with huge in-house capacities.

A second factor imposing the multiple external supply sources approach results from the still prevailing destabilization of the oligopolistic structure. In other words, cut-throat competition and insufficient control over the introduction of new product and process technology requires that firms adjust significantly their size, structure and strategy.

Besides the multiple external supply sources approach, Lamborghini expects the following trends in corporate restructuring to emerge:

- A relative decline of manufacturing activities, and a relative increase and redefinition of r+d, marketing, selling and customer engineering.

- A trend towards splitting up of existing highly integrated firms into three types of independent or at least only loosely interreleted firms: specialized component manufacturers, component assemblers, and suppliers of services, i.e. software, applicatic solutions, and technical assistance and maintenance.

- A significant reduction of vertical integration internal to the firm and the emergence of new patterns of plant external sourcing or subcontracting. 65/

This scenario would seem to be a good description for strategies applied by medium-sized multinationals, particularly those coming out of the office machinery sector, such as Olivetti. (see chapter 5.3.3.). But the dominant trend clearly leads in an opposite direction, i.e. towards increasing vertical integration, based on an increasing penetration of established multinationals both from within and from outside of the electronics sector into information processing and telematics.

5.3.2. The New Economics of Computer Building - Its Implications for Corporate Strategy and Structure

The economics of building computers are undergoing a radical change: from a custom-built, one-at-a-time product the computer has evolved in recent years to a high-volume, mass-produced commodity. 66/

(a) Rising capital requirements - towards a "capital crunch"?

As a result, capital requirements of computer manufacturers have been increasing at a very high speed. This applies both for investment into the automation and streamlining of manufacturing operations, soaring r+d costs and the increasing amounts of capital needed for financing the expansion of field service operations and opening new channels of sales distribution.

So far, most computer companies have not had much trouble raising the money. They have avoided high-priced borrowing by taking advantage of their rapidly growing cash flows and a robust equity market still attracted by high-technology stocks.

But this might rapidly change. Business Week, for instance, in March 1981, 67/ was already speaking of a "capital crunch" that could spell desaster, at least for some of the smaller companies. In fact, computer firms are experiencing a heavy profit squeeze. Despite soaring industry sales, the falling price of equipment has eroded profit margins. For example, Sperry Corp.'s Sperry Univac Div. will ship 40,000 computer terminals during 1981, but these products will bring in only about the same revenue as the 25,000 units that it turned out 1980. This kind of profit squeeze is compounded by rising competition from the production-efficient Japanese companies and by the quickening technological pace of the industry itself. Product life cycles are becoming compressed, forcing manufacturers to develop and apply new technology at an accelerating rate.

(b) The new focus on low-cost production

What are the implications for corporate strategy? According to industrial analysts, computer firms have little choice other than to reduce capital requirements.

But where to start and how to avoid forgoing growth potential and competitive strength?

A review of electronics trade journals and of specialized literature and informal discussions with industrial analysts and managers shows: the driving force now in computer industry is the lowering of production costs. This implies that capital investment to automate manufacturing is perceived to be a more critical determinant of future success than investment to develop new technology. According Glen Haley, Vice President for Worldwide Marketing, Sperry Univac: "... those companies that can design, fabricate, and assemble machines most economically will have an edge over companies that concentrate on r+d". 68/ The underlying logic is succinctly stated by Thomas A. Vanderslice, President of General Telephone + Electronics Corp., Stamford, Conn.: "The r+d portion of a product development may account for only 10% of the costs needed to bring that product to market. Therefore any reasonable manager has to have some assurance that the other 90% needed for plant and capital equipment is going to be there at the conclusion of development. Some firms are being forced to drop worthwile r+d plans not because they cannot afford them, but because they cannot afford to capitalize on them. 69/

Table 5.7. indicates to what degree US computer manufacturers have increased spending on productivity improvement. According to Ulric Weil, industry analyst with Morgan Stanley + Co., the leading computer makers are "...tooling up like the auto companies to run true assembly lines that automate production, testing and materials handling." 70/

This applies also to traditional minicomputer firms. DEC for instance plans to increase its capital spending by 90% this year to $ 400 million. While much of this will go for expanding production capacities, the new manufacturing facilities will be equipped with automated test facilities.

Tab. 5.7. Computer Manufacturers' Increased Spending on Plant Automation

	1978	1980
(1) IBM: annual investment spending on plant automation (million $)	1300	2250
(2) Burroughs Corp.: annual investment spending on plant automation (million $)	110	225
(3) Data General Corp.: - 75% of capital spending for manufacturing now goes into plant automation - Spending for automated test equipment has leaped 500% between 1978 and 1980		

Source: Figures are taken from: "Computers. A Capital Crunch that Could Change an Industry", Business Week, 23 March 1981.

(c) A further push towards backward integration?

The focus on low-cost production is by no means an exclusive concern for computer manufacturers. As we have shown elsewhere, 71/ semiconductor manufacturing is undergoing a similar transformation in its production economics. The increasing mutual integration of semiconductor and computer manufacturing adds further to the spread of low-cost production-oriented investment strategies. In fact, the backward integration of computer manufacturers will probably receive an additional push from this increasing focus on low-cost production. NRC for instance announced in February 1981 that it will spend $ 15 million over the next four years to increase its in-house semiconductor capacity from 40% of its requirements to 60%. The reasons are obvious: "Companies like ours will have to integrate backwards (selectively) to get costs down and improve reliability ...". 72/

This trend towards increasing captive production capacities relates particularly to complex, custom logic chips. These are the building blocks around which computers are increasingly designed, and an inadequate supply or poor quality could bring computer production to a grinding halt because there is often no second source for the product. In other words, the new economics of computer building has increased the computer industry's reliance on custom semiconductor circuity. But custom devices are not as rapidly available as standard commodity chips. It is this increased need for custom circuits which has probably boen the major driving force behind backward integration moves à la NRC. Witness the following statement by William F. Buster, senior-vicepresident of enigineering and manufacturing, NRC: "We see specific areas for cost and function improvement that's driving most large companies into building their own microcircuits.

Overall, the increasing focus on low-cost production will lead to an acceleration of the concentration trends, prevailing in the computer industry, but also in the semiconductor industry. This is not to say that there will be no scope for new entrants. In fact, with ready venture capital available, scores of new startups - companies such as Apollo Computer Inc. and Stratos Computer Inc. - have sprung up to built computers using newly developed technology.

But it seems highly improbable that any of these newcomers will ever become a full-line computer company.

In fact, given the new convergence of information processing and telecommunications, I would expect that integrated manufacturing of information processing and communications systems will be dominated by only a handful of firms. This is due inter alia to the high cost of productivity-improving investment and the increasing importance of low-cost producers vis-à-vis small or medium-sized "innovation maniacs" firms.

5.3.3. Innovation and Corporate Strategy - the Case of Olivetti

In order to illustrate some of the aforementioned interactions between recent technological breakthroughs and corporate strategy, let us take up the case of one specific firm, i.e. Olivetti.

Carlo De Benedetti, Vice President of Olivetti and the driving force behind its new management doctrine, is not only fulfilling public relations obligations when he underlines the "model character" of Olivetti's restructuring strategy. "Things have changed dramatically for Italian industry in the past two years and I think Olivetti has been responsable for that change."[74/] De Benedetti further claims that the "success" of Olivetti during the last three years is inducing now other major Italian companies to test out this approach.

(a) Indicators of success

Viewed by conventional criteria, Olivetti's strategy can indeed claim some success: group profits have been nearly trebling within a year to more than L 100 billion (=$ 89) in 1980 which corresponds to nearly 4.6% of global sales worth L 2183 billion. The parent company Ing C. Olivetti and C., doubled its profits from L 23.8 billion in 1979 to L 50.1 billion. Dividends which have not been paid from 1974 till 1978, increased from L 100 per share in 1979 to L 140 per share in 1980.

No doubt, profitability has been regained - for the time being at least.

This has to be contrasted with the company's situation three years earlier, i.e. in 1979. According to De Benedetti, the company was then ineffectively managed, under-capitalized, burdened down with debts to the extent that 10% of sales revenue went to pay interest, over-manned and suffering from low productivity. But it did have a strong technological base.

De Benedetti claims that, in addition to regaining profitability, Olivetti's new strategy was able to lay the foundation for long-term growth and viable international competitiveness.

(b) The Olivetti strategy

Four basic elements can be discerned:

1) Broadening the base for capital formation through raising new capital on the stock exchange.

The nominal capital of the holding company went up from L 60 billion to L 100 billion with De Benedetti's arrival in 1978 and was further increased in 1979 and 1980. It now stands at L 208.7 billion.

An additional increase is planned which will take the nominal share capital up to nearly L 233 billion and bring it in a total of L 180 billion new funds, partly through a convertable bond issue.

2) Reinstating sound financial management, particularly through a reduction and restructuring of debt.

Over-all debts which stood at L 939 billion in 1978, have steadily declined to L 761.4 billion at the end of 1979, and there has been an important shift in its structure, away from short-term to medium and long-term.

3) A massive reduction of the labour force, combined with very aggressive policies to compress labour costs and increase labour productivity.

Olivetti's labour force in Italy has been cut by roughly 5,000 through early retirement and that of the group world-wide by 13,000 to 53,000. Productivity improvement has been considerable: output per man has risen from L 20 million in 1978 to L 40 million 1980 and De Benedetti claims that much more will be achieved during the near future.

4) A more selective and aggressive policy on choice of product, innovation and marketing.

Product-wise, the three main pillars of Olivetti's business are banking terminals, business computers, and electronic type writers. In 1980, data processing systems accounted for 53% of sales, against 47% of business machines. But the electronic type writers include so much software that the distinction is barely valid anymore.

De Benedetti claims that the markets for these three product groups will continue to boom because they will not be affected by the crisis. "The recession ... forces companies to cut their costs and raise white colour productivity, which automation can do for them. Any of these products can pay for itself in a year." 75/ Latest figures for the first quarter of 1981, when sales went up by almost 20%, seem to back up this statement. Consequently, a great part of Olivetti's innovative capacities are geared to these three product groups.

In the future, Olivetti intends to penetrate into two other potential high-growth markets, i.e. telecommunications and consumer products. In Italy, it expects to profit from a planned restructuring of the telecommunications sector through establishing close alliances with IRI-STET and SGS-Ates. 76/ Furthermore, Olivetti hopes that its recently established relationship with the French conglomerate Saint Gobain will give it access to the strong French market for office and telecommunications automation equipment (the socalled "bureaumatics" and "telematics") in which Saint Gobain is involved through its 20% holding in the CII Honeywell-Bull group.

Yet, particularly with regard to telecommunications, industry analysts remain sceptical and point out that intentions and reality still seem to diverge considerably.

(c) Lessons to be drawn

How do these various elements interrelate, what is unique about the Olivetti strategy and particularly how is control over innovation interlinked with the other elements of this type of restructuring strategy?

I think that the first lesson to be drawn is that applying technology, or more precisely capitalizing on it, requires a sufficiently strong capital base. This is so because applying technology to industrial products and processes requires a lot of investment capital and involves very high risks. In-house availability of a broad spectrum of innovations is a factor of some importance - but is definitely not enough.

To transform these innovations into profitable assets is a complex and very costly process. This starts with the need to engineer the original design concept into feasable production standards and flow diagrams, the definition of quantitative and qualitative personnel requirements, and the development of spare part and maintenance manuals. But this is only part of the story. Take into account the considerable outlays needed for reducing costs of production through productivity improvement and for increasing the flexibility of machines and equipment to react towards feedback information considering markets and performance. Add further the outlays for marketing and distribution logistics, which due to the increasing internationalization of markets and production tend to increase considerably. All of this indicates that r+d costs needed to develop innovation, which are substantial on their own, are only the tip of the iceberg, i.e. of the capital assets needed to transform an innovation into profits.

In the case of Olivetti, the implications are obvious: a large infusion of capital has completely changed the structure of ownership and control. Today one-third of shares that make up the syndicate of control are hold by the French company Saint Gobain, and the remaining two-thirds are held by CIR, De Benedetti's own holding company and a consortium of major Italian companies.

The <u>second lesson</u> to be drawn is that applying innovation to restructuring in the way it is done at Olivetti has a considerable social cost. In addition, the burden of this social cost is very unevenly distributed and hardly taken into account in the original decision-making. Job displacement, deskilling and reducing social security standards might be politically feasable for a certain period. Yet, there are trade-offs involved which tend to be neglected, but might be of considerable importance: the potential negative impact on labour motivation and labour productivity within firms and the weakening of the socalled "social consensus".

CHAPTER 6.

IMPLICATIONS FOR THE INTERNATIONAL RESTRUCTURING OF SEMICONDUCTOR MANUFACTURING AND FOR GLOBAL PATTERNS OF TECHNOLOGICAL DOMINANCE AND DEPENDENCE

6. Implications for the International Restructuring of Semiconductor Manufacturing and for Global Patterns of Technological Dominance and Dependence

6.1. Crisis, Innovation and International Restructuring of Industry - the Key Questions of this Study

We have gone a long way to identify some of the basic interrelations between the economic crisis, innovation and international restructuring characteristic to the semiconductor industry. We have shown to what degree this industry has been prone to cyclical fluctuations and unable to resist the economic crisis. In addition, we have outlined how innovation influenced corporate strategy and structure and in turn was conditioned by them. We have analysed the consequent changes in the economics of semiconductor manufacturing and how this has modified the structure of the industry. In particular, we have discussed changes in the market structure, the emergence of new patterns of conflict and cooperation between major firms involved, and the new modes of integrating this industry into the overall electronic sector.

Based on this analysis, we are now going to discuss in detail some recent changes in international location patterns and will show that innovation has been an important but by no means an exclusive factor. In order to identify the specific impact which the application of microelectronic devices to industrial products and processes is going to have, we have focussed our analysis on three basic questions:

- Our first question deals with the interaction between innovation, comparative advantage and changes in international location patterns. Due to the proliferation of microelectronics, are we to expect or are we already experiencing an erosion of existing patterns of comparative advantage in developing countries, particularly in some socalled Newly

Industrializing Countries (NICs), and is there evidence of a consequent relocation of industrial activities back to the classical growth areas of the OECD? In other words, will the application of microelectronic devices to industrial products and processes act as an important structural constraint to a world market-oriented industrialization of developing countries, thus increasing further the already considerable obstacles to this "industrialization scenario" piled up by the vigorous neo-protectionism applied in practically all major OECD countries?

In trying to answer this question we are again focussing on one specific sector, i.e. semiconductor manufacturing and particularly chip assembly. This choice has been deliberate - chip assembly after all since the mid-1960s has been expected to play a prominent role in implementing the doctrine of export-oriented industrialization.

- Our <u>second</u> question relates to the role technology is going to play in this process of restructuring semiconductor manufacturing on a global scale. In particular, we will ask what factors did prevent semiconductor firms from implementing radical strategies which, based on an extensive automation, would strive to bring home practically all stages of production and to subordinate them under a highly centralized control? In addition, we will ask to what degree prevailing theories of international restructuring of industry are capable of answering this question and thus could be used as guidelines for policy prescriptions.

  Finally, this second question is meant to underline the need for a fresh theoretical approach which could help to bring more light into the complex and dynamic interplay of factors conditioning international location decisions in industry.

- Our <u>third</u> question then concerns the options available to developing countries to proceed from worldmarket-oriented chip assembly to integrated semiconductor design and manufacturing. There are two main concerns: First, is it realistic to expect that production activities of an increasingly complex technological nature will be transferred to industrial sites of the Third World, particularly to some industrial growth poles in NICs and some OPEC countries? And second, assuming that at least for some countries this would be a realistic perspective, what then would be the impact on the inter-industrial integration and the innovative capacities of these countries and their international competitiveness?

All of these three basic questions are linked together by one common denominator. The overriding concern of this study is how innovation in a period of crisis affects global patterns of control over international trade and over strategic assets needed for developing and producing industrial products and services, particularly technology and capital? What impact are we to expect on the capacity of major actors in the international restructuring of this industry to push through their strategies? And, finally, what are the implications for developing countries trying to implement strategies of transition to more self-reliant patterns of industrialization?

Overall, available evidence points to a further hierarchization of North-South and South-South relations with the result that industrial production activities based on high technology and catering for dynamic world markets will be increasingly concentrated in a few industrial growth poles located primarily in the OECD region, to a lesser degree in the COMECON area, and finally in a few OPEC countries and NICs.

What this study basically is trying to show is that the use of new technologies and the distribution of control over the relevant innovative capacities conditions, but does not determine by itself the restructuring of world industry.

In the final analysis, industrial restructuring is determined by the economic, social and political power structures within which the social actors who are engaged in industrial production, trade and in the exchange of production factors have to operate.

6.2 Will Industries be Relocated back to the North? - A Review of Recent Studies on the TV and the Garment Industry

The application of microelectronic circuits to industrial products and processes is already about to change considerably the established modes of designing, producing and consuming industrial products and services. 1/ Obviously, it will also play an important role in corporate decisions on how to proceed with the process of continuously readapting international location patterns in a process of crisis. But what exactly will be its impact and how is it going to influence the comparative advantages to be reaped from locating industrial production in some growth poles of the Third World? Are we to expect a relocation back to the North of industrial production activities which during the 1960s and 1970s due to their relatively high labour-intensity, had been "running away" from the classical production sites of the OECD region to some new growth poles particularly in South East Asia and Latin America?

6.2.1. The "Relocation back to the North" - Hypothesis

An outspoken proponent of the "relocation back to the North" hypothesis has been Juan Rada. In his extremely stimulating study for the ILO 2/ he starts from the following diagnosis: "...the increase in automation lessens the importance of direct labour costs in total production costs, thus making the manufacture of formerly labour-intensive goods economically feasible in developed countries." 3/

This is certainly a correct statement - as far as it goes, i.e. in pin-pointing the huge potential for radical changes in the economics of all stages of industrial production.

However, the conclusions which Rada draws from this diagnosis, would seem to be highly debatable: "This effect is already apparent with regard to goods such as textiles, garments and electronic products, which the developing countries used to export in large quantities to the economically more develcped part of the world. In these cases, the competitive advantage of less developed countries is being eroded through automation, and some key industries are returning to the developed countries (underlining added, D.E.)." 4/

6.2.2. An Empirical and Theoretical Critique

Our critique centers around the following two points:

- First of all, Rada's statement implies that, in the textiles, garments and electronics sectors, industries are already returning on a significant scale to the developed countries, which is simply not borne out by empirical evidence.

  Thus it would seem to be a serious misreading of reality if policy prescriptions on innovation and international restructuring in industry would insist that the most immediate concern from a developing country's perspective would be relocation back to the North.

  Today's industrialization strategies in the Third World are certainly confronted with a wide range of obstacles and dangers and some of them are indeed conditioned or further intensified by the development and application of micro-electronic devices. But to reduce them to "relocation back to the North" would mean a gross underestimation of the real dimensions which the interaction between innovation and international restructuring in industry is going to have in a period of crisis.

- Second, the comparative advantage of manufacturing activities located in Third World countries could indeed wither away rapidly. This comparative advantage is based on two pillars: low overall labour costs first, and, secondly, greater machine utilization made possible by the longer annual work hours characteristic for countries with high degrees of internal repression and severely constrained trade union movements. 5/ Today, capacity utilization is not any more depending on workers toiling 60 hours or more per week but can rely on robotised systems tending to work around the clock with just a few periodic interruptions due to preventive maintenance. 6/ Further, labour cost differentials are no longer playing the decisive role in total product cost that they used to and this erosion of labour cost advantages will tend to accelerate with the progressive introduction of micro-electronics-related innovations. How fast this is going to be translated into a massive retransfer of industries to the North however is still open to question.

In the long run it would certainly be plausible to expect large producers to bring back "a large share of offshore production" 7/ - if we assume that none of the actors engaged in the international restructuring of industries would succeed, separately or in coalition with others, to implement effective counter-vailing policies. However, this is not automatically going to be the case, since human beings and social classes are involved who have already shown their capacity to fight for their interests. History in fact teaches us that, when introducing new technologies, the original expectations of management with regard to how these technologies will work, how the relations of work will have to be reorganized and what this would mean for international investment decisions, in reality hardly ever materialize without substantial changes. 8/

6.2.3. The Case of Manufacturing TV Sets

Let us take the case of consumer electronics, and more particularly the manufacturing of TV sets, to develop some of our earlier arguments. A major recent study by Ed Scriberras from the Science Policy Research Unit in Sussex, prepared for the OECD secretariat [9/] shows that relocation back to the North has not been an issue for the industry - at least if one defines "relocation" to mean a closing-down of labour-intensive production lines in Third World locations and their return to the classical industrial sites of the OECD region. Of course, the availability of automatic insertion techniques and the reduced number of components [10/] did change considerably the economics of TV manufacturing and thus is bound to be reflected in corporate decisions on industrial restructuring and international location. Scriberras in fact shows that the already very heavy trend in the industry towards increasingly centralized vertical integration internal to the firm has been further strengthened due to the introduction of these new technologies, and that it is increasingly taking place on a worldwide scale.

The major findings of Scriberras [11/] on this question can be summarized in fact as follows:

- "Firms which had adopted advanced manufacturing processes did not transfer the most advanced processes abroad. The policy of all the firms is that automated techniques of production, testing, handling and packaging is concentrated in the parent company." (p. 48)

- "Some Japanese subsidiaries in the US and in the less developed countries still operate manual insertion processes. For developing countries subsidiaries this is partly due to the firms' international organisation of production. In some Far East subsidiaries, labour costs are so low that production concentrates on labour-intensive sub-assembly functions and automatic insertion is not required. But Japanese firms have transferred automatic insertion machines to both developed and developing countries (underlining added, D.E.). Component insertion is done automatically in some

Far East subsidiaries and (these components are, D.E.) then transferred for final assembly to the US and Japan." (p.49) Further, "Japanese firms gain competitive advantage from insertion and sub-assembly in the offshore areas and transfer of these to the US for final assembly. Japanese firms therefore could obtain better cost advantages from large production bases in the Far East and serve not only the US but also other world markets." (p. 51) Where transfer of automatic insertion machines has taken place, "... the machinery is not as advanced as that adopted in the Japanese factories. The level of automation including testing, handling and packaging is not as extensive as in Japan. Firms' policy is to 'prove' technology in Japan before transfer but preference is basically to keep advantages and problems of advanced automation in Japan." (p. 49) "This transfer process remains strictly under the control of the central manufacturing engineering management in Japan." (p. 51)

- "US firms located in the Far East and in Mexico to exploit low labour cost, sometimes in the face of failed attempts towards automation. Automated techniques that are used are located in the US. Sub-assemblies are transferred to these offshore areas for manual insertion and assembly and brought back to the US for final assembly. <u>There are no plans to return such operations to the US and no plans to introduce automation offshore. Low labour costs are considered to make such transfer inappropriate</u> (underlining added, D.E.)." (p. 49)

Rather than a relocation back to the North, world market-oriented production lines like TV assembly would seem to face the two following major constraints:

- the rising neoprotectionism in major OECD markets;

- the increasing technological protectionism applied by the dominant firms originating from the OECD region and the consequent further hierarchization of control over 'technological building blocks' and systems knowledge.[12]

The first of these constraints has been extensively documented in the existing literature.[13]

The aforementioned OECD study for instance shows that it has been the "...imposition of import restrictions on off-shore regions such as Taiwan and Korea finally (which, D.E.) compelled the Japanese to consider assembly in the US."[14] The study further adds "the imposition of OMA's (= Orderly Marketing Agreements, D.E.) and PAL licence constraints"[15] among the factors which "...made the transfer of products through exports increasingly uncompetitive and precarious in the long term." Thus, according to the OECD study, it has been the result primarily of these neo-protectionistic devices that "...Japanese firms were compelled to consider transfer of production to secure US and European markets."[16]

But the really important structural constraint would be the second one, i.e. the increasing hierarchization of global patterns of technological dominance and dependence. If this constraint would really materialize, this would have far-reaching implications indeed.

Unfortunately, we still lack a systematic study on this topic for the TV industry or, for that matter, for the consumer electronics sector at large. A recent study by the ODI[17] however, which discusses some aspects of this problem from the point of view of the British electronics industry, indicates a further hierarchization of access to key technologies in this sector.

The report describes Western European countries as "early technological followers" with the main innovations being made elsewhere in the US and Japan. It warns that the shortening gap between innovation and the wide dispersal of technology raises questions about the viability, let alone the stability, of this type of specialization. The result, according to the ODI report might well be that Western European countries, and particularly the UK, might find themselves increasingly squeezed on the one hand by Japan and the US which lead in electronics technology, and on the other by the low labour costs of electronics assembly work in the Far East.

On the other hand, some of the classical NICs like Singapore, Taiwan and South Korea, have recently drawn up rather pretentious programmes to upgrade their production activities from labour-intensive, low value-added assembly to somewhat more integrated and higher value-added production lines. On this issue, the ODI report underlines its concern whether, in the context of the present international market structure and the unequal division of control over technology, such programmes are not simply wishful thinking which in fact would distract the countries' energies from socially much more useful approaches to the development of an electronics industry.

6.2.4. Applying Microelectronic Industrial Automation Systems to the Garment Industry - the Gap Between Expectations and Reality

According to Pada, a second target for relocation back to the North would be the textiles and particularly the garment industry.[18/] The latter is an industry which so far proved to be remarkably resistant to the introduction of automation - at least as long as relatively rigid and centralized modes of automation prevailed.[19/]

But would not the emergence of new flexible industrial automation systems based on microelectronic devices considerably change this picture?

According to a recent study prepared for the ILO by Kurt Hoffman and Howard Rush, "the introduction of microelectronics in the late 1970's raised the expectations of some observers, both inside and outside of the industry, that the formidable technical obstacles to automation would be removed. It was felt that the microprocessor, with its vast information processing capacity and inherent flexibility had the capacity to facilitate radical technical change at the sub-process and systems level." [20/]

For instance, production steps which used to be labour-intensive, such as monitoring the quality of fabrics, design, producing patterns and cutting, could be increasingly penetrated by new modes of highly automated production. Examples would include the use of self-programming robotics and laser beam cutters for cutting, and the application of computer aid systems for design, patterning and quality control. Further, production steps which already had some tradition of being mechanised and automated, could experience the introduction of a new generation of automation systems. Cases in point would be the massive integration of microprocessors into control systems for sewing patterns, fast stitching, knitting heads and ink injectors that can be rapidly adjusted to produce different designs and colours.[21/]

But the accelerating automation of separate production steps would be only part of the story. The real issue would be that clothing manufacture could become more and more conditioned by the application of integrated automation systems. This is a trend which has progressed most in continuous-flow basic industries,[22] but has recently also gathered momentum in a typical batch production industry like the machine tools industry.[23] For the clothing industry, this basically could mean two things:

- First, various steps of production which have recently been automated could now be linked together into one continuous automation system. The novelty would be that this could also be done for small and medium batch production and auxiliary operations. In analogy to recent developments in the machine tools industry, clothing manufacture could then be integrated into Flexible Manufacturing Systems (FMS) with automatic feeding and transportation of the fabric from point to point, with self-programming the sequences of operations, selection of the stations, selection of tools, selection of optimum speeds for cutting, sewing etc., and, last but not least, with in-process dimensional control.

- Second, through the application of Computer Aided Manufacturing Systems (CAM), it would be possible to apply computer control not only to the process of production itself, but to all the functions needed for clothing manufacture, such as design, patterning, inventory, tooling, production planning, scheduling, machine control, inspection, quality control, storage and marketing. In other words, the transition towards completely automated clothing factories, manned by just a handful of highly skilled "trouble-shooting" personnel, would become feasible.

Even if one would assume that the final stage will never be reached,[24] the fact remains that the availability of such "automated factory" systems would rapidly change the economics of clothing and textile production. This would apply for example to savings in labour, skills, materials and capital. Such savings could be considerable, even if microprocessor-based automation devices would be introduced only into separate stages of production and would not yet be interrelated. Yet, with the introduction of FMS and CAM, such savings would be bound to experience a real "quantum jump".

This, in short, are some of the expectations concerning the scope for applying microelectronic devices to the garment industry and thus to retransfer a broadening range of production stages back to industrial sites in the OECD region.

However, reality has turned out to be much more complex. In fact, relocation back to the North has not yet taken place on a significant scale and the introduction of flexible and integrated automation systems is not yet a reality for this industry. The aforementioned ILO study for instance found that "... trends in technical change are directed at increasingly comprehensive and integrated systems of garment production. The time period, however, during which radical technologies will be incorporated into the industry is bound to be longer than previously anticipated, due to a number of factors including a low level of R & D, the lack of the necessary maintenance skills, undercapitalisation, and technical difficulties associated with limp fabric."[25]

6.3. Innovation, Comparative Advantage and Changes in International Location Patterns - the Overall Picture in the Semiconductor Industry

6.3.1. The Context and the Basic Message

We have already seen that the basic trend of industrial restructuring in semiconductor manufacturing by and large points to an increasing vertical integration and concentration.

This applies even more so to the global electronics sector centering around the design, production and application of new information technologies based on microelectronics. Only a limited number of actors will remain active in information technology, once the present crisis will be over. In the long run, concentration and internationalization trends will gather further momentum and small and medium-sized laboratory firms (the real innovators), but also some of the big firms will be liquidated.

This is the context in which we have to analyse the interaction between innovation, comparative advantage and changes of international location patterns in the semiconductor industry. The main message of this study is that the issue of immediate concern is not so much the possibility of outright relocation of industrial activities from the South, particularly some Southeast-Asian 'export platform' countries, back to the OECD region. Manufacturing of semiconductors in the Third World will continue to expand - at least for certain product families, for those specific stages of production which are not essential for exercising systems control,[26] and restricted to a fairly small number of 'exclusive' production sites. But changes are taking place and they are in fact of a considerable dimension: they relate to product and process technology, to management techniques and particularly to the ways of organizing shop-floor production and industrial relations. Industry insiders keep stressing that managing offshore semiconductor production activities today is a completely different affair from what it used to be hardly five to eight years ago. In fact, transition to automatic assembly requires a considerably modified management approach simply because this mode of assembly is based on a different economic logic than manual assembly. The strategic concern with automatic assembly is how to run extremely expensive equipment [27] with a minimum of interruption, if possible around the clock and in such a way that final yields can be significantly improved over standards achievable with manual assembly. In addition, the structure of the labour force, and particularly of operators, is changing very much: while it normally took about three months "for a worker to become competent at manual bonding", today, with automatic bonding, it takes only two weeks to train a machine operator. [28]

It is to these changes and their impact on industrialization scenarios in the Third World that future analysis should be mainly geared.

In the final analysis, it is the overall trend towards increased concentration of control over strategic assets and the concomitant emergence of new patterns of global and regional oligopolistic competition which should be in the centre of future discussions. Intra-OECD rivalry, particularly among US firms, and between them and Japanese firms, is the main driving force and gives rise to ever new rounds of a global technological race.

In particular, four points are worth emphasizing:

- The new economics of semiconductor manufacturing are already having a considerable impact on international location patterns.

- However, our understanding of what is really happening is handicapped by a serious lack of empirical evidence which would allow us to differentiate the analysis of changes in international location patterns according to products and stages of production involved.

- There is a complex interaction of factors conditioning the new strategies of international location in semiconductor manufacturing which do not fit into the mono-causalistic approaches of prevailing theories of "international re-structuring of industry".

- Offshore chip assembly is already undergoing major structural changes, with the result that positive effects, to be reaped by developing countries, on employment generation, forward and backward inter-industrial integration, skill formation and technological spinoffs, may become even smaller and less valuable than today.

6.4.2. The Lack of Empirical Evidence

Before outlining some recent changes of international location patterns in the semiconductor industry and particularly in offshore chip assembly, we should first like to add a point of warning. There is still a serious lack of empirical evidence, and this relates in particular to material which would allow us to differentiate our analysis of changes in international location patterns according to products and stages of production involved.

It will not be easy to overcome this gap, simply because most firms hardly ever release any quantitative information on key variables underlying their foreign investment decision-making process. 29/ This would relate in particular to informations on employment figures abroad, local wage rates and other elements of labour costs, especially in low wage countries, but also to the methodology used to establish the overall costs, benefits and risks of a specific investment project. Add to this the considerable flaws of technology forecasting, 30/ and it will become clear that most of the available projections of possible future trends of international restructuring in the semiconductor industry are based on very unsafe ground, simply because they have been deduced from a fairly incomplete knowledge of what is presently happening.

This would apply for instance to international allocation trends for chip assembly lines.

Tab. 6.3. (see chapter 6.4.) gives the overall trends for US firms as projected by some of the major studies on this topic.

In reading this table, what we learn is that, for whatever reason, the explosive growth of new companies, particular US merchant firms, rushing to offshore locations in the Far East, which was typical for the late 1960s and early 1970s, has clearly abated by now.

But this is only a very partial picture of what really happened. What was it that "caused US firms to rethink the rationale for offshore investment"?[31/] In order to arrive at a conclusive answer to this question, we need to dig out some further informations which would allow us to identify more clearly the driving forces behind the new strategies of international location in this sector and their main constraints.

This should in fact be a priority area for future research, as has been outlined by a recent expert group meeting on the implications of microelectronics for developing countries, organized by UNIDO.[32/]

6.3.3. Recent Changes in the International Location of Semiconductor Manufacturing

The new economics of semiconductor manufacturing are already having a considerable impact on international location patterns in this industry. New production sites have been rapidly emerging and new actors have entered the stage. This meant that the rules of the game characteristic for this industry today are very different from what they used to be hardly ten years ago. Yet, most of these changes have passed by largely unnoticed, at least outside the inner circles of headquarters management of major firms, and attempts to analyse the international restructuring process for this industry are still to a large extent based on theories deduced from the experience of the 1960s and the early 1970s. 33/

(a) Four levels of international restructuring

Changes in geographic location patterns are taking shape at four levels:

- Locational shifts among major OECD countries, i.e. mainly between the US, Japan and a few production centres in Western Europe;

- Locational shifts from the centre to the periphery of the OECD region, particularly to Ireland, Scotland and Wales;

- Transition to new patterns of investment in the classical "export platform" countries like Singapore, Taiwan, Malaysia and South Korea;

- And, finally, relocation from classical "export platform" countries to new offshore locations like the Philippines, some new locations in the Caribbean Bassin, Sri Lanka, the PR China and Bangladesh.

It is probably still too early to get a complete picture of the logic underlying the manifold and often contradictionary moves taking place on these four levels and the interests of the actors involved. But at least we should start to dig out bits and pieces of it. The first step would be to make an inventory of the more important moves and to inquire into the rationale behind these individual cases. This would allow us to deduce at least some tentative working hypotheses which could then be subordinated to more systematic research.

The present study can only make a modest contribution. It will present some evidence for the three probably most important structural changes conditioning international location patterns today: the economics of demand are about to increase considerably in importance; the economics of production are about to change with an increasing focus on systems productivity; and the pressure on both semiconductor and systems firms to increase their vertical integration throughout the global electronics complex is going to increase.

We will focus on recent locational shifts within the OECD region, in particular to the European periphery and to Japan (see (b) - (d)). By and large, it will be these three types of international restructuring moves which will dominate the 1980s.

However, before doing so, I want to underline one important point. The last two modes of international restructuring in the semiconductor industry, i.e. relocation to and within the South are bound to become of increasing importance. In fact, radical cases of relocation within the South and of a consequent industrial restructuring of offshore production facilities can already be discerned. This study will discuss some pieces of evidence in chapter 6.4. Yet, there are still vast deficits of empirical knowledge characterizing this particular field of research on international restructuring in industry and there is an urgent need to make it a priority for future research. In particular, the following developments would seem to deserve in-depth empirical research:

- the rapidly expanding engagement of US semiconductor firms in the Philippines and the new patterns of specialization between US and Philippine firms, particularly in assembly subcontracting which reached its peak during the 1979/80 chip shortage ;

- the engagement of Philippine firms, particularly of Dynetics Inc. in marketing and "silicon foundry services" in Monteca/ California ;

- recent attempts to proceed to more integrated forms of semiconductor manufacturing in Singapore (Nanotek), Taiwan (Industrial Technology Research Institute in cooperation with RCA) and South Korea (High Technology Area in Samsung);

- recent developments in Mexico and Brazil.

(b) Locational shifts within the OECD region

Since 1975, the bulk of international investment of semiconductor manufacturers went into locations within the OECD region.

Till the 1970s, inter-OECD international investment flows consisted mainly of investment of US firms in Western Europe and these investments were predominantly geared to the computer industry and to serving government procurement markets, particularly the military and the telecommunications sectors.

Since 1975, however, this pattern is rapidly changing. In fact, three location trends are increasingly dominating international investment in the semiconductor industry: [34]

- a move of West European and Japanese firms into US locations;

- increasing Japanese investment in Western Europe;

- and the growing importance of the European periphery, particularly Ireland, for US and Japanese investment geared to the Western European market.

(c) Three main conditioning factors

By and large, these changes of international location patterns in the semiconductor industry and their focus on the OECD region can be explained in terms of three main factors:

- First and foremost, the growing importance of access to huge, sophisticated and dynamic markets. This market orientation would in fact seem to be the single most decisive determinant of international location patterns in the semiconductor and, for that matter, also in the electronics industry at large.[35] If this diagnosis would be correct, this would then imply that, if possible, all stages of production, from design to assembly, should be located as close as possible to areas of market growth.

  Within the OECD region, the US market will of course remain by far the most attractive one. However, in terms of market growth, other areas are bound to gain in importance. A recent major study of the OECD secretariat on the electronics industry arrived at the following conclusion: "The last decade has seen the growing importance of the Japanese market for electronic capital goods following the liberalisation of Japanese trade and foreign investment policy in this area which has occurred gradually since 1974. Over this period the growth of demand for advanced electronic products (particularly the most advanced integrated circuits) in Western Europe has tended to lag behind that of the United States and Japanese markets. Forward-looking market surveys expect this trend to be reversed over the next ten years with growth rates of demand in Europe substantially higher than in the United States with Japan lying somewhere in between. It is thus likely that the geographical focus of the industry will shift accordingly." 36/

According to a recent study by Mackintosh Consultants on the European electronics industry. 37/ Western Europe will be the most important "future growth market" for the global IC market. Mackintosh in fact expects that a fivefold growth in real terms will take place from around $ 2.2 bn (in 1980 $s) in 1981 to about $ 11 bn in 1991.
It concludes that "a market of $ 11 bn (in 1980 dollars) in 1991 clearly represents a very substantial and exciting opportunity for the world's IC producers,...this $ 11 bn market is likely to be contested vigorously and (...),given their natural advantages, if the Europeans and Americans allow the Japanese to capture a major part of it, they will really have only themselves to blame."

In addition, future growth markets are already emerging outside the OECD region: the Gulf area, Mexico, Brazil and the ASEAN region.

Tables 6.1. and 6.2. indicate the tremendous growth potential for computer imports in these growth areas of the Third World.

Tab 6.1 Regional Trends in Computer Imports 1975 - 1978
(in Mill of $ US)

Region	Total Imports in 1978	Total Imports in 1977	Total Imports in 1976	Total Imports in 1975	Percent Change 1977-1978	Percent Change 1975 -1976
World Total	14,983,2	11,683,9	10,520,8	9,482,5	+28,2	+10,95
Western Europe	8,856,6	7,019,5	5,989,2	5,231,8	+26,2	+14,48
North America	2,751,8	2,041,2	1,790,4	1,441,7	+34,8	+24,19
Asia (incl. Far East)	1,106,7	882,0	768,7	703,6	+25,4	+ 9,25
Latin America	731,3	566,9	520,8	601,7	+28,9	-13,45
COMECON countries[1)]	482,3	389,5	775,7	826,8	+23,8	- 6,18
Oceania	407,6	330,8	279,2	276,8	+23,2	+ 0,87
Africa	333,7	263,6	235,0	236,0	+26,6	- 0,42
Middle East	317,7	189,9	-	-	+67,3	-
Arab States only[2)]	277,8	169,4	134,5	108,1	+63,9	+24,42
China	20,9	7,9	-	-	+164,5	-

1) Also enclose Cuba, Mongolia and Vietnam.

2) Arab States are a group of 20 Arab countries located in the Middle East and Africa. The totals for Africa and Middle East also include their constituent Arab countries in these statistics. These figures are developed by region for comparative purposes. They do not add up to the world total, since some duplication and overlap will occur.

Source: Figures are taken from the U.N. International Trade Statistics for category SITC 714 which includes computers and office machinery but does not include software or other computer services. United Nations, New York, September 1980 and October 1978.

TABLE [illegible]

THE FASTEST GROWING IMPORT MARKETS

RANK	RANK AMONG TOP 50	COUNTRY	PERCENT GROWTH 1977-1978	MARKET SIZE IN MILLIONS OF $U.S.
1	36	Iraq	+219.7	47.0
2	49	China	+161.5	20.9
3	29	Saudi Arabia	+105.3	[illegible]
4	17	Hong Kong	+ 61.9	180.4
5	46	Thailand	+ 59.1	21.0
6	20	Mexico	+ 50.6	160.8
7	45	Romania	+ 49.7	24.7
8	26	South Korea	+ 46.9	96.2
9	19	South Africa	+ 43.1	157.4
10	16	Brazil	+ 43.3	193.7
11	1	United States	+ 43.2	1,961.5

Source: Szuprowicz, B.O. - "The World's Top 50 Computer Import Markets", Datamation, January 1981

The degree of homogenization of demand is already such that it is possible to talk of an emerging world market for electronic products. In other words, COMECON countries, NICs and OPEC countries tend to demand the same kind of highly complex devices and electronic capital goods.

- Second, the economics of semiconductor manufacturing are undergoing substantial changes. We have extensively discussed this aspect before. Suffice it to draw out two implications for the choice of international location patterns:

  - the need to integrate all stages of production as far as possible in order to be able to reap technical and industrial synergetic effects;

  - the pressure to go ahead with worldwide sourcing for cheap, unskilled labour has been somewhat releaved, due to important changes in the cost structure, such as the increasing weight of the very high cost of equipment and r&d, of developing and maintaining software and of highly trained professionals.

- Third, in order to survive in an increasingly concentrated and global industry, semiconductor manufacturers have no choice but to increase their vertical integration with the overall electronics sector. One important implication for international location decisions would be that semiconductor firms have to subordinate increasingly their product and marketing strategies to application needs which would further strengthen the market orientation of their international investment decisions.

In short, the point which is really worth underlining at this stage is that during the 1970s the impact of innovation on international restructuring in the semiconductor industry has been formidable indeed and that changes in international location patterns are already taking shape which discussions on international restructuring have not yet taken sufficiently into account.

(d) Shifting high-technology investment to Japan - the trend of the future?

We have seen that possible future location shifts in semiconductor manufacturing will probably focus on the US and Western Europe, and particularly on the European periphery. Non-OECD locations might become of increasing importance during the 1980s.

However, we have to add again a point of warning and that is that all previous statements are based on very unsafe grounds and that, in addition, key variables of this sector are changing extremely fast. A case in point would be recent shifts of high-technology investment to Japan. Are they again going to change the structure of this industry?

According to an announcement made in July 1981, Texas Instruments Japan plans, by the end of 1981 to be by far the biggest maker of 64 K random access memories (RAM) in Japan - with plant capacity for no less than 1 million units a month. This target in fact would mean a doubling of the monthly production figure reported for 1981.

If these plans would materialize, their consequences could be formidable indeed:

First, TI Japan then would considerably outpace its Japanese competitors. Compared to the 1 million monthly output figure, Fujitsu and Hitachi are making about 300,000 and 200,000 units of 64 K RAMs now, and are said to increase output to 600,000 and 700,000 units respectively by the end of the year. NEC, Oki and Toshiba are each expected to be up to 300,000 units by the end of the year, while Mitsubishi is going up to 200,000 units.

Second, it would establish Japan as the largest centre for VLSI circuit manufacturing - for 64 K RAMs for instance, Japanese production figures would increase threefold, from 1.25 million to 3.4 million units a month.

Third, TI's move to Japan could have a tremendous impact on international location patterns, not only in VLSI circuit manufacturing itself, but also for the producer of the relevant equipment and for applications.

For VLSI circuit manufacturing and particularly 64 K RAM other US merchant firms are likely to follow TI in going Japanese. Viewed from the perspective of US merchant firms, the rationale underlying TI's move to Japan is an attractive one indeed: in order to regain market shares in the crucial mass market of random access memories, which they have lost to Japanese firms in the market of 16 K RAM, US firms would exploit themselves the advantages in terms of quality and cost inherent to the industrial structure and work organization patterns of Japan. According to the Electronics Times, TI Japan "...clearly feels that it can do better with Japanese than US manufacture, thus confirming the general view that Japanese workers and manufacturing systems give an advantage in terms of quality." [38]

A recent commentary in a Japanese newspaper, quoted by Business Week,[39] aptly describes the underlying logic: "The Japan-U.S. semiconductor war is jumping from the U.S. to Japan and is entering a second round of the struggle for brains and highly productive labor."

In addition, TI will be able to borrow investment funds in Japan at about one third of the price of interest rates in the US - the going rate in Japan as of July 1981 being under 8%. Given the extremely negative impact of the excessive interest rates on industrial investment and particularly on high-cost investment in VLSI manufacturing.[40] Japan's low interest rates are indeed attractive for US investors.

If more US firms would start VLSI manufacturing in Japan, this could mean for US makers of VLSI manufacturing equipment "the beginning of the end".[41] Electronics Times concludes that "...after all ...the Japanese companies will have an inside line as they negotiate with Japanese engineers. Thus it is not surprising that some American makers are setting up manufacturing facilities or joint ventures in Japan."[42]

Yet, it is probably still too early to judge whether these plans of Texas Instruments Japan will really materialize. In fact, the introduction of VLSI circuits seems to require much more time than originally perceived. This would seem to apply particularly to 64 K RAMs with their notoriously protracted introduction period.[43]

6.4. The Restructuring of Offshore Chip Assembly - An Empirical Assessment

6.4.1. Major Developments in the Industrial Restructuring of Offshore Chip Assembly

Offshore chip assembly has been experiencing major structural transformations which have passed by largely unnoticed outside the inner circles of corporate headquarters' management, professional industry analysts and consulting firms. Due to the changing economics of semiconductor manufacturing, offshore chip assembly today hardly corresponds anymore to what it used to be less than five years ago.

The introduction of new technologies to automate chip assembly did play an important role - but a somewhat different one than was expected only a few years ago by informed industry observers. Then, relocation back to the North seemed to be the most obvious implication.

In 1977 for instance, the most comprehensive description of chip-making had this to say: "The traditional cost-saving technique has been to employ less expensive overseas labour for the labour-intensive packaging operation. As the cost of overseas labour rises and improved packaging technology becomes available, overseas hand labour is gradually being supplanted by highly automated domestic (i.e. US, D.E.) assembly".44/

And it was Juan Rada in his otherwise extremely stimulating study for the ILO who took this position to its logical extreme, stating that "... the competitive advantage of less developed countries is being eroded through automation, and some key industries (Rada mentions textiles, garments and electronic products, D.E.) are returning to the developed countries." 45/

We have already discussed some of the major short-comings of this position (see chapter 6.2.). We will now discuss more in detail recent structural changes in offshore chip assembly which, according to Rada, should have been a priority candidate for relocation back to the North.

This study shows that, defined as a closing-down of labour-intensive production lines in Third World locations and their return to the classical industrial sites of the OECD region, "relocation back to the North" has not been an important issue for the semiconductor industry. The availability of new techniques, such as new equipment generations for automatic bonding and testing did of course change considerably the economics of semiconductor manufacturing - a point which we have documented extensively in chapter 3. Thus, the increasing automation of chip assembly is bound to be reflected in corporate decisions on international location.

Yet, however plausible it might sound that, viewed from the perspective of semiconductor firms headquarters' management, "relocation back to the North" would be the most appropriate solution, we have to accept the fact that empirical research simply does not bring out this hypothesis. In fact, the real question to be answered is what factors did prevent major semiconductor firms to proceed along these lines, i.e. what factors really conditioned their international restructuring decisions.

That is what we will try to do in chapter 6.5. But before we will present an empirical assessment of some major structural changes in offshore chip assembly which have been recently emerging. In particular, we would like to underline the following four developments:

- there has been a slowing-down of investment into offshore assembly lines since around the mid-1970s;

- employment figures in practically all offshore locations have been stagnating, if not declining;

- output and export figures continue to rise for all major offshore locations;

- and, finally, the value-added in offshore manufacturing which initially used to increase roughly till 1973, since then has been dramatically declining.

6.4.2. A Slowing-down of Investment into Offshore Assembly

Table 6.3 presents some overall allocation trends for offshore chip assembly by US firms as reported in some major studies on this topic. We have already underlined the shaky empirical basis from which both the inventory till 1979 and the projection from there on have been derived. But the important point for us now is that, without any doubt, the run into new offshore production sites, characteristic for the late 1960s and the early years of the 1970s, has not been sustained after 1974/75.

Tab. 6.3. Allocation Trends for Chips Assembly Lines: US Firms

1961	Fairchild establishes the first "offshore" SC assembly plant in Hong Kong
1964	Fairchild "opens up" South Korea
ca. 1968/69 - 1973	Peak of offshore movement. Since then several factors have caused US firms to rethink the rationale for offshore investment.[1]
1974/75	First "chip crisis". Little new or expanded offshore investment by mature US firms. While some newer US firms continue to establish offshore operations in the Far East to gain the cost advantages that still exist, the run into new offshore production sites, characteristic for the late 1960s and the early 1970s, is clearly over.[2]
1979	29% of chip assembly by US-based firms is conducted within the U.S.[3]
March, 1981	1980/81 chip crisis will accelerate the process of phasing-out offshore assembly facilities, particularly those using older technologies and less capital equipment.[4]
1989	Nearly 40% of chip assembly by US-based firms will be done in the U.S.[3]

Notes: 1) Sources: Truel, J.L. - "L'industrie mondiale des semi-conducteurs", Diss., Paris, 1980; Scottish Development Agency - "The Electronics Industry in Scotland. A Proposed Strategy", study prepared by Booz, Allen & Hamilton, April 1979, and Siegel, L. - "Delicate Bonds: The Global Semiconductor Industry", Mountain View, Calif., January 1981. See also table "Factors causing US firms to rethink the rationale for offshore sourcing"

2) Scottish Development Agency - "The Electronics Industry...", op. cit., p. 27

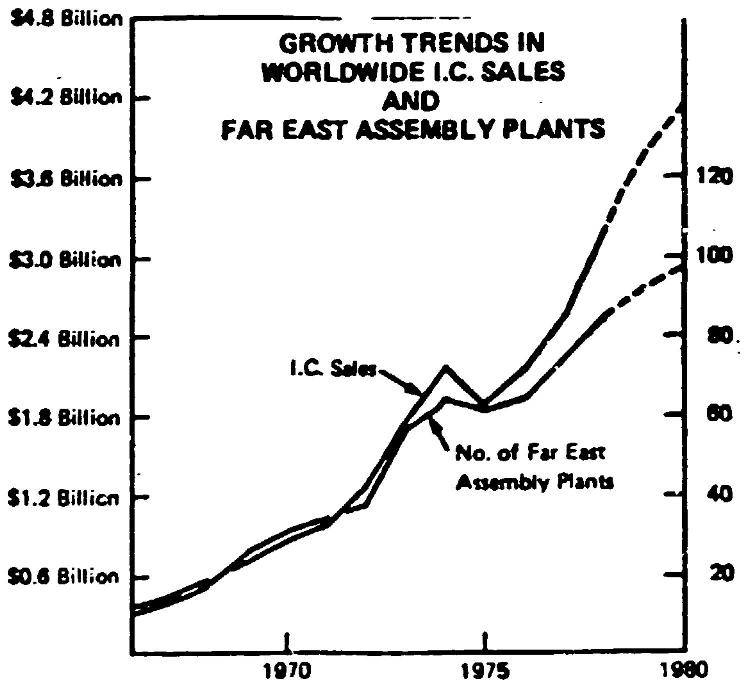
3) 1979 estimate and 1989 projection are from Frost & Sullivan, Inc. New York, quoted from "Northern California Electronics News, January 7, 1980.

4) "Global Electronics Information Newsletter" (Mountain View, Calif.) No. 8, March 1981 and various issues of "Electronics Times" (London)

In fact, there has been an overall slowing-down of investment into offshore assembly since around 1975.

Fig.6.1. documents that the number of Far East assembly lines which, till roughly around 1974, used to grow with practically the same speed as worldwide IC sales, since then has significantly lagged behind.

Figure 6.1.: Growth Trends in Worldwide I.C. Sales and Far East Assembly Plants



Source:
Rosen Associates, New York, November 1980

But this kind of information does not tell us too much. First, we would need to know whether this slowing-down in the expansion of offshore assembly lines has been just a short-term result of the 1974 - 75 semiconductor crisis or whether it did continue once demand recovered and global semiconductor production capacities expanded very rapidly again. Second, of even greater importance would be to know what concrete moves are behind this aggregate figure.

Table 6.4. gives a more differentiated picture of what happened to important offshore locations in the Third World. It is based on a sample of 27 leading US, Japanese and Westeuropean firms which in 1979 were responsible for more than 90% of the world semiconductor production.

Table 6.4. The Development of Offshore Investment in Various Third World Locations by Major US, Japanese and Westeuropean Semiconductor Firms [a)], 1971 - 1979

Country	Number of Firms Present [b)] 1971	1974	1976	1979
South-East Asia:				
Korea	6	8	8	8
Hong-Kong	1	6	6	7
Indonesia	0	3	3	3
Malaysia	0-2	11-13	13-14	14
Philippines	0	0	1	6 + 1 planned
Singapore	9	10	12	13
Taiwan	3	3	6	8
Thailand			1	1
Latin America:				
Brasil	0-2	2	5	5 + 3 planned
Mexico			12	13
Barbados	0	0	0	1
Puerto Rico			2	3
El Salvador		1	1	2
Mediterranean Bassin:				
Morocco			1	1
Malta			1	1
Portugal			2-3	3

a) The sample includes 24 US firms (AMD, Burroughs, Fairchild, General Electric, General Instrument, Harris, Hewlett Packard, Intel, International Rectifier, Intersil, ITT, Litronix, Mauman, Monsanto, Mostek, Motorola, National Semiconductor, Pulse Engineering, Raytheon, RCA, Rockwell, Texas Instruments and Zilog), 6 European firms (Ferranti, Philips, Plessey, S.G.S., Siemens and Thomson), and 7 Japanese firms (Hitachi, Mitsubishi, NEC, Oki, Sanyo, Toshiba and Toyo).

b) Each firm is counted only once in each country, even if it owns more than one plant.

Source: Truel, "Les nouvelles stratégies . . . ", 1980, p.12.

Whatever its shortcomings [46] this table amply documents four developments:

(a) In the "classical" offshore locations in South East Asia, i.e. in Singapore, South Korea, Taiwan, Malaysia (starting from the early 1970s) and Hong Kong, the arrival of new entrants has clearly levelled off since around 1974.

(b) After that date only one South East Asian country, i.e. the Philippines, was able to attract an important amount of new investment. Indonesia and Thailand on the other hand had very poor results. One should add that since 1979 three additional candidates for late-comer offshore location became available in the region: the PR China, particularly its coastal "Special Economic Zones", [47] India and Sri Lanka.

(c) The traditional locations in Latin America, i.e. Mexico's "border industries' belt" and the Caribbean Bassin also show a relative stagnation, whereas Brazil shows an overall dynamic trend. In fact, for Brazil, access to the potentially huge Latin American market has been the guiding principle, and costs,particularly labour costs were only of secondary importance. [48]

(d) In the Mediterranean Bassin only very recently some offshore locations have been developed, but still on a fairly limited scale.

6.4.3. Stagnating, If not Declining Employment

Employment figures in Third World offshore locations have been stagnating if not declining.

Table 6.5 shows that the employment figures for US affiliates abroad have only slightly increased between 1974 and 1978. Taking into account the increase of US implementations in Western Europe, this would mean that employment figures for Third World locations have at least stagnated.

Tab. 6.5. "Development of World Employment Figures for US Semiconductor Firms, 1966-1978" (thousands)

Year	Employment U.S.A.	Employment Abroad a) (estimation)	Employment Total
1966	82	4	86
1967	85	10	95
1968	87	20	107
1969	99	40	139
1970	88	45	133
1971	75	50	125
1972	98	60	158
1973	120	80	200
1974	133	85	218
1978	-	89	-

a) Till 1974, the great majority of foreign employees was located in Third World locations. In 1974 for instance, of a total of 85.000 only 5.000 were employed in factories located in Western Europe and Japan.

Source: For 1966 - 74: U.S. Department of Commerce - "U.S. Report on the Semiconductor Industry", Washington, D.C., September 1979. For 1978: USITC. Adapted from: Truel, 1980c, p. 6

In addition, table 6.6, presenting figures for Intel Corp., a leading US semiconductor merchant firm, gives evidence for a declining share of foreign employees as a percentage of total employees.

This is at least the interpretation given to these figures by Robert N. Noyce, vice-chairman of Intel Corp., in his statement before the U.S. Congress in January 1980: "As progressively higher threshholds are reached by the U.S. semiconductor industry in product and process technology, the tendency appears to be a decrease of foreign employees. This trend is enhanced by the increased use of automatic bonding equipment in the offshore assembly plants. Intel, for instance, more than tripled total corporate employment from 1975 to 1979, but the proportion of foreign employees dropped from a peak of 41% in 1976 to 30% in 1979 even though a higher percentage of sales were abroad and a higher percentage of our total employees were foreign sales and marketing personnel." 49/

Tab. 6.6. Intel Employment - Global Trends

	Yearly Employment Increase	Foreign Employment
1975	—	36%
1976	58%	41%
1977	11%	39%
1978	34%	33%
1979	31%	30%

Source: Intel Corporation

Quoted from: Global Electronics Information Newsletter, (Mountain View/California), No. 1, June, 1980, p. 5.

Intel, which currently employs about 14,000 worldwide, may not be entirely representative of the industry however, since it concentrates on microprocessor production, one of the most sophisticated branches of the semiconductor industry. Other semiconductor operations (when seperated from non-semiconductor activities of the same companies) tend to employ larger percentages of employees abroad.
Thus, it would be important to dig out additional informations which would allow us to test to what degree the Intel case indicates a general trend.

6.[illegible]. Output and Export Figures Continue to Rise for all Major Offshore Locations

Output and particularly export figures for assembled semiconductors continued to increase for practically all major offshore locations.

We can document this with data on semiconductor imports to the US under tariff code items 806.30 and 807, recently made available by the U.S. Department of Commerce. 50/ These figures give a fairly good picture of recent trends in output and export figures of major offshore semiconductor assembly locations for two reasons: First, most of the semiconductors assembled in offshore locations are re-exported to the U.S., where they are tested and marketed or in some cases marketed directly following testing in Asia. Second, most of these re-exports qualify for special treatment under tariff code items 806.30 and 807 which, in essence, exclude from duty the U.S.-produced content of the assembled goods.

Table 6.7 shows that, except in the case of Taiwan, import figures covering TSUS items 806.30 and 807.00 are a good proxy for the overall semiconductor exports of these countries to the U.S.

Tab. 6.7. **Exports of Semiconductors by Selected Less Developed Countries, 1976 (millions of dollars)**

Exporting Countries	Total Exports	Exports to U.S.	806/807 Portion	Exports to Japan	Exports to Other Third Countries
Singapore	339.5	237.0	197.1	4.3	98.2
Mexico	102.5	100.7	83.4	-	1.8
Korea	298.6	164.8	148.3	47.9	85.9
Hong Kong	126.2	90.6	71.2	5.2	30.4
Taiwan	197.7	68.6	36.9	17.5	111.6
Malaysia 1/	na	206.0	192.2	16.5	na

1/ Complete data for Malaysia was not available.

Source: BIC Country Market Surveys, Electronic Components, 1978; Japan Tariff Association, computed by Ministry of Finance, 1976.

Quoted from: "A Report on the US Semiconductor Industry", US DOC Industry and Trade Administration, Office of Producer Goods, September, 1979, (GPO Stock No. 003-009-00327-9)

Table 6.8 documents recent trends in the U.S. semiconductor imports from offshore locations in the Third World.

Tab. 6.8. **Semiconductor Imports from Offshore Locations[1)] - their Role for Imports and Supply of Semiconductors in the U.S. and Recent Structural Changes, 1970 - 78**

Year	(a) Shipments of US based semi-ductor firms[2)]	(b) Total Imports	(c) Total 806.30/ 807.00 Imports	(d) (=c/a)	(e) (=c/b)	(f) U.S. Content	(g) (=f/c)	(h) Dutiable Value	(i) (=h/c)
1970	1,720	157,464	139,071	8	88%	78,409	56%	60,662	44%
1971	1,502	179,092	152,204	10.	85%	81,255	53%	70,949	47%
1972	1,848	330,277	249,717	13,5 %	76%	127,346	51%	122,371	49%
1973	3,124	618,613	410,207	13,1 %	66%	185,637	45%	224,570	55%
1974	3,646	961,338	681,844	18,7 %	71%	310,359	46%	371,485	54%
1975	3,002	802,687	617,276	20,5 %	77%	291,718	47%	325,558	53%
1976	4,312	1,107,399	877,648	20,4 %	80%	400,908	46%	476,740	54%
1977	4,841	1,352,317	1,120,121	23,1 %	83%	616,860	55%	503,261	45%
1978	-	1,800,000	1,478,535	-	82%	886,705	63%	591,830	40%

1) =Semiconductor imports from offshore locations are measured by imports under the TSUSA Items 806.30 and 807.00

2) =Excluding shipments from affiliates located outside the U.S.

Sources: Census Bureau Foreign Trade Data Printouts/TSUSA 806/807 as quoted in: US Department of Trade - "A Report on the U.S. Semiconductor Industry", Washington, D.C., September 1979, and "Import Trends in TSUSA Items 806.30 and 807.00", U.S. International Trade Commission Publication 1029, Washington D.C., January 1980

There are four basic informations to be drawn from this table:

- imports from offshore locations have been rapidly increasing during the 1970s;

- semiconductor imports from offshore locations during the 1970s increased their share in the shipments of US semiconductor firms to the US market;

- the share of semiconductor imports from offshore locations in the overall semiconductor imports of the US, which has been falling from 1970 to 1973, since then has been recovering to the levels of the late 1960s;

- the foreign content of semiconductor imports from offshore locations, i.e. the value-added in these production lines, has been considerably changing.

It is the last point which is probably the most important characteristic of the newly emerging modes of industrial restructuring in offshore chip assembly. We will thus discuss it in detail in 6.4.5. But let me first develop further the first three points:

First, imports from offshore locations have been rapidly increasing during the 1970s. In fact, from 1970 till 1978 they increased more than tenfold from $ 139 million to nearly $ 1479 million. It is true that after a fivefold increase from $ 139 million in 1970 to $ 682 million in 1974, there was a fall of approximately 9.4% in 1975. Obviously, this one year reduction of offshore imports was a reflection of the 1974-75 semiconductor crisis. But since 1976, offshore imports have clearly recovered. In fact, from 1975 till 1978, they have more than doubled with a per annum average growth rate of 33.9%.

Second, relative to the overall shipments of US based semiconductor firms to the US market, semiconductor imports from offshore locations during the 1970s significantly increased in importance. Whereas in 1970 their value equalled 8.1% of shipments of US based firms, their share increased to 23.1% in 1977. At this last year, imports from non-offshore locations, i.e. from Japan and Western Europe, were significantly lower, $ 232 million relative to the $ 1120 million from offshore locations; in terms of shipments of US based firms they hardly covered 5%.

Third, in relation to the overall semiconductor imports of the US, the share of semiconductor imports from offshore locations has been falling from 88% in 1970 to 66% in 1973, but since then has clearly recovered again, reaching 82% in 1978. In other words, on this aggregate level it is still safe to say that the great majority of semiconductor imports to the US is produced in Third World locations, particularly in Southeast Asia and in Mexico.

But reality is more complex. In fact, we have already shown that this statement needs to be modified, once we turn to specific product groups, particularly if we talk about standardized memories, like 16 K RAMs, where Japanese firms have already made significant inroads.

In addition, the DoC figures end at 1978, indicating for that year already a significant increase of imports from non-Third World locations (up 38% from $ 232 million in 1977 to $ 321 million in 1978). Yet, as we have already indicated, the run into new OECD locations started only in response to the chip shortage of 1978/79 and the consequent Japanese penetration of important US market segments. In other words, the picture drawn by these figures up to the year 1978 might not apply anymore today. In the meantime, imports from Japan and even more so from the European periphery, particularly Ireland, have increasingly gained in importance.

6.4.5. The Rise and Fall of Value-Added in Offshore Chip Assembly

Finally, and probably of greatest importance, are changes in the foreign content of semiconductor imports from offshore locations. (See columnes (h) and (i) of table 6.8.) Whether or not the value added in offshore locations will cover an increasing part of the overall value of semiconductor exports is in fact of crucial importance both for employment and for the scope for strategies to increase the integration of these activities with overall industrial production.

Two completely distinct phases can be discerned:

- the <u>rise of foreign content</u> from 44% in 1970 to 55% in 1973, followed by a period of consolidation till roughly 1976 around the 54% mark. According to the Commerce Department study, three factors did play an important role: rising wage levels in the classical offshore location sites; the availability of locally produced parts in some of these countries, particularly in Singapore, Taiwan, Malaysia and South Korea; and the availability of parts from third countries, particularly from Japan.
- the <u>decline of foreign content</u> since 1977 which, if it continues, may lead to a leveling off, or even drop, in Asian semiconductor employment.

In fact, this decline is a direct reflection of some recent changes in the economics of semiconductor manufacturing which we have already discussed extensively. As the complexity of circuitry increases, more value is produced in the early wafer-fabrication stage, i.e. in the U.S., in Japan or in some locations in Western Europe. Furthermore, the more complex circuits require much more complex, computerized final testing, which again is usually done in OECD locations, particularly in the U.S. and Japan.

Table 6.9 shows that, except for Hong Kong which had a much higher foreign content level, all the other major offshore locations had foreign content shares close to the average share of 45% (Malaysia, Singapore, Taiwan) or significantly below it (South Korea and Mexico). By far the lowest foreign content (32%) can be found in the Philippines. Thus it would seem safe to conclude that the decline of foreign content is a well-established trend for all major-offshore semiconductor production sites.

Tab. 6.9. Comparison of U.S. and Foreign Contents In Imports Under TSUSA Items 806.30/807.00, 1977 ($000)

Country	Total 806.30 & 807.00	Foreign Content	Percent	U.S. Content	Percent
Malaysia	$269,936	$120,313	45	$149,623	55
Singapore	234,616	108,958	46	125,658	54
Korea	208,971	81,413	39	127,558	61
Taiwan	72,720	33,286	46	39,434	54
Hong Kong	63,885	35,896	56	27,989	44
Mexico	63,286	21,785	38	41,501	62
Philippines	52,182	16,579	32	35,603	68
Total seven countries	965,596	418,230	43	547,366	57
Other countries	154,525	85,031	55	69,494	45
TOTAL	$1,120,121	$503.261	45	$616,860	55

Source: Bureau of Census, Foreign Trade Data Printouts/TSUSA 806/807

Quoted from: "Report on the US Semiconductor Industry", US DOC Industry and Trade Administration, Office of Producer Goods, Washington, D.C., September 1979, (GPO Stock No. 003-009-00327-9)

To conclude, the recent decline of foreign content in semiconductor imports from offshore locations, at the same time when these imports continue to increase in absolute terms, would in fact underline our main point: relocation back to the North of chip assembly is not a significant issue, despite the gradual automation of that process. Rather it is the considerable structural changes of semiconductor manufacturing taking place in offshore locations, both with regard to product and process technology, and its implications for a restructuring of conventional offshore activities, to which future in-depth empirical research should be directed.

Worldmarket-oriented semiconductor manufacturing might in fact continue to expand in some Third World locations, but compared to the status quo, this new type of offshore semiconductor manufacturing might produce even smaller and less viable positive effects on employment generation, forward and backward inter-industrial integration and technological spin-offs.

6.5. Possible Future Trends - the Conflicting Evidence

What are going to be the most likely future scenarios for the international restructuring of the semiconductor industry and in particular what is the role which production sites in the Third World are going to play?

This study has repeatedly warned that ready answers to these questions are not available and that those, who claim to have them, are arguing on very unsafe grounds.

6.5.1. Options Depend on the Actors Involved - the Complex and Dynamic Interplay of Factors Conditioning International Location Patterns

What is possible however is to identify some of the options facing the major actors of international restructuring in this sector, particularly private firms based in the OECD region, and to confront them with those bits and pieces of, mostly conflicting, evidence which is available today. Four points would seem to be worth underlining:

- First, if only the interests of semiconductor manufacturers would be at stake, then "relocation back to the North" would indeed be the most probable future scenario for a large part of chip assembly lines located today in developing countries (see 6.5.2.)

- If we proceed however, secondly, to the broader picture of the integrated electronics sector and try to identify the options open to highly diversified systems firms, then we would find that a much more complex and dynamic interplay of factors is going to condition international location decisions and that, by and large, the drive for internationalization is going to continue (see 6.5.3.)

- A third point then would be that as long as developing countries would contine to rely predominantly on the willingness and capacity of private firms originating from the OECD region to redeploy production facilities and technology, they could hardly expect to increase the viability of their existing segmented worldmarket-oriented chip assembly lines. Within such a scenario of passive and unselective worldmarket integration, the vulnerability of these production lines to the economic crisis and to the impact of radical technological break-throughs will remain excessive and there will be not much chance to proceed to an increasingly integrated electronics industry which could be subordinated to the specific requirements of these countries.

In other words, as long as developing countries do not devise and implement effective counter-vailing strategies to the prevailing modes of international restructuring, the most likely outcome will be that a handful of privileged "high technology enclaves" will emerge close to the future growth markets in the Gulf region, in South East Asia, and probably also in Brazil and Mexico, thus complementing today's developments in the European periphery, particularly in Ireland and Scotland.

- A <u>fourth</u> and last point would be that any projection on possible future trends in international location patterns of industry could hardly claim to be realistic, if it would not be related to a much broader context, i.e. the overall perspectives for future interactions of innovation, international transfer of technology and international restructuring in a period of crisis. This is what we are going to do in chapter 6.6.

6.5.2. "Automate, But Bring it Back Onshore" - The Rationale Underlying Future Trends in Semiconductor Assembly

Viewed from the perspective of established US semiconductor merchant firms, relocation back to the US would seem to be a preferred scenario for most of their offshore chip assembly lines. Take for instance recent statements by Donald Levinthal, editor of the influential magazine Semiconductor International. In his April, 1981 editorial,[51/] Levinthal argued that US semiconductor companies should not only automate their assembly operations but move them "back onshore". He claims that this would be the only way for US firms to counter the Japanese challenge.

In fact, in contrast to US major semiconductor firms which since around the early 1960s have made extensive use of global sourcing for cheap labour, particularly in South East Asia, Japanese firms have concentrated from the beginning on assembling products at home, using more automation in their operations.

Levinthal argues that insistence on offshore operations, very useful in the early stages of the industry, could put US firms in an increasingly weak position for at least two reasons:

- it deprives them from significant systems productivity gains;

- it will make them more vulnerable to political turmoil abroad.

With regard to the first point, Levinthal argues that in order to evaluate correctly the complex trade-offs between US or offshore location, a "...systems concept rather than a fragmented operation-by-operation process mechanization procedure" would be needed. Only then would it be possible to avoid being roped into ever new traps of mono-causalistic cost-benefit approaches. He quotes as a typical example that "...people who make the monetary decisions are always quick to bring up the argument that even if they automated their operations, personnel to operate and maintain are still less expensive offshore than here in the US."

According to Levinthal this is of course a valid argument - but it fails to view a complete picture to be taken into account when deciding on choice of technology and locational patterns. After all, this argument would neither take note of such hidden costs as the increasingly high costs of transportation, the benefits forgone with regard to industrial synergism, and, last but not least, the increasing vulnerability to external decisions and political unrest.

This last point is particularly underlined by Levinthal: "If political turmoil begins to haunt the world, especially in those areas where US companies have their assembly operations, it would be a desaster for the US semiconductor industry. It would be an almost impossible task to immediately begin onshore assembly in the event of serious political unrest."

In Levinthal's view, the US seminconductor industry is already highly vulnerable in this aspect in contrast to Japanese firms, which, in his view, have wisely avoided this danger. "With the new, more vigorous US defense posture", Levinthal adds, "political polarization and turmoil are bound to occur. We can expect that some countries which now openly welcome the semiconductor industry will make greater demands on companies hoping to maintain their facilities or open new ones."

No doubt, this analysis does reflect fairly well some of the major preoccupations of US semiconductor firms in a period when both the international competition and the economic crisis are intensifying. In addition, political destabilization is rapidly proliferating in former show-pieces of US offshore sourcing investment and governments and technocrats in some of the early offshore location countries like in Singapore, Taiwan, Malaysia and South Korea are already very active in devising much more aggressive and demanding strategies. Thus, from the point of view of major US semiconductor manufacturers, Levinthal is probably right when he concludes: "If the US semiconductor industry is to maintain control over its destiny it must give serious consideration to investing in automation, getting its act 'back together', and moving assembly processes home."

However, there is reason to doubt whether US semiconductor could or even would like to proceed very far along these lines of international restructuring. After all, they are not at all alone in this business anymore - of the ten major US firms only two can still claim the status of formal independence, whereas all the others are to one degree or another integrated into huge highly diversified corporate giants. We have extensively documented in chapter 5 the trend towards an increasing vertical integration internal to huge, highly diversified conglomerates, linking together all major sectors of the global electronics complex. Let us now discuss some possible future trends in international location, as perceived by a highly diversified multinational with a focus on information processing.

6.5.3. A Renewed Drive for Internationalization - the Case of Siemens

According to Karl Heinz Kaske, president and chief operating officer of Siemens, this company is putting greater emphasis on building up its foreign operations, which already employ about one third of its 338,000 workers. This would include overseas manufacturing, but also certain r+d activities.

This new drive for internationalization comes on top of an already high degree of internationalization: the company's foreign sales and exports, already in 1980 accounted for around 54% of overall sales worth DM 32 billion ($ 13.3 billion).[52/]

What is the logic underlying this renewed drive for internationalization? In contrast to the 1960s and the 1970s, the search for cheap labour does not seem to be anymore the dominant motivation. Rather it is the need to use the new capital-intensive equipment efficiently, i.e. to run it, if possible, around the clock, without any need to comply to labour or environmental regulations. This new strategic focus has been clearly underlined by Kaske in a recent statement for the Financial Times: "Siemens' strategy is partly influenced by the inability to use expensive new capital-intensive equipment efficiently in Germany....such equipment needed to be put into a country where it could be worked for seven days a week, three shifts a day, and that country is not the Federal Republic of Germany." [53/]

In the not too distant future a second motivation might increasingly gain in importance: it relates to the need for worldwide recruiting of qualified but relatively low-cost engineers. In fact, electronics companies in West Germany are facing increasing difficulties to find qualified engineers, even at relatively high wage levels.

A case in point would be the plans of Siemens, announced in December 1980, to shift its Random Access Memory (RAM) wafer fabrication to Villach, Austria, from Munich. The new 40,000-sq.ft. plant will cost the company $ 25 million. Electronics News of 1 December 1980 quotes Siemens engineers according to whom this move was mainly due to the need to take advantage of "good and lower cost engineers".

As some of the major export platform countries, both in the European periphery (Ireland) and in South East Asia (Singapore, Taiwan and South Korea) are about to expand significantly their training programmes for electronics engineers, computer programmers and systems analysts, [54] this sourcing for low-cost electronics engineers will increasingly be geared to these locations.

In the final analysis, this new kind of internationalization drive results from the increasing emphasis which companies like Siemens since the beginning of the 1970s have been laying on productivity improvement through the introduction of heavily capital-intensive equipment. In other words, international restructuring and innovation have been linked in a very specific manner.

Since 1976, Siemens in fact has been cutting back sharply its work force, doing away with about 40,000 work places. At the same time annual capital expenditure has been increased to DM 2.2 billion in 1980 and the company is planning to maintain if not to increase this level of capital formation during the years to come. [55]

Such a productivity-oriented strategy obviously has its hidden costs, i.e. the vastly increasing recruiting requirements for highly qualified engineers and the dramatic increase of equipment costs. It seems as if management, when it originally conceived this strategy, underestimated these negative side-effects.

In other words, automating industrial production in classical OECD locations seems to run into certain substantial constraints due to the lack of low-cost skills and the limits to cash in on expensive equipment as rapidly as possible. This seems to apply even to certain areas of high-technology production, like in the fields of semiconductor and telecommunications production - but we still need more systematic research on this important topic.[56]

6.5.4. From Worldmarket-Oriented Chip Assembly to an Integrated Electronics Industry - a Realistic Option for Developing Countries?

What scope does exist for developing countries to transform, both individually and collectively, their existing segmented worldmarket-oriented chip assembly lines into an increasingly integrated electronics industry which could be subordinated to the specific requirements of these countries?

Our research forces us to conclude that this is a very remote possibility indeed - at least if developing countries continue to rely nearly exclusively on OECD-based firms and their willingness to redeploy production facilities and technologies.

Within such a strategy of passive and unselective worldmarket integration, only a handful of countries could expect to keep some offshore chip assembly lines within their borders and to upgrade them into more integrated patterns of a national electronics industry.

Obviously, only those countries could qualify as candidates for such a strategy which, in addition to their export-oriented chip assembly plants, have already established a more than embryonic network of capital goods industries. That would exclude for instance a country like the Philippines which is booming in chip assembly plants, but is practically devoid of any serious capital goods base. Overall, no more than 15 - 20 countries would probably belong to this category.[57/]

For these countries then the question of immediate concern would be, under what conditions they could hope to achieve a sufficient transfer of production activities of an increasingly complex technological nature.

Three points should be underlined in this context:

(a) For some major electronic components and systems firms in the US, Japan and Western Europe, it might indeed be rational to transfer, albeit in a strictly selective manner, relatively advanced microelectronic technology to a few industrial growth poles in Latin America, South East Asia, the Middle East and the Mediterranean area. In addition to access to some regional "future growth markets", four factors seem to be of particular importance:

- The availability of cheap and docile, but highly skilled labour and engineers (availability of low-cost skills and brains);

- The need to run extremely expensive equipment practically around the clock, i.e. to maximize its overall annual utilization and to minimize possible "down-times". Pending further major technological break-throughs in robotics, for instance with regard to sensors, transducers and actuators, it might well be profitable to run NC machine tools worth $ 75,000 to $ 100,000 on a multi-shift basis in a free export zone, say in Malaysia, where labour regulations are extremely soft and unions practically do not exist.

- In some industrial growth poles of NICs there might be less resistance of the labour force against the necessary experimenting with new forms of organizing the production process, and particularly with regard to the gradual introduction of robots and flexible machining systems. In other words, some of the relatively untouched industrial locations in a couple of NIGs might be perceived by multinational corporations' headquarters management to be an excellent testing ground for developing strategies and tactics of introducing these new technologies into industrial production based in the OECD region.

- The availability of low-priced, i.e. highly subsidised infrastructure and a minimum of regulations with regard to environmental and labour standards, are probably becoming of increasing importance for instance for wafer-fabrication and silicon foundries.[58/]

(b) With regard to technological spin-offs and learning effects, and with regard to international competitiveness, there will be no doubt some positive effects.

This would apply for instance to learning effects for supervisory and technical support management functions. International competitiveness might be achieved with regard to certain market niches: assembly subcontracting; silicon foundry and partiuclarly wafer-fabrication subcontracting geared to regional markets.

Yet three questions remain to be answered:

- Will these new export markets be of a viable nature? In fact, demand on these markets tends to vacillate excessively, the number of competitors will rapidly expand, and it is not at all sure whether these markets will not disappear soon. Further, the present pattern of international subcontracting for instance with regard to assembly, are due to the existence of certain technological bottlenecks, which, given the high speed of innovation in these areas, might soon be removed.

- What are the complementary social costs involved?

- What will be the impact for strategies of transition to a more self-reliant development pattern?

The available evidence would seem to indicate that all of these three questions would have to be answered in the negative.[59/]

(c) The scope for a policy of import substitution and export promotion in the field of complementary services, for instance software and computer services, seems to be limited. For developing countries to pursue such a policy, this would require a combination of selective protectionism and export promotion, either on a national scale or as part of collective self-reliance arrangements.

Yet, pressure is increasing to subordinate trade in services under GATT rules. According to the US special trade representative, Bill Brock, "...free-trade in services is a priority aim." 60/ The same message can be found in the fervent plea for free trade in electronics by Robert Noyce, Vice-Chairman of Intel at the 1981 Financial Times World Electronics Conference. 61/

Even if we would assume that there would be sufficient scope for promoting the export of software, the second question would be whether it would really pay off to focus on software exports. Take for instance the policy of the British Department of Industry to promote the marketing overseas of software used in the Prestel View Data System and the software marketing efforts of the States-based INSAC consortium in the UK. According to the Financial Times, "...software on its own is not a big revenue-earner, like the plot of a novel, it is little more than a collection of ideas whose full value is realized only when it is packaged as a finished product. A bestseller makes more money for the publisher than for the author. In just the same way, the electronics industry's fattest rewards go to the companies which turn an idea into a manufactured product, rather than those who thought of the idea in the first place." 62/

Instead of relying exclusively on software sales, real profits could only be reaped by including hardware sales, for instance terminals. The Financial Times concludes that, "by emphasizing software sales, Britain is not only failing to maximize the commercial return on its technological assets. It is also jeopardizing its international competitive position. When Japan's computer industry steps up its export drive to Europe - as seems certain to happen - it will be no consolation that its machines contain British know-how. ...Britain's current approach looks disturbingly like a formula for a new kind of brain drain." [63]

If this analysis of the Financial Times' computer expert is assumed to be correct for a country like Great Britain, how much more would such an evaluation apply for countries like Brazil, Singapore or South Korea!

6.6. International Transfer of Technology and Indust Restructuring - Perspectives for the 1980s

Today it is more urgent than ever before to understand how control over technology and international restructuring in industry are interlinked. It has been shown elsewhere[64] that much depends on who are going to be the dominant actors in this game, and that without a theory of the international economic crisis it will be impossible to link together technology, demand and structural change in world industry.

It is in this context that we are now going to discuss some perspectives for international transfer of technology and industrial restructuring for the 1980s. In particular, we will deal with two questions:

- Is the consensus among privileged actors of international restructuring of industry running into increasing constraints?

- What options are available for OECD countries and what is their scope for implementing these strategies?

6.6.1. Increasing Constraints to a Consensus Among Privileged Actors

During the 1960s and during most of the 1970s, major actors by and large viewed prevailing patterns of international transfer of technology and industrial restructuring as "functional" for their goals and long-term interests.

Take for instance firms based in major OECD countries. For them, the balance was fairly positive: trade increased; surplus petrodollars were effectively recycled into demand for goods produced by OECD-based firms; offshore investment in low labour cost countries allowed them to compress labour costs and counter the decline of productivity growth in home locations; the capital goods sector was able to benefit considerably from technology transfers to developing countries; and, finally, the trade balances of the major OECD countries with non-OPEC developing countries improved.

Yet, negative side effects could not be denied, even in the hardcore growth areas of the OECD. In fact, the destruction of jobs, the devaluation of skills and the relative de-industrialization, both geographically and sector-wise did increasingly create serious economic and political problems for these countries and were thus perceived to be important constraints to the continuation of this type of international transfer of technology.

The balance was even more negative for a growing number of regions in the Third World where the increasing import of technology originating from OECD-countries, rather than initiating a process of "modernization", caused tremendous economic and social deformations which, not only in the case of Iran, prepared the way to chaos and socio-economic retrogression.

But overall, it remains true that the prevailing modes of international transfer of technology and international investment, i.e. the dominant patterns of "international industrial restructuring", did not run into basic, truly antagonistic contradictions between major protagonists.

But this may rapidly change. In fact, the golden age of international transfer of technology with its relative harmony among privileged actors might soon give way to a series of new and basic contradictions.

Viewed from the technology exporter's perspective the process of transferring and disseminating technology, once started, could increasingly erode his capacity to control the technology, i.e. to remain in a position of technological dominance.

Whether or not this will occur, depends on a couple of factors influencing the international diffusion of technology and innovative capacities.

In a recent study, the OECD secretariat has identified three major concerns of technology exporters: 65/

- To what degree has the international transfer of technology contributed to a strengthening of technological and innovative capacities in at least some NICs?

- Will Third World markets continue to increase their importance for OECD-based firms and, if so, what role will transfer of technology have to play as a market penetration instrument?

- Will it be possible to generate the financial resources needed to transform the potentially infinite import needs of developing countries into effective demand, i.e. under what conditions and for what type of countries will it be possible to secure a sufficient capacity to import technologies from OECD-based firms?

In the context of the present crisis, it is difficult to give an unequivocal answer to these questions. But it is possible to outline three major trends which might change considerably the international distribution of economic and political power:

- a qualitative intensification of international trade competition;
- few challenges to the technological dominance of OECD-based firms;
- recent changes in the factors conditioning the export of capital goods and technologies to developing countries.

(a) A qualitative intensification of international trade competition

Trade competition from the Third World during the 1970s has come from countries which were only relatively unimportant customers for capital goods and technology originating from the OECD. Take for instance the four most important "export platform" countries of the Third World, i.e. Hong Kong, South Korea, Singapore and Taiwan. They have been providing roughly two-thirds of manufactured imports from developing countries in recent years, but their share in total exports of capital goods from OECD to developing countries remained low during the whole period: in 1968 this share was 8.1% and in 1977, the last year for which figures are available, it had increased to nothing more than 8.9%. In the same period, five major OPEC countries, i.e. Saudi Arabia, Iran, Venezuela, Nigeria and Algeria increased their part in OECD-capital goods exports to the Third World from 12.2 to 28.1%. 66/

The study is probably right in concluding that "... OECD countries have so far been able to protect and even strengthen threatened industries without risk of direct retaliation as the countries importing most technology did not produce on a very large scale for export (large domestic markets, type of product, running-in time required for plant and equipment)." In other words, the major receivers of transfer of technology from the OECD, such as Brazil, Mexico and Argentina in Latin America, India in Asia, and major OPEC countries are still not important competitors for world export markets. But this is bound to change, as growing export-orientation is inevitable, if only because of the technology-built-in pressure to realize economies of scale. **To quote again the OECD study:**

"There are no guarantees that this favourable situation will continue. As industrial development advances in countries with large domestic markets, the need for sophisticated technologies will increase and there will be increasing pressures to pay for such imports by exporting manufactured products, or further increasing international borrowing with attendant debt-servicing problems. A renewed swing towards export promotion policies is one way of financing imports of technology. The exact effects of this evolution will depend on whether increases in exports and income outweigh losses of markets and imports and how successfully the adjustment process works in OECD countries." 67/

In other words, even the most powerful multinational corporations might frequently be confronted with situations where trade competition becomes an increasingly "tricky affair", full of trade-offs for which practically no reconciliation would seem possible. This is due to the fact that at least a few of the new competitors, like some OPEC countries and NICs, cannot anymore be so easily pushed around as this was possible with the classical 'export platform' countries. 68/

On the other hand, the position of OPEC countries and NICs off late seems to have considerably deterioriated. This would be due to the combined impact of a softening world petroleum market and the debilitating impact which the present economic crisis has even on those NICs which, like Brazil and South Korea, only a few years ago seemed to abound with unbeatable vitality. 69/ **It is hard to judge how this will influence patterns of international trade competition for specific industrial sectors. Suffice it to say here that overall the multipolarization of international trade competition for industrial products cannot be stopped**

anymore and that this is indeed a considerable challenge for OECD-based multinational corporations.

(b) New challenges to the technological dominance of OECD-based firms

Apart from mature and standardized technologies, OECD-based firms have been able to keep effective control over technology transfers and integrate them into their worldwide trade and production strategies.

According to the OECD secretariat, this technological dominance of OECD-based firms is bound to be increasingly challenged: "...it will become more difficult to control technology as the number of sources increases and the diffusion of technology accelerates both vertically and horizontally." 70/ The reasons are obvious: In spite of the extremely high social costs of transfer of technology, a learning process to receive and adapt technology imports is certainly under way in a number of growth regions in the Third World. Adaptation engineering skills are developing which would allow to lower the real cost of imported technologies and enable local firms to reap economies of scale that may facilitate entry to new domestic and foreign markets. 71/ There has also been some improvement of the ability of local engineering firms to participate in the more complex engineering tasks, particularly in resource-based industries. Potentially at least, this could mean that for a growing number of technologies, the speed of international transfer might increase and that former technological advantages of OECD-based firms could be eroded away. This in turn, according to the OECD study, would mean: "...losses of export markets when restructuring of industrial activities is involved; industries in member countries may not expect major increases in export shares in such industries. Furthermore, there is the possibility of keener competition in OECD and third markets." 72/

(c) Capital goods exports to developing countries and transfer of technology - possible future trends

During the 1970s, capital goods manufacturers in the OECD region, particularly the producers of infrastructural equipment and of large scale equipment and turnkey plants, were increasingly compelled to look for new growth markets outside the OECD region. 73/ Capital investment in the industrialized market economies slowed down considerably at the same time as OPEC countries began importing huge amounts of infrastructure, capital goods and turnkey factories. In addition, a handfull of non-oil exporting developing countries with rapidly expanding industrial activities, the so-called NICs continued to rely heavily on the import of capital goods by borrowing extensively of the Euro-dollar and Asia-dollar market.

This internationalization of the capital goods buiness has been particularly prominent for the huge highly diversified multinational corporations dominating these markets. Take for instance, General Electric (GE). 74/ It is a major exporter in the US - in five of the last 7 years the company has topped the US league of exporters. In 1980, GE had 38% of its $24.6 billion sales and 42% of its $1.5 billion in net profits from international business. Total exports in 1980, by GE's domestic businesses, were $ 4.3 billion , giving the company a $ 1 billion positive trade balance.

The economics of penetrating the potentially huge markets for infrastructure, heavy equipment and complete industrial complexes in a handfull of OPEC countries and NICs has been rapidly changing during the last years. Viewed from the perspective of multinational corporations headquarters' management three questions are of key importance:

- Does the company have the capacity to organize the export of whole systems of infrastructure and industrial production, including those segments of technical knowledge needed to run and maintain them?

- Is the company capable to show sufficient flexibility with regard to contractual arrangements, particularly for sub-contracting patterns and for devicing compensatory trade schemes (counter-trade arrangements)?
- Is it possible to mobilize sufficient credits, both private and public ones, and can one count on government support?

Take again the example of GE. Its executive responsible for international operation, Bob Frederick strongly feels that technology is the key to GE's future as an overseas manufacturer. " Where we have special strengths in technology, we feel most confident about entering markets" 75/ he says. Turbine technology has in the past provided just such a lead.

In fact, GE remains extremely well positioned to take a driving seat in the industrialization of developing countries. It is able to offer products and technology useful to an economy from the earlier stages of industrialization (light bulbs and power generation) through an intermediate stage (locomotives) and on to consumer society sophistication (appliances and perhaps information processing). In applying these strengths, GE has also a well-established pattern of moving from a position of direct exporter to joint venture to domestic manufacturer.

Of course, technological strength is a highly perishable good. In other words, huge amounts of money have to be constantly invested to up-grade and restructure it. In fact, leading capital goods firms, including GE, have been increasingly using their enormous financial muscle to strengthen their overall technological capacities, particularly in microelectronics and robotics.

With regard to finance and structural flexibility, let us take GE's recent deal to sell $142 million of steam turbine generating equipment for a Romanian nuclear power station. The deal provides for an 8% export-import loan, which GE will eke out from its own resources to offer 7.45% money to the Romanians. 76/

In addition, GE was able to get the US Government's authorization for a $120.7 million Export-Import Bank Loan for Romania at a time when the Reagan Administration was proposing a 32% drop in the agency's 1982 budget which clearly documents the importance of this type of complementary funding. With regard to barter counter-trade, GE accepted to sell a large quantity of Romanian industrial goods over an 11 year period, probably mainly in Third World countries. In the final analysis, GE was able to match competing offers, particularly from French firms, not because of superior technology, but because of available finance and its willingness to undertake counter-trade arrangements.

Other factors which, during the 1970s, used to be of importance for large-scale capital goods exports to the Third World, like the availability of huge numbers of skilled and semi-skilled manual workers originating from the homecountry and willing to join the on-site work-force abroad, have been rapidly loosing in importance. In fact, contractors' hiring patterns will continue to shift away from expatriates, not only for skilled and semi-skilled manual workers, but increasingly for middle-level engineers and other professional staff, except a handfull of engineers and project managers controlling the key co-ordinating functions. This will be so for three reasons :

- First and foremost, multinational corporations based in the US and Western Europe are facing increasing difficulties to find those workers and engineers, who would be adequately skilled, would be "disciplined" enough and would be willing to accept the harsh working and living conditions of a globally mobile on-site workforce - at least at the wage levels companies are ready to pay.
- Second, a growing number of developing countries is competing in the packaging and exporting of extremely cheap and docile workers. The pioneers have been some South Korean firms, like Hyundai, Daelim and Dong Ah, which, based on their experience during the Vietnam War as contractors to the US Army, have exported low-priced construction labour crews, mostly organized in a kind of

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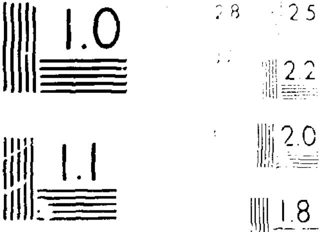
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para-military fashion, to sites in the Middle East, but also to Africa and Latin America. Today, the Korean firms are under increasing pressure from even lower-range countries like India, Thailand and the Philippines which have also entered the labour-export business. The latest development has been the entrance of the PR China who is now offering crews of trained workers for monthly wages (based on a 48-hour week, no holidays) of $ 300-450. 77/

- Third, some of the NICs and OPEC countries, who for economic or geo-political reasons were able to strengthen their bargaining power, have been increasingly insisting on foreign contractors to hire and train national engineers and workers.

The aforementioned changes in the economics of penetrating the markets for large scale equipment in some growth areas of the Third World have one basic common denominator - increasingly these markets have become closely watched government procurement markets. This would apply in fact to a number of the high-growth countries of the Third World, with the exception of Argentina and Chile in Latin America, and some extremely "open door" export- platform countries in South-East Asia, particularly Hong Kong. Viewed from the perspective of multinational corporations, these kinds of problems have been a feature of doing business in Western Europe for years, of course, but it is now obvious that the same conditions are fast developing in some of the more important markets in the Third World. 78/

6.6.2. Strategic Options for OECD-Countries

What are the strategic implications drawn by the OECD secretariat, i.e. what priorities are suggested for innovation policies and industrial restructuring?

(a) The new OECD Doctrine of Industrial Restructuring

The two basic documents on this issue prepared for the OECD-Meeting of the Committee for Scientific and Technological Policy at Ministerial Level (Paris, March 1981) [79] are very outspoken on the role of innovation for international competitiveness: "...a capacity for innovation in manufacturing and related services will be vital for competitiveness amongst OECD countries in the 1980s".[80] Technological competition will intensify, both with regard to intra-OECD rivalry and in relation to the NICs. Technological protectionism will have a role to play - but it should be implemented in a very selective way, focussing on key technologies and hardcore knowledge. In addition, it needs to be complemented by a revitalization of innovative capacities. If firms originating from the OECD-region are to retain their technological dominance, "...the rate of renewal of technology held by the North must offset the acceleration of technological obsolescence coming from transfers to the South."[81]

The following priority areas and prerequisites are identified: "a strong base in capital goods, process engineering, fine materials, or automatic assembly, dependent on formally established R&D and design, and on the ability to mobilise and assimilate technologies from a wide range of sectors, especially electronics; strong links with academic research and with the market; highly trained managers, engineers and workers; the continuing commitment of resources to innovative activities, even in unfavourable conjunctural circumstances." [82]

Thus, it is expected that "the degree of flexibility of the industrial system to respond to changing opportunities and constraints" [83] will considerably increase, which in turn would improve the chances to overcome the present economic crisis.

The main actors behind this type of "innovation renaissance" would be private firms and "...one of the main objectives of government policy must be to create a framework in which market incentives stimulate the innovative capacity and performance of firms". [illegible]

If this prescription of the OECD secretariat could be effectively implemented, a slowing-down of the multipolarization trends of international economic relations might take place. This would not only apply for relations between OECD countries and NICs, but also for OECD-COMECON relations and intra-OECD rivalry.

Yet, it remains to be seen whether such a strategic concept of interlinking innovation and industrial restructuring will really work. In fact, I would tend to be rather sceptical for at least two reasons:

- First, the constraining impact of the present economic crisis on innovation;

- Second, the incapacity of major OECD countries to implement a concerted approach.

(b) The Impact of the Economic Crisis

The present economic crisis has had an important constraining impact on innovation. In fact, the OECD secretariat is very outspoken on this point: "Obviously, technological renewal can only take place if economic conditions are favourable. But the outlook at present is not conducive to taking the risks associated with uncertain innovation." [85]

There are two main constraining factors involved: the high and growing rate of inflation and stagnant investment, particularly investment into machinery and equipment. According to Hill, [36] in a capitalist economy the rate of inflation is probably the best indicator of uncertainty about the future. With high rates of inflation (the latest figures for the OECD area put them at roughly 14%), [37] potential investors in general will hesitate to invest their money into 'new technology' issues with their inherent high uncertainty and risk. Of course, one could argue that the recent run of US venture capital into high technology issues countercdicts this argument and that it will proof to be more than just an ephemeral flash in the pan. [38] In any case, high inflation rates are bound to provoke restrictive monetary policies with high interest rates and that is exactly what happened in all major OECD countries, particularly in the US. High interest rates in the context of crisis can in fact become an important constraint for non-speculative investment - this has been amply testified by the experience of the first half of 1981.

This brings us to our second point, i.e. stagnant investment. Innovation in fact requires huge investment outlays, but private investment has been virtually stagnant since the first oil price rise (See table 6.10).

Tab. 6.10 "Private Investment Performance in Eight OECD Countries, 1960 - 1978

Country	Average growth of business investment		Share of private machinery and equipment in total private investment (a) (volume)			
	1960-73	1973-78	1960	1968	1973	1978
United States	4.9	0.7	36.9	43.8	44.9	48.0
Japan	14.3	.0	50.0[b]	51.7[b]	59.7[b]	55.6[c]
Germany	4.2	-0.2	34.7	39.1	42.9	48.6
France	7.2	0.2	43.6	46.1	50.3	52.5
United Kingdom	4.0	3.5	47.4	46.7	51.3	52.3
Italy	4.6	-1.2	38.8	37.6	46.7	48.0
Canada	6.0	2.4	34.1	37.7	40.0	41.3
Sweden	4.1	-2.8	40.6	41.9	46.3	47.2[c]

a. Data not comparable between countries. For France, the United Kingdom, Italy and Sweden, total machinery, transport and other equipment expressed as a percentage of gross fixed capital formation in industries. It is assumed that government investment is in non-equipment items.

b. Japanese figures are on a fiscal year basis.

c. The ratio reached almost 52 per cent in 1977.

Sources: **OECD National Accounts: Annual Report on National Income Statistics of Japan, as presented in OECD Economic Outlook, December 1979, quoted from: OECD - "North-South Technology Transfer: The Issue of Feedback Effects", p. 113**

According to the OECD-Interfutures project, 89/ this slack in private investment which exists despite a relative abundance of savings, is due to insufficient demand for investment funds. There is not yet any convincing theory on which factors are mainly responsible for this insufficient propensity to invest, but three factors are definitely involved:

- **declining real profitability of industrial investment, at** least for important sectors;

- increasing problems to avoid very costly excess capacities which are mainly due to the technology-built-in inflexibility of existing production structures to adapt to market fluctuations;

- the perception of a majority of potential investors that risks of investment are rapidly getting out of control and that this would be not only due to inflation, energy prices and variable exchange rates, but also due to changes in industrial relations and in political power structures.

In any case, there is much reason to believe that stagnant investment is not just a conjunctural, but a structural phenomenon. 90/ The conclusion drawn by the OECD secretariat sounds convincing indeed: "There is thus a great risk that firms will not innovate at an adequate rate, but that they may prefer to wait until the business outlook clears. Furthermore, it is not evident that measures being taken to stimulate innovation are suited to the slow and difficult economic situation which confronts us." 91/

(c) Constraints to intra-OECD Co-operation

Even if we would assume that the economic foundation for this type of strategy would exist, i.e. a "healthy" investment climate, the problem would remain whether at least the major countries of the OECD region would be able to achieve a concerted approach and implement effective intra-OECD cooperation. 92/ But this is hardly a realistic perspective. In fact, intra-OECD rivalry is the name of the game both for innovation and international restructuring of industry 93/ and this is also reflected in the increasing difficulties of major OECD countries to arrive at workable compromises, at least for short-term crisis management. There are two recent examples:

- the outspoken disengagement of the Reagan administration from the OECD secretariat's attempt to promote government intervention in S&T policy and to strengthen intra-OECD cooperation; [94]

- the failure of the Western Summit at Ottawa to arrive at a minimum consensus on how to proceed with anti-crisis management and its complete silence on problems of industrial restructuring. [95]

6.6.3. Perspectives

To conclude, the failure of concerted action to regain technological dominance along the lines of the OECD secretariat's recommendations, will put individual OECD countries under increasing pressure to search for individual and short-term gains. Rather than accepting to adapt to the forthcoming transformations of existing international economic and political power relations, at least the major OECD countries will try to "fight it out on their own", if necessary by means of "fuite en avant"-strategies, and to take increasingly recourse to cut-throat technological competition and protectionism.

Thus, viewed from a Third World perspective, the future of international restructuring of industry and of the related international flows of technology looks rather bleak. It remains to be seen, whether developing countries, both collectively and individually, will be able to anticipate these developments in time and thus, as for instance a recent UNCTAD study has proposed, increase industrial cooperation among themselves, including trade. technology and finance. [96]

CHAPTER 7.

INNOVATION AND INTERNATIONAL RESTRUCTURING OF INDUSTRY IN A PERIOD OF CRISIS - SOME TENTATIVE CONCLUSIONS DRAWN FROM THE EXPERIENCE OF SEMICONDUCTOR MANUFACTURING

7. Innovation and International Restructuring of Industry in a Period of Crisis - Some Tentative Conclusions Drawn from the Experience of Semiconductor Manufacturing

7.1. The Basic Message of this Study

What have been the driving forces behind recent changes of international location patterns in semiconductor manufacturing and in particular what lessons can be drawn from this sector concerning the interaction between innovation and industrial restructuring in a period of crisis?

Based on a vast body of recent empirical material, this study has shown that technology *per se* has not been the most important factor behind the newly emerging patterns of industrial restructuring and international location.

It matters of course that new technologies are available for automating production steps which previously used to be labour-intensive ones. But this is only part of the story. Whether and how rapidly these new technologies will be used, depends on a host of other factors, including for instance:

- the stage of development of the relevent industrial sector, both with regard to its "industrial organization", the maturity of its technology and the amount of accumulated innovative capacities;

- the interrelations prevailing between this sector and other industrial sectors, particularly key sectors, its role for the dominant pattern of growth and its integration into the world economic circuits;

- the patterns of conflict and cooperation between major actors involved in this sector;

- general factors like the political system, patterns of government intervention, the investment climate and the economic and geopolitical importance of the country or the region.

It is the complex and dynamic interplay of these various factors which sets the stage for decisions on whether or not to apply a new technology and how rapidly. It also conditions the kind of complementary restructuring of organizational patterns, strategies of major actors and prevailing modes of international trade and investment allocation.

This study has shown that amidst a severe crisis of the world economy, innovation and industrial restructuring are interacting in a rather different manner than during a period of high growth of industrial production and trade, as experienced till the early 1970s. The study has shown in particular that this applies to the factors conditioning the choice of priority areas for the development of micro-electronic technologies, ranging from circuit design to applications software; that it further applies to the timing of introducing these technologies into industrial products and services and to the process of production. In addition, it has been emphasized that, in a period of crisis, the actors involved in innovation and industrial restructuring are confronted with rather different constraints than in a period of high growth and that this is bound to be reflected in their scope for compromise and in the intensity of the conflicts prevailing between them.

In the final analysis, what the evidence presented shows, is that most of the prevailing expectations of how restructuring of industries in the industrialized countries and redeployment of industries to the Third World would interrelate, will have to be considerably revised. This applies both to main-stream concepts, for instance the World Bank doctrine 1/ and to some attempts of a marxist conceptualization, for instance the "New International Division of Labour" theory. 2/

Further, established modes of analysing trends in international transfer of technology are of only limited relevance today and a fresh approach is needed to the conceptualization of how control over technology and industrial redeployment are interrelated.

In short, without a theory of the international economic crisis, it will be impossible to link together technology, demand and structural change in world industry. There is still a long way to go , but some of the next steps are clear.

1.2. The Need for a Fresh Theoretical Approach

Unfortunately, we still lack an adequate theoretical approach to these problems. Most of the attempts to analyse how innovation, restructuring and redeployment of industries to the Third World interrelate, are basically mono-causalistic approaches. Consequently, they are bound to misread reality.

This would apply for instance to three otherwise very useful attempts to demystify conventional wisdom on international economic relations.

<u>First</u>, this critique would hold for <u>new forms of a technological determinism</u> which claim that technical innovation per se would be sufficient to explain recent changes in international location patterns. Primarily, this concerns the neo-technological theories of international trade, as embodied in the writings for instance of Posner, Hufbauer, Vernon and Tilton. 3/ Further, this critique would also apply to some attempts to link innovation to the business cycle, particularly Freeman's theory of the Kondratiev cycle. 4/ Some elements of this "technological determinism" can be found even in three of the most stimulating studies on microelectronics-related innovations and industrial restructuring, i.e. the studies of McLean, Rada and Kaplinsky. 5/ As this study shows, the availability of automated assembly lines for instance would not be sufficient to explain the relative decline of investment into offshore locations undertaken by OECD based semiconductor firms.

<u>Second</u>, also the "New International Division of Labour"-school, 6/ for all its valuable contributions to a critique of mainstream international economics, has increasingly run into the trap of "mono-causalism": it claims that the search for low-cost labour would be invariably and by far the dominant factor in international restructuring and thus fails to comprehend the complex interplay of conditioning factors and their changes over time.

Third, those theories of internationalization of capital which tend to restrict their analysis to a specific branch, 7/ for instance the semiconductor industry, are unable in the final analysis to grasp the logic underlying recent changes in international location patterns. As Truel 8/ has convincingly pointed out, the perspective of management decisions in this industry has become much broader due to the increasing integration of semiconductor manufacturing into the overall electronics industry.

To conclude, a fresh approach is needed to the conceptualization of how innovation and international restructuring in industry are interrelated. Otherwise, predictions on possible future changes in global patterns of comparative advantages will continue to be as speculative as today.

7.3. The "New International Division of Labour" Theory - a Critique [9/]

The "New International Division of Labour" (=NIDL) theory is certainly one of the most innovative attempts to capture recent structural changes in the world economy. Its contribution to a critique of established theories of international economic relations has also been considerable. Yet, as I will show, it has serious shortcomings, both with regard to its capacity to explain reality and in its methodological and theoretical approach.

7.3.1. The Theory

According to the NIDL theory, a new capitalist world economy has emerged, its main feature being a massive migration of capital from major OECD countries to low-cost production sites in the Third World. The main purpose of establishing such a new international division of labour is to exploit reserve supplies of labour on a world scale. This type of an internationalization of capital requires the existence of world markets for labour and production sites, and of one global industrial reserve army of labour.

What are the causes for these changes in international allocation patterns, what is new about it, and how did it all come about?

The NIDL school offers the following propositions:

First, the intensifying capitalist peentration and the consequent break-down of traditional socio-economic structures in developing countries, for instance through the "Green Revolution", induced a process of proletarization on a huge and increasingly global scale, reaching now even such exotic pockets of world geography as the Amazonean bassin or Papua-

New Guinea. In other words, the destruction of traditional modes of agricultural production and manufacturing forces a dramatically increasing number of unemployed and undernourished men and women to search for urban jobs and to accept them at nearly any cost and work condition. For the first time in history, OECD-based capital has available a potentially unlimited global labour reserve army. This immense potential for tapping a fresh, extremely low paid and docile labour force is bound to play a decisive role in investment decisions of major OECD capital groups.

Second, the potential for utilizing this global labour reserve army has risen because of three recent trends in technical and management innovations:

- New transport and communications technologies have considerably reduced the constraints for worldwide sourcing and site location.

- Thanks to the availability of new techniques for organizing and automating processes of production, management is now able to apply much more refined forms of a fragmentation of production processes and thus of selective deskilling. This in turn enables management to further compress labour costs.

- New management techniques guarantee that low-cost labour available at Third World production sites will produce at productivity levels which can be considered adequate or even comparable to those in OECD economies.

Further, there is a third factor which makes the utilization of this global reserve labour army more probable, i.e. the provision by governments of developing countries, encouraged by international agencies, of industrial infrastructure, services and utilities at those sites where cheap labour is concentrated, and through the granting of trade, currency and fiscal concessions which allow the unimpeded flow of goods and capital - such provisions increasingly being implemented in the form of the "free export zones".

So far, we have only stated necessary but not sufficient conditions for the emergence of a new international division of labour. What remains is to explain why OECD-capital should make use of this potential, in which form, and what would be the importance this process is going to acquire? It is in trying to answer this question that the NIDL school has unfortunately insisted to translate some of its very stimulating empirical and theoretical observations into unsound over-generalizations which have increased rather than decreased the confusion with regard to what are the causes and mechanisms of the internationalization of industrial trade and production.

So the fourth and decisive proposition of the NIDL school would be: in order to maximize the profit rate or to minimize any decline in it, OECD-based capital groups cannot but unleash a frantic rush of investment funds towards new production sites in the Third World. In other words, countering the deterioriating conditions for capital valorization can only be achieved through reducing labour unit cost which in turn can only be realized through capital migration to Third World production sites.

7.3.2. Two Key Analytical Statements

Let us now discuss more in detail the validity of the NIDL school's fourth proposition. It can be split up into two key analytical statements:

(1) In order to maximize the profit rate (or minimize its decline), firms must minimize its labour cost per unit of output.

In other words: $Y/w \cdot E = \max!$

Where Y = output value
w = average wage paid to all employees of an enterprise
E = number of workers employed.

(2) Such a minimization of unit labour cost can only be achieved through a combined strategy of fragmenting and relocating industrial production to Third World sites. This would enable the firm originating from the OECD region to reduce the average wage paid to its employees for all countries - by simualtaneously appropriating the gains from paying its Third World work force a lower average wage rate for any skill composition of employment, and from reducing the skill composition itself by using relatively more unskilled labour in the more fragmented production sub-processes.

If we define: $w = \alpha \cdot w_s + (1 - \alpha)\, w_n$,
where w_s, w_n are the wage rates for skilled and unskilled labour and α = the skilled worker coefficient per output unit,

we can identify the twofold effects of a "fragmentation + relocation" strategy. Not only does it allow for a reduction of w_s and w_n, but also of α, thus generating additional wage rate savings, since w_s is assumed to exceed w_n at any location.

It is on the basis of these statements, that the following conclusion is drawn: even if Y/E (= labour productivity) would be lower in industrial plants located in growth poles of the Third World (which may not be so because, for instance, of a lack of worker organization abroad due to heavy restrictions on or direct suppression of trade union activities), Y/w·E would be higher there, thus reducing Y/w . E for the whole firm.

7.3.3. A Theoretical and Methodological Critique

The afore-mentioned two basic analytical statements of the NIDL doctrine are misleading for at least seven reasons:

- First, labour costs are just one element of total costs; their importance varies according to sector and location. Other cost elements such as the costs of extremely expensive equipment, r+d costs, resource and energy costs and costs of socalled "externalities" are becoming of increasing importance. This report in fact presents evidence for significant changes in cost structure due to the introduction of new technologies based on microelectronics innovations and shows for instance that for the semiconductor industry the cost of extremely expensive automated equipment has become a major concern.

- Second, even if excessive unit labour costs would be the crucial issue, the "fragmentation-relocation" strategy would be just one among various possible counter-vailing strategies. Other strategies would include for instauce:

  - the introduction of new production and management techniques aimed at raising Y/E;

  - policies to achieve greater scale economies, for instance through an increase of market size.

This report shows that both types of counter-vailing strategies are being extensively used by firms originating from the

OECD region, and that without analysing their impact it would be impossible to understand the logic linking together innovation and international restructuring of industry.

- Third, even if we assume that the minimization of unit labour cost without any change in technique and "accessible" market size would be the only relevant issue, this would not necessarily imply a relocation of production. For the individual firm utilization of cheaper immigrant worker or local non-unionized labour could be superior, for at least the following reasons:

  - it would not only permit to realize gains from process fragmentation but also from increasing returns to scale;

  - a demand increase through the multiplier effect could be internalized in the home country, i.e. would benefit all employers;

  - the state's tax receipts could be increased.

  It is true that in some industrial agglomerations of the OECD region the social costs of this approach are already very high - witness the miserable living conditions of immigrant workers and the consequent potential for far-reaching social conflicts. It is also true that overall the wage differences between on the one hand imported or non-unionized labour and, on the other, organized labour, at least in Western Europe, has been decreasing. Yet, the scope for this type of strategy does seem to be still considerable, particularly in the United States and Japan, at least under the conditions of a new boom.

- Fourth, even if we would assume that a minimization of unit labour cost would by necessity imply geographic relocation, it would still not have to be of necessity relocation to low labour cost countries in the Third World.

For the individual firm, the relevant variable is not Y/w • E, but Y/(w + c) • E, where c are the indirect labour costs (for instance social security contribution, payments for time off, negotiated benefits in kind, etc.) to be paid by the employer. Now, c varies considerably within the OECD region (for instance US versus the Federal Republic of Germany) and even within a country (for instance the non-unionized "Southern belt" of the US versus the traditional industrial centres of the East). Thus, if there are substantial differences in labour productivity between OECD locations and locations in the Third World, Y/(w + c) • E may best be maximized through a relocation to another industrial economy. Gèze[12] for instance has shown that this in fact has been one of the causes of the recent upsurge for instance of West European investment in the US. Yet the most crucial factors seem to have been the perception of a safe investment climate, access to the most developed continental markets, the need for preventive "tariff hopping", and acute problems of foreign exchange fluctuations.

- Fifth, cost reduction in itself would not be enough to counter a falling profit rate. The second equally decisive factor is effective demand, i.e. the volume and structure of accessible markets.

  If demand is constrained, non-price factors such as product quality, deliver dates etc. may be prominent, especially in maintaining and/or improving world market competitiveness. It is not at all obvious that relocation to low-cost sites in Third World countries would be the best way to increase this non-price competitiveness.

  In addition, pending protectionist barriers are of much greater importance for decisions on whether or not to relocate industrial production than comparative unit labour costs.

- *Sixth*, relocation of production and structural changes in demand are to some degree interrelated variables. Changing demand patterns have in fact been largely by-passed by the proponents of the NIDL school and consequently their impact on international location patterns has not been understood. Yet, as we have shown for the semiconductor industry, the economics of demand have recently gained considerably in importance for international location patterns.

- *Finally*, the NIDL school has a fairly restricted and static concept of the role of innovation and technological development. There is no attempt to identify the conditioning factors of innovation and technological development nor to identify their specific role in the genesis of the economic crisis. Further, the NIDL school fails to ask what changes did occur as a result of the crisis in the interaction between innovation and industrial restructuring, both sector-wise and in an international context.

7.4. Towards an Alternative Approach: Capital Accumulation, Work Relations and New Information Technologies

In order to understand the impact of innovation on industrial restructuring and on international location patterns, we need to know more about the conditioning factors of innovation and technological development. Two factors are of importance: the modes of capital accumulation prevailing in a specific historical and geographical context and the related changes in the social relations of production, particularly in the work relations.

Let us first discuss some interrelations between modes of capital accumulation and technological change. I would propose to divide modes of capital accumulation into three basic classes. 11/

Class I = those modes of capital accumulation aiming at a rationalization of the socalled variable capital, that is of the use of labour.

Class II = those modes of capital accumulation aiming at a rationalization of constant capital, as incorporated in buildings and space for industrial plants, industrial machinery, raw materials and energy sources and storage.

Class III = those modes of capital accumulation aiming at the most rational use of intangible production inputs, the socalled information or knowledge inputs, ranging from basic design to systems and applications software and including complementary logistics and maintenance services. 12/

7.4.1. Work and Labour Rationalization

Historically, modes of capital accumulation geared to work and labour rationalization (Class I) clearly predominated. Three subgroups can be discerned:

- A first subgroup (I.1.) covers those modes of capital accumulation which are based on attempts to keep unit labour costs as low as possible.

In the extreme case this would mean to keep wages as close as possible to the level needed for the short-term reproduction of the labour force only - witness the extremely low wages of early capitalism or the strategies of world-wide sourcing for low cost labour as pioneered by U.S. multinational corporations during the 1960s. 13/

However, this mode of capitalist accumulation can also cope with increasing wages - if productivity per work unit can be increased, particularly through a deepening of the social division of labour. In fact, wage levels have been increasing sooner or later, even under the most extreme conditions of a repressive police state - cases in point would be the Germany of Bismarck, South Korea, Chile and the Philippines. Traditionally the counter-strategy of management used to focus on segregating the labour force along the lines of skill differentiations, sex and race, and to segment the production process in such a way that it becomes possible to seperate manual and mental labour and to buy exactly the quantity of skill and muscular power needed for each single operation (the socalled Babbage principle). 14/ Consequently, work relations have been characterized by significant wage differentials related to different skill levels within an increasing division of labour and to the sexual and racial split-ups of the labour force. It is true that in some rare cases like in Sweden of the 1960s and early 1970s, wage differentials have been considerably narrowed down through trade union action, for instance by substituting less differentiated monthly salaries for differentiated piecerate payments. But even then this mode of capital accumulation was able to work, through discrimination against low-productivity workers, i.e. unskilled or semiskilled workers, and by means of selectively promoting a demand for restricted labour elites.

- A second subgroup (I.2.) relates to those modes of capital accumulation geared to increasing the length of the working-time. Whereas in some industrial growth poles of the Third World this would still seem to be a viable approach, it clearly has become of less interest today for industrial production in major OECD countries.

- A <u>third subgroup</u> (I.3.) then relates to modes of capital accumulation aiming to minimize what Marx called the "porosity" of the working day,[15] that is time for resting, for waiting, for walking between different stations of work, for making unnecessarily time-consuming movements of work, and generally to increase the intensity and speed of work. It is in this context, that Taylorism became an important instrument to deprive the workers from effective control over the labour process and to vest it into a special planning section of the firm. "Management's monopoly of knowledge and planning is used for a detailed programming and control of the production process; the worker only goes through the movements already programmed.[16] Ford's assembly line was another instrument to control and increase the intensity of work. Characteristic for the work relations implied by this mode of capital accumulation were deskilling, routinization and complete loss of workers' control over the labour process.

During the 1970s it has become increasingly obvious that, at least for industrial production within the OECD region, modes of capital accumulation based primarily on work and labour rationalization have become obsolete in many ways. Today, the rationalization of constant capital in combination with attempts to increase and rationalize the use of intangible production inputs, particularly with regard to information flows, seem to be the privileged approach in an increasing number of industrial sectors.

7.4.2. Rationalization of Constant Capital

With regard to the rationalization of constant capital, five subgroups can be discerned:

- A first subgroup (II.1.) would focus on economizing the amount of real estate and space needed for industrial production. Attempts to miniaturize equipment and whole production plants together with attempts to devise new forms of decentralized industrial production are logical consequences of this approach.

- A second subgroup (II.2.) emphasizes the need to maximize the intensity of machine-use (the socalled MAX-strategy.[17]

  We have shown in detail for the semiconductor industry how this pressure to run extremely expensive equipment if possible around the clock, i.e. with a minimum of "downtime", has gained in importance and influenced decisions on geographical and sectorial industrial restructuring.

  In order to apply this mode of capital accumulation, radical changes are required in corporate structure and strategy as much as in prevailing patterns of industrial organization and international location. The same would apply to work relations, with shift-work and a high intensity of work and functional organizational units, together with a narrowing-down of job variations within each unit gaining considerably in importance.

- A third subgroup (II.3.) covers attempts to reduce considerably the amount of energy and scarce raw materials used in industrial production. In fact, the development and application in industry of less energy-intensive product and process technologies and of technologies needed to make increasing use of alternative energy sources has become today an essential prerequisite for opening up new accumulation possibilities and for securing international competitiveness. 18/

- A fourth subgroup (II.4.) focusses on speeding-up the flow of products in work, the socalled PIW-strategy. 19/

  This approach has recently gained in popularity. According to Björkman et al, 20/ radical changes are involved. "You must reorganize all functional units according to a new principle, the product or process principle. In very general terms this leads to decreasing use of machinery but it is compensated by a higher rate of turnover. The sum of the interest rates on capital tied up in 'products in work' (PIW) is normally much larger (two or three times as large) than the yearly investments in the companies' machinery and real estate. An economizing with PIW is therefore a very profitable rationalization in the interest of capital accumulation."

  Inherent to this approach is a rapid expansion of industrial automation and control systems and stricter timing, especially in time-consuming parts of the production process like in transportation and handling, but also in design. It has been shown in fact that the greatest potential use for new industrial automation systems and particularly for the new generation of 'intelligent' robots lies in speeding up the passage of materials through factories. 21/ Already in some extreme cases, the storing or products is eliminated, and production starts only if there is a written order from a consumer.

- Finally, a fifth subgroup (II.5.) consists of efforts to decrease the system vulnerability of the process of capital accumulation.

  This is probably the most exciting of all attempts to reconstitute profitability of industrial investment under the present conditions of the economic crisis. There are basically four approaches to achieve this goal:

  - on the level of plant lay-out: the concept of "parallel units" (= if one unit closes down, the other still can be operating); 22/

- on the level of organizing the production process: decentralization of production, either within the framework of big companies and conglomerates or via new forms of subcontracting to small and medium-sized formally independent firms;

- on the level of work relations as social relations of production: attempts by management to de-unionize industrial production and to introduce new forms of labour management by consensus, the socalled "new industrial relations" approach based on concepts like "Quality-of-Work-Life" (QWL) programmes, "Quality Circles" etc. 23/

- on the level of technology: the expansion of industrial automation and control systems, from numerical control systems and the robotization of specific work posts to the introduction of flexible machine systems, further to the introduction of integrated computer aided management (CAM) systems, with the ultimate solution being conceived to be "unmanned production" or a fully automated factory.

7.4.3. New Information Technologies - Towards a Radical Change of Established Modes of Industrial Production

The rationalization of labour and of constant capital require both organizational and technical innovations. For a long time they were constrained by the lack of certain intangible inputs, i.e. information and knowledge needed to devise, implement and secure systems control over the necessary organizational and technical innovations.

The introduction of new information technologies based on microelectronic circuits could contribute to a significant reduction of these constraints.

Information technology covers: 24/

- the processing of information (currently performed by computers or manual methods)

- the storage of information (currently largely non-electronic)

- and the communication of information (currently performed by voice, telecommunications and postal services).

At present, the various aspects of information technology are regarded as separate subjects,like electronic engineering, communications and computer science. Yet, the recent substitution of microelectronic devices for discrete components and especially the development of the micro-processor [25] provide a sound basis for interlinking them and thus for converging the processing, storage and communication of information. Telematics [26] is the catchword for this development which is bound to significantly affect the scope for rationalizing the use of information and knowledge and consequently also of labour and constant capital.

In fact, major innovations in the field of information technology are already causing, on a worldwide scale, dramatic changes in the established patterns of producing goods and services, of consuming them and of organizing systems of social control and regulation. Cases in point would be: recent brea[illegible]roughs in designing and producing micro-electronic circuits, recent developments in information storage technology (for instance bubble memory, [27] in software engineering, in computer architecture (especially in the field of microcomputers), in computer peripherals, in the development of computer languages, in the development of new telecommunication techniques (such as package switching, fibre optics and standardization).

It is the interplay of these new technologies which is behind for example the emergence of Distributed Data-Processing (DDP), [28] the proliferation of new modes of computer based numerical control, [29] particularly in machine tools manufacture, and the introduction of computer aid systems in design (CAD= Computer Aided Design), manufacturing (CAM= Computer Aided

Manufacturing), testing (CAT= Computer Aided Testing) and even management (CIM= Computer Integrated Management). 30/ Technically at least, these new technologies would today make transition towards "automated factories" feasible, which would bring automation not only to the shop floor, but also to the offices, to the design departments and research labs and to the conference rooms of top managment.

But this is only part of the story. The impact of new information technology is reaching much further. All said and done, probably the most dramatic challenge for future generations is that it allows for the increased computerisation of societies, with all the negative effects this is probably going to have on the already highly skewed distribution of power, both within societies and international relations, particularly the North-South context.

For changes of power relations in the labour process, take as an example the description of H. Shaiken, a consultant to the United Auto Workers Union in the U.S., of an automobile plant in which a computer-controlled assembly line had been installed: "The system links a large central computer to a micro-processor on a machine. When the machine cycles, it is recorded in (the) central computer. When a machine doesn't produce a part in its alloted time, it is immediately obvious to more than the computer: that information is displayed in the foreman's office and recorded on a computer printout". Under this system, Shaiken says, "the foreman no longer decides to discipline the workers. He merely carries out the 'automatic' decisions of the system". 31/

In addition, as Antonelli has shown in his pioneering study, 32/ new forms of a global tele-management have recently emerged, based on integrated systems of transborder data flows (TBDF) internal to multinational corporations. Their impact on capital accumulati... and on the international distribution of information power could become tremendous indeed. According to Antonelli, three types of transborder data flows internal to manufacturing multinational corporations can be discerned:

"(i) Flows of information for <u>control functions</u>: these flows of data serve to keep headquarters informed about the behaviour and performance of affiliates. Typically, these flows are most important in highly centralised firms operating in a number of product lines.

(ii) Flows of information for <u>logistic coordination</u>: these flows serve to coordinate the production, transport and commercial activities of multinational enterprises. These flows are particularly important in firms supplying a broad range of diversified products, sold in large numbers to a large number of customers. These flows tend to be of greater importance to firms supplying consumer goods than to those supplying capital goods, and are also important to firms operating flow production processes on a large scale.

(iii) Flows of information for <u>financial management</u>: these flows make it possible for corporate headquarters to retain overall control of the asset and liability position of individual affiliates. This control is particularly important in firms operating in a large number of countries, with extensive intra-corporate trade flows and receiving continuous flows of many different currencies." 33/

According to this study, the firms asked were expecting to reap the following major benefits:

- Economies in working capital from improved inventory management.

- Greater specialisation of production affiliates in the product lines most appropriate to the country's factor endowment.

This increases the economies of scale available to the firm as a whole.

- Purchasing economies of scale derived by centralising purchasing functions.

- Reductions in exchange rate risk and improvements in firms' overall financial management from the coordination of financial decision-making.

Overall, the increased use of international computer communication within multinational corporations is bound to have a significant impact both on corporate strategy and structure and on international location patterns.

In terms of corporate strategy and structure, the Antonelli report suggests that a number of major changes are underway:

" - Flows of data for control functions tend to increase the degree of centralisation of multinational firms, reducing the autonomy of local affiliates. Affiliates become responsible for a progressively narrower range of functions: for example, commercial functions are separated from production functions, each function being the responsibility of a separate local affiliate which answers directly to the parent company.

- The increasing specialisation of affiliates is associated with the creation, within the group, of new functional firms. Trading companies, reinvoicing centres and trading and reinvoicing companies, which are the most conspicuous examples of this trend, specialise in providing coordination services to the group as a whole.

- The demand for these internal coordination functions increases with specialisation within the groups, both in terms of the distribution of production and in terms of the range of functions affiliates can carry out.

- Finally, the overall structure of multinational enterprises becomes increasingly complex, with a juxtaposition of global product divisions, domestic product affiliates and global functional management centres." 34/

Its impact on international location patterns are expected to be as dramatic:

First, increased transborder data flows internal to multinational corporations might accelerate the process by which labour-intensive activities are transferred to low-wage countries. "In some cases, these 'delocalisation' effects may be counterbalanced by increases in service activities in the home country: for example, reinvoicing centres or corporate DP centres. In other cases, however, the transfer of manufacturing activities may be accompanied by the transfer of service activities to countries offering a particularly favourable service environment. 35/ It would seem that Singapore is becoming increasingly a favorite location from this point of view - witness the Institute of System Science which has been recently set up by the National University of Singapore in collaboration with IBM to train computer software specialists and develop Singapore as a software center. 36/

Second, it might mean that the association between foreign direct investment and effective transfer of technology will be even further weakened. "If affiliates can access remote engineering or scientific know-how, they do not need to develop this know-how locally; their global scientific and technological capabilities may increasingly lag those in the firm's research centres. 37/

Overall, the growth of international computer communications controlled by multinational corporations is bound to accelerate the hierarchization of international economic relations: for instance the process of international specialization, rather than occuring between firms, may increasingly occur within firms.

7.4.4. Implications

To conclude, the interrelations between capital accumulation, work relations and technological change have been experiencing considerable changes. The once predominant focus on work and labour rationalization still continues to play an important role - but to view it as the all decisive factor of capital accumulation would be misleading indeed.[38] In fact, the rationalization of constant capital, particularly of energy and raw materials used, machine utilization and product flow speeds, together with attempts to decrease the systems vulnerability of capital accumulation have gained considerably in importance.

Both the rationalization of labour and of constant capital require increasingly complex systems of processing, storing and communicating information and knowledge. It is in this context that the introduction of new technology, particularly of new information technologies based on microelectronic circuits, can be expected to play a prominent role in the restructuring of world industry.[39]

NOTES

Notes

Chapter 1 - Innovation and Industrial Restructuring - What Can Be Learnt from Historical Experience?

(1) Ernst, D., - "Industrial Redeployment and Control over Technology - Consequences for the Third World", in: Ernst, D. (ed) - "Industrial Redeployment and International Transfer of Technology: Trends and Policy Isses", Vierteljahresberichte. Probleme der Entwicklungsländer (Friedrich Ebert Foundation), Vol 83, March 1981.

(2) Figure is quoted from: "Analysis y Perspectivas del Desarollo Industrial Latinoamericano", (ST/CEPAL/Conf. 69/1.2), UN-ECLA, Santiago, August 1979. For detailed figures on post-war industrial dynamism in major OECD countries see Maizels, Alfred - "Industrial Growth and World Trade", Cambridge, 1963 and Sutcliffe, R.B., - "Industry and Underdevelopment", London, etc., 1971, chapter 2.

(3) Freeman, Christopher - "The Economics of Industrial Innovation", Penguin Books, Harmondsworth, 1974, p. 62.

(4) For in-depth analysis and background information on the petrochemical industry see, inter alia: UNIDO - "First World-Wide Study on the Petrochemical Industry: 1975 - 2000", UNIDO/ICIS. 83), Vienna, December 1978; Achilladelis, B., - "Emerging Changes in the Petrochemical Industry: An Overview", (CD/TI (74) 27, 1st Revision), OECD Development Centre, Paris, November 1974; and Stobaugh, R.B., - "The International Transfer of Technology in the Establishment of the Petrochemical Industry in Developing Countries", study prepared for UNITAR, New York, 1971.

(5) Fajnzylber, September 1980, p.11.

(6) See Ernst, D., - "The Concept of the Post-Industrial Society - A Critique", chapter 4, in: "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming).

(7) Pioneering studies are Salter (1960) and Crips and Tarling (1973). For recent controversial discussions see the proceedings of the CIDE symposium on Newly Industrializing Countries, Morelia, 3-6 September, 1981.

(8) Fajnzylber, September, 1980, p.32.

(9) ibid., pp. 32, 33.

(10) Denison, E.F., - "Explanations of Declining Productivity Growth", The Brookings Institute, Washington, D.C., 1979 and OECD - "Productivity Trends in the OECD Area", study prepared for the Working Party No.2 of the Economic Policy Committee, OECD, Paris, April 1980.

(11) See particularly the studies quoted in note (7).

(12) This applies for instance to major policy documents of the OECD secretariat where, implicitly at least, the concept of a "cumulative virtuous circle" plays a key role. See for instance OECD - "Technical Change and Economic Policy. Science and Technology in the New Economic and Social Context", Paris, 1980. For similar discussions from a Third World perspective, see proceedings of the CIDE conference on Newly Industrializing Countries, Morelia/Mexico, September, 1981.

(13) Figures are taken from "Analisis y Perspectives del Desarollo Industrial Latinoamericano (ST/CEPAL/Conf. 69/1.2), UN-ECLA, Santiago, August, 1979.

(14) The recent industrial decline in some NICs, particularly in Brazil and South Korea is documented in various issues of the Financial Times Survey. For a theoretical treatment see Fajnzylber, September 1980, pp. 86 ff.

(15) GATT - "Annual Report 1981", Geneva, September 1981, as quoted in: "GATT - Jahresbericht. Der Welthandel nimmt seit Mitte des vergangenen Jahres kontinuierlich ab", Handelsblatt, 18 September 1981.

(16) Lafay and Fouquin, 1980, pp. 14 ff.

(17) GATT, September 1981.

(18) For an outspoken presentation of this argument for the semi-conductor industry see Levinthal (April 1981). It is this important point which has been left aside by the "New International Division of Labour" school thus reducing its explanatory value for recent major structural changes in the international economy. See Chapter 7.3. The "New International Division of Labour Theory - A Critique".

(19) For two excellent historical case studies see Tilton (1971) (on US electronics industry) and Noble (1981) (on numerically controlled machine tools).

(20) The computerization of industrial products and processes and its role for industrial restructuring will be analyzed in detail in: Ernst, D., - "Automating Capital Goods Production in a Period of Crisis - The Impact of Microelectronics and Implications for Industrial Restructuring and International Location Patterns", study to be prepared for UNIDO, 1983 (forthcoming).

(21) See for instance the pioneering studies of Commoner (on energy) and Pimentel (food sector). For an excellent overview see Barnett, 1980.

(22) Quoted from Fajnzylber, September 1980, p. 18.

(23) ibid., p. 24.

(24) See Sylos-Labini (1962), particularly Part III and Merhav (1969), especially chapters 3-5.

(25) See in particular Lorenzi et al 1980; Brender, Chevallier et al 1981 Gèze, September 1980, Aglietta 1976. See also Castells, 1980; Altvater 1981; Müller-Plantenberg 1981; and Gamble and Walton, 1976.

(26) A comprehensive theory of the crisis should also analyze the specific influence of three additional factors: financial flows and monetary policies; the impact of an unequal distribution of control over strategic assets, within firms, nations and for the international context; and, finally, the changing patterns of intercourse between society and nature.

(27) Developed from Denison, E.F., - "The Puzzling Drop in Productivity", The Brookings Bulletin, Vol. 15/2, 1979.

(28) "Externalities" are defined as the costs of measures needed simply to keep at a constant level the environmental damages and the health hazards for the labour force, resulting from industrial production. See the pioneering study of Kapp, K. William - "Volkswirtschafliche Kosten der Privatwirtschaft", Tübingen - Zürich, 1958.

(29) Denison, E.F., ibid.

(30) For a critical appraisal of the Denison approach see Ernst, D., - "Innovation, Productiivty and International Competitiveness - a Critique of Conventional Wisdom", chapter 3 , in: "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming).

(31) For empirical evidence see OECD-Interfutures, June 1979, pp. 152-158.

(32) Jones, D.T., - "Output, Employment and Labour Productivity in Europe since 1955", N.I.E.R., August 1976, table 16.

(33) UN - Economic Commission for Europe - "Structure and Change in European Industry", New York, 1977.

(34) OECD - "The Impact of the Newly Industrialized Countries on Production and Trade in Manufactures", Paris, 1979, p.43.

(35) ibid., table 20, p.44.

(36) For a concise description see: OECD-Interfutures - "Facing the Future . . .", op. cit., p. 152 - 158.

(37) Although this rise in real unit labour costs has been a general trend, the scope for and timing of these increases have diverged considerably between major OECD countries.

(38) The perception of dominant actors is aptly summarized in: OECD-Interfutures - "Facing the Future . . .", op.cit., especially under the headline "Increasing Cost of Exchange with the Physical Environment", pp. 144-150.

(39) Barnett, 1980

(40) For a theoretical treatment of these issues see the excellent study of Aglietta, 1976, particularly part II "Les transformations des rapports intercapitalistes: les lois de la concurrence"

(41) For a theoretical treatment see the pioneering study of James O'Connor - "The Fiscal Crisis of the State", St. Martin's Press New York, 1973. For an inventory of recent developments see OECD - "The Decline of the Welfare State", Paris 1981

(42) See Interfutures, June 1979, pp. 168 - 180 which concludes that "the recent revolt of the Californian taxpayers shows only too well that we are approaching one of the most delicate conflicts of the future in the advanced industrial societies" (p. 174)

(43) See for instance UN - "Transnational Corporations in World Development: A Re-examination", study prepared for the Commission on Transnational Corporations (E/C.10/38), New York, 20 March 1978, chapter IV

(44) See Interfutures, June 1979, p. 128

(45) OECD - "Technical Change and Economic Policy...", Paris 1980, part II

(46) Empirical evidence for the decline of world demand for bulk chemicals is presented in Lafay, 1980, figure 3, p. 19 and UNIDO - "First Worldwide Study on the Petrochemical Industry, 1975 - 2000", (UNIDO/ICIS. 83), Vienna, December 1978

(47) Ernst, D. - "Industrial Redeployment and Control over Technology - Consequences for the Third World", in: Ernst (ed), 1981 a

(48) Empirical evidence on recent developments can be found in Fouquin, M. et al - "Redéploiements geographiques et rapports de force industriels", Economic Prospective Internationale, Paris, 1981, 116 p. and Turner, L. and Woolcock, S. (eds) - "The Implications of Newly-Industrializing Countries for Trade and Adjustment Policies", The Royal Institute of International Affairs, London, 1981 (forthcoming)

(49) For a vivid account of the problems confronting the FRG, see Thomas, U., May 1981

(50) Any reading of the international business press and their increasingly pessimistic predictions will testify to this point. See for instance: Lascelles, David - "Wall Street Fears for the Future", Financial Times, 13 May 1981. Valuable attempts to analyse some of the conditioning factors of the present crisis can be found in· Lorenzi, Pastré, Toledano, 1980; Barnett, 1980; and Frank, 1980. See also the excellent article by François Gèze - "La crise en son jeu triangulaire", Le Monde Diplomatique, June 1981, p. 2

(51) For an outspoken account see "The Ax Falls. Reagan's Plan for a 'New Beginning'", cover story, Time, 2 March 1981, pp. 24-37

(52) This point has been underlined in: "The End of the Industrial Society", 50th Anniversary Issue of Business Week, dedicated to the crisis of 1929, 3 September 1979, pp. 2-56

(53) For a theoretical and empricial treatment see Ernst, D., - "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming).

Notes

Chapter 2 - The Crisis of Semiconductor Manufacturing - From the Chip Shortage of 1979 to Demand Stagnation and Profit Squeeze

(1) In France for instance, the average stocks of discrete semiconductors of users fluctuated in the following manner: they were sufficient for 9 weeks of production in 1973 (a period where access to chips was perceived to be 'normal'), to 15 weeks in 1974 (chip shortage) and fell to 7 weeks at the beginning of 1976 (end of the chip crisis 1974/1975). Source: Truel, February, 1980, p. 0.

(2) An excellent presentation of the then prevailing perceptions of the chip shortage can be found in "Microelectronic Survey", The Economist, 1 March 1980, pp. 3-18. For an analysis of some underlying causes see Truel, 1980a, pp. 210 ff.

(3) For a vivid account of the drastic measures undertaken by practically all major US firms see: "Show Time for a Nervous Industry", Business Week, 16 June 1975 and "New Leaders in Semiconductors", Business Week, 1 March 1976 where it was assumed that the radical cutting-back of investment and the far-reaching layoffs would pave the way for a new uninterrupted rebound to profitability.

(4) Quoted from "Can Semiconductor Industry Survive Big Business?", special report, Business Week, 3 December 1979.

(5) Quoted from "Microelectronic Survey", The Economist, 1 March 1980

(6) For details, see chapter 3.3. "The Changing Economics of Semiconductor Manufacturing"

(7) Figures are quoted in: "Microelectronic Survey", The Economist, 1 March 1980, p. 4

(8) ibid.

(9) Quoted from ibid., pp. 4,5

(10) "1981 World Markets Forecast", Electronics, 13 January 1981, p. 121

(11) Figures are taken from Crisp, Jason - "Microchips: Down But By No Means Out", Financial Times, 17 June 1981. See also chapter 2.4.3. "Recent Trends in the Memory Market"

(12) Figures are from Hartley, John - "The Aim is World Leadership in Micro-Electronic Field", Financial Times Survey "Japan. The Information Revolution", 6 July 1981, p. X. For background information see also: Gregory, Gene - "The US Wages Micro-War", Far Eastern Economic Review, 16 March 1979 and "Japan - U.S. Semiconductor Issue", The Oriental Economist (Tokyo), March 1980.

(13) Gnostic Concepts Inc., the Menlo Park (Calif.) market researcher, even projects that Japanese firms will snare 60% to 70% of the 64 K RAM market, see "The Chip Makers'

G'amorous New Generation", Business Week, 6 October 1980. For a Japanese projection see "Japan May Become World's Top Center for Production of VLSIs", The Japan Economic Journal (Tokyo), 28 October 1980, which predicts that Japan may become "the world's largest production and supply center" for 64 K RAMs. But these expectations might be somewhat premature, as we are going to argue in chapter ?.1.2. "Transition to Cut-Throat Competition - the Role of Japanese Firms

(14) Quoted from Crisp, Jason - "Microchips...", Financial Times, 17 June 1981

(15) Mackintosh Consultants - "Semiconductor Microlithography Equipment and Materials Outlook to 1985", Luton, 1981

(16) For an early statement of this dilemma see the special report "The New Cold War Economy. A Strategy to Answer the Soviets", Business Week, 21 January 1980. For an insider's evaluation of the major technological constraints to this new round of militarization, see Spinney, Franklin C. - "Defense Facts of Life", The Heritage Foundation, Washington D.C., 5 December 1980, who claims that faith in high technology of increasing complexity and the escalation of costs that it involves works as a form of "organization cancer". Because operating costs of modern military systems turn out to be much higher than expected, the military has to make its cuts in its investment budget in order to run the new and ever more complex weapons systems. The consequence thus is a "...tendency to reduce our current readiness to fight in order to modernize for the future." It should be underlined that this critique of U.S. military technology has been published by a very conservative organization which is close to the present US administration and that this report was originally an unofficial Pentagon staff paper. For an excellent analysis from an disarmament point of view, see SIPRI Yearbook 1981, Stockholm 1981.

(17) F[illegible] an in-depth discussion of the Philips case see "Philips. An Elec[illegible]s Giant Rearms to Fight Japan", Business Week, 30 March 1981.

(18) [illegible]noric expectations can be found in: Saint-Geours, January 1978, particularly pp. 133 ff., and Orme, 1979, particularly pp. 147 ff. For more moderate recent forecasts see for instance Mackintosh, Ian - "An Overview of the Electronics Industry in Europe", background paper No 3, UNIDO Exchange of Views with Experts on the Implications of Technological Advances in Microelectronics for Developing Countries, Vienna, 10 - 12 June 1981.
For an in-depth discussion see Ernst, D., - "Constraints to the Application of Microelectronic Devices - A Much Neglected Research Area", chapter 5 in, "Crisis, Innovation and the the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982, (forthcoming).

(19) Crisp, Jason - "Microchips...", Financial Times, 17 June 1981

(20) See various articles in Electronics Times, Datamation and Financial Times, particularly "Texas Instruments to Pull Out of Activities", Financial Times, 2 June 1981

(21) Kehoe, Louise - "Why Bubble Memories Fell From Grace", Financial Times, 16 June 1981

(22) ibid.

(23) See chapter 5.2. "The Dialectics of Forward and Backward Integration - Towards a New Semiconductor Industry of Corporate Giants".

(24) **Mackintosh Consultants Inc. - "Worldwide Semiconductor Industry Outlook - 1985", San José, California, October 1980**

(25) Quotations are from: Baker, Stan - "Electronics Men Peer into the Future at Annual Conference", Electronics Times, 16 July 1981

(26) ibid.

(27) Quoted from "Intel encouraged by profit figures", Electronics Times, 16 July 1981

(28) Quoted from: Baker, Stan, op.cit.

(29) Semiconductor International, May 1981

(30) Quoted from Baker, Stan, op.cit.

Notes
Chapter 3 - Innovation and the Changing Economics of Semiconductor Manufacturing

(1) Scottish Development Agency, April 1979, pp. 8 and 17.

(2) Oldham, William G., - "The Fabrication of Microelectronic Circuits", in: Forester, Tom (ed), 1980, p.42.

(3) For a discussion of some implications for the application of micro-electronic devices see Ernst, D., - "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", particularly chapter 6: "Constraints to the Application of Microelectronic Devices - A Much Neglected Research Area", 1982 (forthcoming).

(4) Truel, February 1980, pp. 216-219.

(5) For a detailed discussion, see Chapter 4.4, "The Software Bottle-neck - Relevance and Underlying Causes".

(6) Bassak, Gil - "Microelectronics Takes to the Road in a Big Way: A Special Report", Electronics, 20 November 1980, pp. 113-122.

(7) Truel, February, 1980, p. 226.

(8) Quoted from Baker, Stan - "Custom Made for Ease of Designing", Electronic Times, 20 November 1980, p.20.

(9) See chapter 4, "The Software Market - Conditioning Factors and Possible Future Trends".

(10) For the strategy of IBM for instance see "IBM System Designs from Scratch. CAD programme can be accessed at 25 sites world-wide for use in everything from silicon to packaging", Electronics, 14 July 1981.

(11) See various issues of Electronics Times, particularly 12 February 1981.

(12) Semiconductor International, May 1981.

(13) ibid.

(14) For details on the economics of designing and producing gate arrays, see the following articles: "Gate Arrays. A Special Report", Electronics, 25 September 1980; McLean, Mick - "Outset of Battle with Arrays on the Gate", Electronics Times, 12 February 1981; McLean Mick - "Ferranti is Fighting to Keep its Place in the Gate Array Scene as Battle Hots Up", Electronics Times, 19 February 1981. Cane, Alan - "Texas Gets Committed to Uncommitted Logic", Financial Times, 11 February 1981.

(15) See for instance Electronics Times, 12 February 1981, p. 12.

(16) See Financial Times, 11 February 1981.

(17) We will immediately discuss this second assumption.

(18) Financial Times, 11 February 1981 and Electronics Times, 12 and 19 February, 1981.

(19) Electronics Times, 19 February 1981, p. 16.

(20) ibid.

(21) For details see Electronics Times, 22 January 1981

(22) Source: Business Week, 1 December 1980.

(23) For implications on the "industrial structure" of semiconductor manufacturing see chapter 5 - "The Interaction between Recent Technological Break-throughs and Industrial Restructuring".

(24) Scottish Development Agency, April 1979, p. 21.

(25) OECD - "The Electronic Industry . . .", 1 August 1980.

(26) ibid., p. 31.

(27) ibid., p. 27.

(28) ibid., p. 28.

(29) Mackintosh Consultants - "Semiconductor Micro-Lithography Equipment and Materials Outlook to 1985", London, May 1981.

(30) Quoted from Cane, Allen - "Growth Expected to be in Optical Equipment Markets", Financial Times, 8 June 1981.

(31) For a detailed discussion, see, for instance, Kehoe, Louise - "A Thrust at the Silicon Heartland. Nippon Electric's Plans for an Advanced Chip Plant in California", Financial Times, 8 July 1981 and "Technology Update. Semiconductors", special report in Electronics, 23 October 1980, pp. 114-131.

(32) Information taken from Kehoe, Louise - "A thrust at the Silicon Heartland . . .", op.cit.

(33) Figures quoted from Posa, John G., - "No Hands' Assembly Packages Chips", Electronics, 2 June 1981, p. 38.

(34) ibid.

(35) Mackintosh Consultants - "Semiconductor Assembly Equipment and Materials Outlook", Mackintosh Publications Ltd., Darmstadt, July 1981.

(36) For an in-depth discussion of recent developments in the application of microelectronic circuits to industrial products and processes see, Ernst D.,"Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", particularly chapters 2 to 5, 1982 (forthcoming).

(37) Jack Carsten, Vice-President of marketing, Intel, quoted from: "The chip revolution . . . a candid conversation", <u>Datamation</u>, June 1979, p. 102. Similar statements can be quoted from practically all leading figures of the US semiconductor industry. According to Robert N. Noyce for instance, who is Vice-Chairman of Intel, ". . . the trick is to design something totally new and then create the markets for it", quoted from "New Leaders in Semiconductors", <u>Business Week</u>, 1 March 1976.

(38) See Lamborghini, B., March 1981.

(39) See Chapter 3.2 in "Trends in Electronics Technology".

(40) Truel, February 1980, p. 249.

(41) For the recent proliferation of automatic assembly equipment, see Mackintosh Consultants, July 1981 ("Semiconductor Assembly Equipment and Materials Outlook").

(42) Oldham, 1980, p. 37.

(43) Noyce, 1980, p. 37.

(44) OECD - "The Electronic Industry...", 1 August 1980, p. 29

(45) For an in-depth discussion see chapter 4 "The Software Market - Conditioning Factors and Possible Future Trends"

(46) OECD - "The Electronic Industry...", 1 August 1980, pp. 29, 30

(47) <u>ibid.</u>, p. 29

(48) <u>ibid.</u>, p. 29

(49) Truel, February 1980, p. 211.

(50) Quoted from "Semiconductor Equipment Takes on its Own Glow", <u>Business Week</u>, 1 December 1980, p. 98 P-E

(51) Quoted from <u>Business Week</u>, 10 September 1979. For similar figure see also "Semiconductor Equipment Takes on its Own Glow", <u>Business Week</u>, 1 December 1980

(52) For details see the case study on computer-aided design, prepared by Raphael Kaplinsky.

(53) Truel, February 1980, p. 212

(54) OECD - "The Electronic Industry...", 1 August 1980, p. 31

(55) OECD - "The Electronic Industry...", 1 August 1980, p. 22

(56) <u>ibid.</u>, p. 33

(57) <u>ibid.</u>, p. 33

(58) <u>Electronique Actualité</u>, 16 November 1978

(59) "Semiconductor Equipment Takes on its Own Glow", <u>Business Week</u>, 1 December 1980

(60) Quoted from <u>Business Week</u>, 3 December 1979

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Chapter 4 - The Software Sector - Conditioning Factors and Possible Future Trends

(1) This chapter is based on interviews conducted in the first quarter of 1981 with firms and research institutes active in this field. In addition, material has been collected from extensive reading of electronic trade journals, particularly Electronics, Datamation and Electronics Times. For useful background information see: Brooks, 1975; Weizenbaum, 1976, particularly chapter 9; Wulf, 1972; and Winograd. I owe much to discussions with Ronald M. Lee of IIASA/Laxenburg.

(2) Welke, Larry - "The Origins of Software", Datamation, December 1980, p. 127. The author is president of International Computer Programmes, Inc. (ICP), Indianapolis and one of the pioneers of the software information service market.

(2a) Recent developments in firmware engineering and also in high-level languages like Ada and their implications for applying microelectronics to industrial products and processes will be analyzed in: Ernst, D., - "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming).

(3) Orme, 1979, p. 73

(4) Welke, op.cit., p. 128

(5) Quoted from "The Risky Business of Selling Home Grown Programmes", Business Week, 9 March 1981, p. 64

(6) ibid.

(7) In reality, market segmentation is of course much more multifaceted and borderlines tend to become increasingly blurred.

(8) Withington, Frederic G. - "The Golden Age of Packaged Software", Datamation, December 1980, p. 131

(9) For a detailed discussion see "Picking and Perfecting the Packages. Banking, Insurance and Manufacturing Executives Talk about Selecting, Modifying and Using Software.", Datamation, December 1980, p. 139 - 148, especially the interventions by Larry D. Woods, manager of special purpose computing with Deere + Co., Moline, Ill.

(10) Figures are taken from Withington, Frederic G., op.cit., p. 131 and include captive development of software packages by IBM and other mainframe computer manufacturers.

(11) Withington, Frederic G. - "The Golden Age...", Datamation, December 1980, p. 131

(12) Similar figures for later dates were not available.

(13) Cane, A. - "Package Software set for Boom", Financial Times, 13 May 1981.

(13a) The results are summarized in: "Bucking the System. The computer services industry expects not only to survive the recession, but to thrive in it", Datamation, July 1980

(14) Financial Times, op.cit., p. 31

(14a) Goetz, Martin A. - "A U.S. View of Software Trends", Financial Times, 15 June 1981

(15) "Microelectronic Survey", special report, The Economist, 1 March 1980

(16) Lamborghini, B. - "The Enterprise: A Mechanism to Transfer Microelectronic Innovation into Society", manuscript prepared for the Club of Rome, March 1981, p. 8

(17) "Microelectronic Survey", <u>The Economist</u>, op.cit.

(18) For Singapore and Malaysia see: Lim, 1978, pp. 441 - 447. For India see: Balachandran. For Brazil see: Erber 1981. For Mexico see: Warman, 1981. For the possible future impact on international location patterns, see chapter 6 "Implications for the International Restructuring of Semiconductor manufacturing and for Global Patterns of Technological Dominance and Dependence"

(19) Lamborghini, March 1981, p. [illegible]

(20) Weizenbaum, 1976

(21) Quoted from "Softwareprobleme behindern den Fortschritt der Computertechnologie", <u>Blick durch die Wirtschaft</u>, 6 March 1981, translated by D.E.

(22) <u>ibid</u>.

(23) <u>ibid</u>.

(24) <u>ibid</u>.

(25) Mc Cracken, Daniel D. - "The Changing Face of Applications Programming", <u>Datamation</u>, November 1978, p. 25; the author is president of the Association for Computing Machinery (ACM)

(26) Cane, Allen - "Fervour for the Language", <u>Financial Times</u>, 6 May 1981

(27) See for instance Yourdon, Edward - "Making the Move to Structured Programming", <u>Datamation</u>, June 1978

(28) See for instance "Computerprogramme vom Reißbrett. Siemens sucht nach Wegen, Software billiger herzustellen", <u>Blick durch die Wirtschaft</u>, 19 March 1981, p. 7

(29) Mc Cracken, Daniel D. - "The Changing Face...", op.cit., p. 30

(30) The most explicit statement of this thesis can be found in: Lamborghini, March 1981

(31) For an in-depth discussion see: Creative Strategies International (CSI) - "Microcomputer Software Strategies", San José, California, May 1981; Bassak, Gil - "Software Wars Hit Home Computers", <u>Electronics</u>, 27 January 1981 and de Jonquières, Guy - "Personal Computers Come of Age. The Growth of a $ 1 Billion Market", <u>Financial Times</u>, 21 August 1981.

(32) Kehoe, Louise - "Personal IBM Secret Revealed", <u>Financial Times</u>, 19 August 1981

(33) CSI - "Microcomputer...", San José, Calif., May 1981

(34) See chapter 5.2 "The Dialectics of Forward and Backward Integration - Conditioning Factors, Constraints and Recent Trends"

(35) Figures are from "Software. An 'Intelligent' Language Takes Off", <u>Business Week</u>, 17 November 1980

(36) Goetz, Martin A. - "A U.S. View of Software Trends", <u>Financial Times</u>, 15 June 1981

(37) ibid.

(38) ibid.

Notes

Chapter 5 - The Interaction between Recent Technological Breakthroughs and Industrial Restructuring

(1) See chapter 3.3 "The Changing Economics of Semiconductor Manufacturing"

(2) Quoted from French, 1980, p. 164

(3) ibid., p. 164

(4) The Boston Consulting Group, Boston is usually credited to have popularized this concept. See, for instance, Hedley, B. - "A Fundamental Approach to Strategy Development", Long Range Planning, December 1976 and January 1977

For an excellent discussion of pricing policies of major semiconductor firms see Truel, February 1980, pp. 145-158 and pp. 254-266.

(5) Oldham, 1980, p. 43

(6) This annual doubling is known as "Moore's Law" after Gordon E. Moore of Intel Corporation, who first pointed out the trend.

(7) See Wise, Kensall D. et al - "Microcomputer: A Technology Forecast and Assessment to the Year 2000", New York, 1980, pp. 12-13

(8) Noyce, Robert N. - "Microelectronics", in: Forester, Tom (ed), 1980, p. 36

(9) For evidence, see for instance: French, 1980

(10) For details see the articles by Louise Kehoe: "Why Bubble Memories Fell from Grace", Financial Times, 16 June 1981; and "Chips are Down for National", Financial Times, 9 October 1981

(11) For one of the most outspoken statements see Robert N. Noyce, vice-president, Intel Corp., Statement before the Subcommittee on International Finance of the Committee on Banking, Housing and Urban Affairs, United States Senate, 15 January 1980, p. 20. See also: "The Japanese Threat:Courteous Destruction", Business Week, 17 January 1980 and the U.S. Semiconductor Industry Association's Yearbook and Directory of 1979 and 1980.

(12) For an excellent inventory see Dosi, 1981. An official statement can be found in: "Erste Vorschläge für Aktionen der Gemeinschaft auf dem Gebiet der Mikroelektronik", report of the Commission of the European Communities on New Information Technologies, (EG-Dok. 9361/80), published by the Bundesrat, Drucksache 506/80, 24.9.1980, Bonn.

(13) Dosi, 1981, quoted from "Europe's Lag in Electronics", Financial Times, 9 September 1981

(14) "Japanischer Rückzug im 'Halbleiter-Krieg'", Blick durch die Wirtschaft, 16 March 1981. For an in-depth analysis of the Japanese semiconductor industry see: "How Japan's Chip Makers Line Up to Compete. Special Report", Electronics, 2 June 1981, pp. 113 - 132; Strategic Business Services Inc. - "The Future of the Japanese Electronic Industry", San José, Calif., July 1981; and Chase Manhattan Bank - "U.S. and Japanese Semiconductor Industries: A Final Comparison", study prepared for the Semiconductor Industry Association (SIA), Cupertino, Calif., 9 June 1980.

(15) Semiconductor International, May 1981. See also chapter 2 "The Crisis of Semiconductor Manufacturing...", particularly [illegible] "Recent Trends in the Memory Market"

(16) The immediate concern might have been the dramatic price fall for 16 K RAMs, see "Der Superspeicher läßt auf sich warten. Preissturz bei kleinen Elektronikspeichern behindert die Markteinführung", Blick durch die Wirtschaft, 5 August 1981

(17) Quoted in: "Trade Gap with Japan Widens", Electronics, 2 June 1981, p. 102

(18) Quoted in: "How Japan's Chip Makers Line up...", Electronics, 2 June 1981, p. 113

(19) ibid., pp. 114 ff.

(20) Statement of the Electronic Industries Association of Japan, as quoted in "Japan steigert kräftig den Halbleiterexport", Blick durch die Wirtschaft, 3 July 1981

(21) See various issues of Electronics Times, and de Jonquières, Guy - "How to Exploit Technology", Financial Times, 3 June 1981, describing plans of the British Industry Department to export software and software experts to Japan.

(22) Electronics News, 2 February 1981

(23) See interview with S. Ishizaka, director general of the Agency of Industrial Science and Technology (AIST) which, on behalf of MITI, was responsible for the much renowned VLSI program ("Japan. The Information Revolution", Financial Times Survey, 6 July 1981, p. XV)

(24) Hanson, Richard - "Computer Softwa... Demand Continues to Outrun Supply", in: "Japan. The Information Revolution", op.cit., p. XIV

(25) For a similar argumentation, see "How Japan's Chip Makers Line Up...", Electronics, 2 June 1981. Such a more realistic evaluation could help to clarify discussions on what options are available for "industrial restructuring" in the U.S. and Western Europe

(26) For an excellent review article see for instance Kehoe, Louise - "Intel Takes a 100%Change of Direction to Silicon Services", Financial Times, 15 September 1981

(27) Quoted from ibid.

(28) Quoted from "Intel Sets Up Silicon Foundry", Electronics Times, 10 September 1981, p. 9

(29) For details see Kehoe, Louise - "Two Major U.S. Semiconductor Makers in Marketing Agreement", Financial Times, 12 October 1981

(30) See the Financial Times Survey on "Communications", 27 April 1981

(31) Truel, February 1980, p. 212.

(32) Details will be analyzed in Ernst, D., - "Automating Capital Goods Production in a Period of Crisis - the Impact of Microelectronics and Implications for Industrial Restructuring and International Location Patterns", study to be prepared for UNIDO, 1983 (forthcoming).

(33) Mackintosh, 1980, p. 93. Formerly with Bell Laboratories, Westinghouse and Elliot Automation, the author is now chairman of the British consultant firm Mackintosh Consultants.

(34) For excellent case studies see: "Schlumberger. The Star of the Oil Fields Tackles Semiconductors", Business Week, 16 February 1981; "General Electric. The Financial Wizards Switch Back to Technology", Business Week, 16 March 1981; "Zilog, At Six, How to Master Plan", Electronics, 13 January 1981 (on Exxon Enterprises) and Truel, February 1980, p. 296 ff. (on Saint-Gobain)

(35) "Texas Instruments to Pull Out of Activities", Financial Times, 2 June 1981. For some of the underlying causes see C r i s p, J a s o n - "Microchips: Down But By No Means Out", Financial Times, 17 June 1981

(36) Quotation from M a c k i n t o s h, 1980, p. 93. Note the modesty of the term used which would seem to imply that after Keynes' General Theory Mackintosh has opened a new era for the science of economics.

(37) ibid.

(38) U.S. Department of Commerce - "The U.S. Semiconductor Industry", Washington, D.C., Gov. Print. Office, September 1979, pp. 37 - 38

(39) Business Week, 1 March, 1976, p. 41

(40) This is probably a conservative estimate. Casual evidence would seem to indicate that since 1980, the amount of mergers has been increasing. See, for instance,

(41) Quoted from: "Can Semiconductor Industry Survive Big Business?" special report, Business Week, 3 December 1979

(42) Archives, Projekt Technologietransfer Hamburg

(43) Quoted from: "Can Semiconductor Industry Survive...?", Business Week, op.cit.

(44) Quoted from ibid.

(45) For details see chapter 3.2. "Trends in Electronics Technology"

(46) Quoted from: "New Starters in Silicon Valley. Hot, Young Outfits are Suddenly Rushing After the Custom Circuit Business", Business Week, 26 January 1981

(47) For an overview of the custom business see Fortune, 9 March 1981. See also: French, Michael B. - "The Semiconductor Industry: An Overview", Datamation, April 1980

(48) Quoted from Charlish, Geoffrey - "Micro Circuit Engineering Joins the Logic Arrays Club", Financial Times, 31 July 1981

(49) In the market for semiconductor materials, particularly semiconductor-grade polysilicon, the concentration is already very high. According to Electronics News (16 March 1981), 10 firms dominate this market, with their 1980 capacity totalling 3070 metric tons. The three leading firms alone control 2/3 of this capacity which is practically identical with world capacity less capacities in socialist countries.

Table Major Suppliers of Semiconductor-Grade Polysilicon, 1980, (capacity in metric tons)

company	metric tons
Wacker	900
Hemlock (Dow Corning)	700
Osaka Titanium	400
Texas Instruments	250
Smiel (Dynamit Nobel)	220
Monsanto	210
Shin-Etsu Handotai	160
Motorola	100
Great Western Silicon (GE)	100
Komatsu	30
Total	3070

Source: Electronics News, 16 March 1981

(50) "Semiconductor Equipment Takes on its Own Glow", Business Week, 1 December 1980, p. 98L-E

(51) "Semiconductor Equipment...", Business Week, 1 December 1980, p. 98 N-E

(52) Quoted from ibid., p. 98 P-E. The rising equipment cost burden and its impact on fixed capital requirements are discussed in chapter "Recent Changes in the Economics of Semiconductor Manufacturing"

(53) Quoted from ibid., p. 98 L-E

(54) Electronics, 14 July 1981. See also Hartley, John - "TI Japan Set to Manufacture a Million 64 K RAMs Per Month", Electronics Times, 23 July 1981, p. 3

(55) Electronics, 14 July 1981

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(56) For an excellent review see "Japan. The Information Revolution", Financial Times Survey, 6 July 1981, particularly pp. XIV ff.

(57) Defined as the capacity of firms, particularly multinational corporations, to preempt (or react) to the loss (or reduction) of nominal control on relatively low levels of the overall productive system of a branch or a product, by increasingly monopolizing control over strategic assets such as r+d, engineering, finance and cash flow management, maintenance and logistics, and, above all, strategy and organizational structure. See: Ernst, D. - "International Transfer of Technology, Technological Dependence and Underdevelopment: Key Issues", in Ernst, D. (ed), 1980, pp. 39ff.

(58) Truèl, February 1980, second part.

(59) See "A Mainframe on Three Chips", Business Week, 2 March 1981, "Schrumpfen Großrechner auf Chipgröße? Intels 32-bit-Mikroprozessor setzt neue Maßstäbe", Blick durch die Wirtschaft, 5 February 1981 and "Mikroprozessoren im Leistungsverbund. Intel stellt ein neues 'Micromainframe'-Konzept vor", Blick durch die Wirtschaft, 9 June 1981

(60) Quoted from "A Mainframe...", Business Week, 2 March 1981

(61) Electronics Times, 16 July 1981

(62) Intel claims to have built more of the instructions into the 32-bit chips than they have ever had before and that consequently programmer productivity increased as much as fivefold in preliminary tests with the micromainframe, see: "A Mainframe...", Business Week, 2 March 1981

(63) According to David Crockett, manager of computer strategy at Hewlett-Packard Co, Intel's micromainframe has "redundancy built right in" to reduce breakdowns, see: ibid.

(64) Lamborghini, B. and Antonelli, C. - "The Impact of Electronics on Industrial Structures and Firms' Strategies", in: "Microelectronics, Productivity and Employment", OECD, Paris 1981, and Lamborghini, B. - "The Enterprise: a Mechanism to Transfer Microelectronic Innovation into Society", Paper Prepared for the Club of Rome, 1981, manuscript

(65) Lamborghini, Club of Rome paper, op.cit., pp. 15ff.

(66) According to Business Week, "Instead of handicrafting individual computers in batches, computer makers are switching to large-volume, assembly-line production", quoted from "Computers. Falling Behind in Mainframe Output", Business Week, 20 October 1980. For further details on the new economics of the computer business see: "Computers", Financial Times Survey, 2 March 1981; "Information. Still on the Leading Edge of Growth", Business Week, 12 January 1981 and DAFSA - "The Data Processing Industry in the World", Paris, August 1976, particularly chapter 10 "Signposts on the Road Ahead for the Dataprocessing Industry".

7) "Computers. A Capital Crunch that Could Change an Industry", Business Week, 23 March 1981

8) ibid., p. 53

9) "R+D Is a Shrinking Resource.", Electronics, 17 January 1980, p. 85

0) "Computers. A Capital Crunch...", Business Week, 23 March 1981, p. 53

1) See chapter 3.3. "The Changing Economics of Semiconductor Manufacturing"

2) Statement by Harold E. O'Kelley, president of Dataprint Corp., quoted from "Computers. A Capital Crunch...", Business Week, 23 March 1981, p. 54

3) Quoted from "Computers. Falling Behind Mainframe Output", Business Week, 20 October 1980

4) Buxton, Ismes - "Olivetti Counts on Electronics", Financial Times, 12 May 1981

75) Quoted from Financial Times, 12 May 1981

6) For details see Lamborghini and Antonelli, op.cit.; and Financial Times, 12 May 1981

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Chapter [illegible] - Implications for the International Restructuring of Semiconductor Manufacturing and for Global Patterns of Technological Dominance and Dependence

(1) For an in-depth discussion see "Automating Capital Goods Production in a Period of Crisis - the Impact of Microelectronics and Implications for Industrial Restructuring and International Location Patterns", study to be prepared for UNIDO, 1983 (forthcoming). For a theoretical treatment see Ernst, D., - "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming).

(2) Rada, J., - "The Impact of Microelectronics. A Tentative Appraisal of Information Technology", ILO, Geneva, 1980.

(3) ibid., p. 106.

(4) ibid. - In the meantime, Rada's position seems to have become much more sceptical with regard to the "Relocation Back to the North" hypothesis. See for instance his "Structure and Behaviour of the Semiconductor Industry", study prepared for the UN Centre on Transnational Corporations, New York, 1982 (forthcoming).

(5) Examples for this established pattern of an international division of labour in the clothing industry can be found in: Fröbel, F., Heinrichs, J. and Kreye, O., - "The New International Division of Labour", Cambridge University Press, 1980.

(6) For examples see: Counter Information Systems - "The New Technology", London, 1979.

(7) Rush, H.J., and Hoffmann, H.K., - "Microelectronics and the Garment Industry: Not Yet a Perfect Fit", in: "International Conference on Informatics and Industrial Development. Conference Papers", 9 - 13 March 1981, Trinity College, Ireland, p.11.

(8) A case in point would be the recent failure of Ford Motor Company to push through its "Japanisation" programme in its affiliate in Halewood/UK. There, the Ford management found out that in order to push through an increase in automation and robotization, a much more authoritarian "discipline code" would have been needed reminiscent of the tough management style prevailing in Ford's US plants in the 1930s. For details see Le Monde, 12 December 1980 and the special report on Ford Motor Company in: TIE (Transnationals Information Exchange), Amsterdam, No. 9, April - August 1981. For an in-depth discussion of constraints to applying microelectronics to industrial production see Ernst, D., - "Constraints to the Application of Microelectronic Devices - A Much Neglected Research Area", chapter 5 of the author's forthcoming book on "Crisis, Innovation and the Transition to New Patterns of Industrial Production", 1982.

(9) OECD - "Transfer of Technology in the Consumer Electronics Industry - The Television Sector", (DSTI/SPR/79.27), Paris, 14 September 1979.

(10) Over the past decade, the number of correspondence in a TV set has fallen from 1400 to 400. For recent technological developments in the TV industry, see "Sources of Competitiveness in the Japanese Colour Television and Video Tape Recorder Industry", a report prepared by the private consulting firm Developing World Industry and Technology, Inc.

(Chairman: Jack Baranson) for the US Department of Labour, Washington, DC 1978. See also OECD - "Transfer of Technology in the Consumer Electronics Industry... ", op.cit., pp. 29-52.

(11) The following quotations are from pages [illegible], [illegible] and 51 of OECD, op.cit.

(12) For an in-depth discussion of these concepts see Ernst, D. - "International Transfer of Technology, Technological Dependence and Underdevelopment: Key Issues", in: Ernst, D. (ed), 1980

(13) See for instance the excellent report by Louis Turner "The Problems of Adjustment in the Consumer Electronics Industry", in: Turner, L. and Woolcock, S. (eds.) - "The Implications of Newly-Industrializing Countries for Trade and Adjustment Policies", The Royal Institute of International Affairs, London, 1981 (forthcoming)

(14) Quotations are from: OECD - "Transfer of Technology in the Consumer Electronics Industry...", op.cit., p. 51

(15) For details see the study by Louis Turner, op.cit.

(16) OECD, op.cit., p. 51

(17) Cable, Vincent and Clarke, Jeremy - "British Electronics Industry and Competition with Newly Industrializing Countries", Overseas Development Institute (ODI), London, July 1981

(18) For background information on the garment industry see: Kurt Salomon Associates - "The 1980s: The Decade for Technology? A Study of the State of the Art of Assembly of Apparel Products", study prepared for the Commission of the European Communities, Bruxelles, December 1979; Cable, Vincent - "World Textile Trade and Production", Economist Intelligence Unit Special Report No. 63, 1979; Woolcock, Stephen - "Textiles and Clothing Industry", in: Turner, C. and Woolcock, S. (eds), 1981 (forthcoming); de la Torre, José - "Decline and Adjustment: Public Intervention Strategies in the European Clothing Industries", INSEAD (= European Institute of Business Administration) - Working Research Papers No 80/07, Fontainebleau/France, July 1980; "The International Division of Labour and International Trade in Textiles, Clothing, Shoe and Leather Products (Including Outward Processing)", part I, International Textile, Garment and Leather Workers' Federation, Third World Congress, Vienna, 6-10 October 1980. See also the pioneering case study on the internationalization of the German textiles and clothing industry in part I of Fröbel; Heinrichs; Kreye, 1980.

(19) For a fascinating account of the constraints to automation applying to the U.S. garments industry up to the late 1970s see chapter V.2. "Textile et habillement: inertia et modernisation", in: Brender; Chevallier and Pisani-Ferry, 1980

(20) Quoted from: Hoffmann, H.K. and Rush, H.J. - "Microelectronics and the Garment Industry - Not Yet a Perfect Fit", in: "International Conference on Informatics and Industrial Development. Conference Papers", Volume I, 9-3 March 1981, Trinity College, Dublin , Ireland, p. 5

For examples see McLean, J.M. and Rush, H. - "The Impact of Micro-electronics on the U.K.: A Suggested Classification and Illustrative Case Study", SPRU (= Science Policy Research Unit) Occasional Paper Series, No 7, 1978 and Bessant, J.R. - "The Influence of Micro-electronics Technology. Report prepared for the UNITAR study of Technology, Domestic Distribution and North-South relations", Technology Policy Unit, University of Aston, 1980, pp. 72-75 and 78-80

For examples in the petrochemical industry see: UNIDO - "First World-wide Study of the Petrochemical Industry: 1975 - 2000", (UNIDO/ICIS.83 and Add 1 (appendices)), Vienna, 12 December 1978. For the steel industry see particularly: UNIDO - "Picture for 1985 of the World Iron and Steel Industry" (UNIDO/ICIS.1961), op.cit.

For a remarkable five-volume report on current technology, trends and direction for r+d in the machine-tool industry see: Sutton, George P. et al - "Technology of Machine Tools. Report of the Machine Tool Task Force Project", 5 volumes, particularly Volume 4 "Machine Tool Controls", (Document No. UCRL-52960), Lawrence Livermore National Laboratory, University of California, Livermore, California, October 1980. An excellent analysis of the impact of dataprocessing technology can be found in: Reijers, L. N. - "Comments on OECD-report 'Inquiry into the Machine Tool Industry' by B. Real", Delft, University of Technology Laboratory for Manufacturing Systems, 22 March 1979 (mimeo). See also: Manoranjan, P.K. - "Report on Technological Perspectives in the Machine Tool Industry in the Next Decades and their Implications for Developing Countries", study prepared for UNIDO, Vienna, October 1980.

(24) For a discussion of the substantial economic, social and political constraints against the establishment of full-scale "automated factories" see for example: Zermeno, R. et al - "The Robots are Coming - Slowly", in: T. Forester (ed) - "The Microelectronics Revolution", Oxford, 1980; H. Wintersberger et al (eds) - "The Socio-Economic Impact of Microelectronics", Pergamon Press, Oxford etc., 1980; and Norman, C. - "Microelectronics at Work: Productivity and Jobs in the World Economy", Worldwatch Paper 39, Washington, D.C., October 1980, pp. 15 - 22

(25) Hoffman, H.K. and Rush, H.J. - "Microelectronics and the Garment Industry...", op.cit., p. 1

(26) For an in-depth analysis of the concept of systems control see Ernst, D.-"International Transfer of Technology, Technological Dependence and Underdevelopment: Key Issues", in Ernst, D. (ed), 1980

(27) For an outspoken presentation of this view see the statement of Karl Heinz Kaske, president and chief operating officer of Siemens, quoted in chapter 6.5.3., p. 259?

(28) Quoted from Posa, John G. - "'No Hands' Assembly Packages Chips", Electronics, 2 June 1981, p. 38

(29) OECD - "The Electronic Industry", 1980, p. 27. See also the research experience documented in Truel, February 1980 and Lim, 1979.

Orme, 1979 for instance in his widely quoted study on trends in the application of microelectronics speaks of "... the futility of employing technical experts to forecast technological developments and applications." (p. 76). He equally sees "... strong reasons for not relying on businessmen and business executives to forecast the impact of technological change on industry and commerce." (ibid.)

(31) Quotation is from Scottish Development Agency, 1979, p. 27

(32) "Report. Exchange of Views with Experts on the Implications of Technological Advances in Microelectronics for Developing Countries", UNIDO, (UNIDO/IS.242/Rev. 1), Vienna, 16 July 1981. For details see Ernst, D.; Hoffman, K.; Kaplinsky, R.; Rada, J. and Rush, H. - "Implications of Technological Advances in Microelectronics for Developing Countries: A Suggested Programme of Policy Studies and Action", paper prepared for the aforementioned UNIDO meeting, UNIDO/B.P. 13, Vienna, 10-12 June 1981.

(33) Much of the recent literature is still heavily relying on three pioneering studies: Chang, 1971; Moxon, Richard - "Offshore Sourcing in Less-Developed Countries: A Case Study of Multinationality in the Electronics Industry", The Bulletin, New York University Graduate School of Business Administration, Institute of Finance, No.s 98 - 99, July 1974; and UNCTAD - "International Subcontracting Arrangements in Electronics Between Developed Market-Economy Countries and Developing Countries", TD/B/C.2/144/Supp.1, New York, 1975. This would apply to some degree even for the otherwise extremely useful study of Lim, Linda J. - "Multinational Firms and Manufacturing for Export in Less-Developed Countries: The Case of the Electronics Industry in Malaysia and Singapore", The University of Michigan, Ann Arbar/ Michigan, 1978. Some recent developments are documented in: OECD - "The Electronic Industry...", 1 August 1980, chapter 8 "International Aspects"; Rada, 1980, particularly chapters 6 and 7; Siegel, 1981; and Scottish Development Agency, chapters I - III. A stimulating attempt to analyse the impact of some recent changes in the economics of semiconductor manufacturing can be found in: Truel, 1980a.

(34) See for instance, OECD - "The Electronic Industry...", 1 August 1980, chapter 8 and Scottish Development Agency, April 1979, pp. 26-35

(35) "It is abundantly clear that the availability of large and innovative markets is an important factor influencing success in the electronics business. Similarly the size and growth potential of markets is the largest single factor influencing the geographical pattern of the activities of firms in the electronics sector.", OECD - "The Electronic Industry", August 1980, Paris, p. 38. For and excellent theoretical discussion see Truel, 1980b and 1980a, particularly pp. 156-173, 249-253, and pp. 306-320. See also Scottish Development Agency, 1979, chapter III

(36) OECD - "The Electronic Industry", op. cit., p. 38

(37) Mackintosh, Ian M. - "An Overview of the Electronics Industry in Europe", paper prepared to the UNIDO expert group meeting on the implications of microelectronics for developing countries (B.P. 3), UNIDO, Vienna, 10-12 June 1981. Quotations are from pages 4 and 6.

(38) Quoted from Hartley, John - "TI Japan set to manufacture a million 64 K RAMs per month", Electronics Times, 23 July 1981.

(39) Quoted from "Selling More Chips to Japan", Business Week, 11 February 1980. In fact, the mobility of Japanese engineers and designers to work for non-Japanese firms has increased considerably during the last years, as documented in: "Unternehmenswechsel ist nicht mehr Schande. In Japan zeigt das Konzept der 'lebenslangen Beschäftigung' Auflösungserscheinungen", Blick durch die Wirtschaft, 13 August 1981.

(40) According to the 1981 World Markets Forecast of Electronics, "...the 21% prime rate that was announced in mid-December 1980 was a backbreaker. Small business will be particularly hard hit. But even large manufacturers, if they have not committed funds previously, will hesitate to spend for new plant and equipment." Quotation from: Electronics, 13 January 1981, p. 122

(41) Quoted from H a r t l e y, J o h n, op.cit.

(42) ibid.

(43) For more details see chapter 2.4.3. "Recent Trends in the Memory Market"

(44) Oldham, W.G. - "The Fabrication of Microelectronic Circuits", in: Scientific American, vol. 237/ no 3, September 1977

(45) Rada, 1980, p. 106

(46) The most important one being that no differentiation is possible between the various plants according to size of investment, sales volume and turnover, product groups, stages of production and technological complexity.

(47) For recent developments see "China Agrees Laws for Special Zones", Financial Times, 24 September 1981

(48) See the forthcoming study on the Brazilian electronics industry by Fabio Erber, University of Rio de Janeiro. See also the forthcoming thesis on the Brazilian computer industry by Paulo Tigre, SPRU Sussex.

(49) Quoted from United States Senate - "Hearings before the Subcommittee on Banking, Housing and Urban Affairs, Gov. Printing Office, Washington, D.C., 15 January 1980

(50) U.S. Department of Commerce - "A Report on the U.S. Semiconductor Industry", Washington, D.C., September 1979 and "Import Trends in TSUSA Items 806.30 and 807.00", U.S. International Trade Commission Publication 1029, U.S. Government Printing Office, Washington, D.C., January 1980

[illegible] Levinthal, Donald J. - "Automate, But Bring It Back Onshore. Editorial", Semiconductor International, April 1981, p. 6 The following quotations from Levinthal are from this article.

[illegible] Figure quoted from: Fleming, Stewart - "Siemens to Build up its Overseas Operations", Financial Times, 7 July 1981. For an in-depth analysis of the Siemens strategy see Williamson, George - "Siemens Starts Second But Finishes First", Fortune, 10 April 1978 and Plettner, B. (chairman of the board, Siemens) - "Für uns ist Japan kein unbekanntes Land", Blick durch die Wirtschaft, 8 May 1981

[illegible] Quoted from Fleming, op.cit.

[illegible] Electronics News of 2 February 1981 for instance gives details on a multi-pronged program to train computer programmers initiated by the Singaporian government. For Taiwan see for instance: Neff, Robert - "Taiwan Pushes High Technology", Electronics, 8 May 1980; Gigot, Paul - "A Show Case in the Park. Taiwan is pinning its future economic growth on a move into high-technology industries", Far Eastern Economic Review, 18 July 1980; and Housego, David - "Foreign Companies Turn to Taiwan", Financial Times, 7 May 1981. The extensive programs which are under way in Ireland and Scotland are frequently published in the major trade journals, like Electronics, Electronic Times etc. See in particular Scottish Development Agency, April 1979.

(55) Figures are from: Fleming, op.cit.

(56) For an in-depth discussion see Ernst, D. - "Constraints to the Application of Microelectronic Devices - A Much Neglected Research Area", chapter 2 of the author's forthcoming book "Crisis, Innovation and the Transition to New Patterns of Industrial Production", 1982.

(57) For a list of these countries see OECD-Interfutures - "Capital Goods - Structural Evolution and World Prospects", Paris, December 1979

(58) In contrast to a widely held belief, semiconductor manufacturing is not all an environmentally "clean" industry. In fact, the production of semiconductor wafers, from which chips are made, and printed circuit board , into which finished chips are stuffed, uses a wide range of toxic chemicals and generates a large amount of toxic wastes. For details see PHASE (= Project on Health and Safety in Electronics) - "A Guide to the Health Effects of Chemicals Used in Electronics Manufacturing", Mountain View, California, July 1980

(59) Case studies on the viability of strategies geared to selective choice of world market niches would deserve a high priority for future research.

(60) Quoted from "U.S. Assault on Trade Barriers", Financial Times, 1 June 1981

(61) Electronics Times, 21 May 1981, p. 14

(62) De Jonquieres, Guy - "How to Exploit Technology?", Financial Times, 3 June 1981

(63) ibid.

(64) Ernst, D. (ed) - "Industrial Redeployment and International Transfer of Technology: Trends and Policy Issues", special issue "Vierteljahresberichte. Probleme der Entwicklungsländer" (Friedrich Ebert Foundation), Nr. 83, March 1981, 123 p.

(65) OECD - "North-South Technology Transfer: The Issue of Feedback Effects", (SPT(80)25) Paris, 15 October 1980 published as: North/South Technology Transfer - the Adjustments Ahead, Paris 1981

(66) Calculated from OECD - "The International Flows of Technology to Developing Countries", Analytical Study No. 2, (DSTI/SPR/79.32), Paris, 22 October 1979

(67) Both quotations are from: OECD - North-South Technology Transfer...", op.cit., p. 77

(68) For attempts to analyse these recent trends in international trade competition, see: Fouquin, M.; Kessler, V. et al - "Redéploiements géographiques et rapports de force industriels" Economic Prospective Internationale, No ,1981, 116 pp. and Turner, L. and Woolcock, S. (eds) - "The Implications of Newly-Industrializing Countries for Trade and Adjustment Policies", The Royal Institute of International Affairs, London, 1981 (forthcoming)

(69) See for instance the proceedings of the conference on NICs, Morelia/Mexico, September 1981

(70) OECD - "North-South Technology Transfer...", op.cit., p. 77

(71) O'Brien, P. - "Third World Industrial Enterprises as Exporters of Technology - Recent Trends and Underlying Causes", in: Ernst, D. (ed), 1981

(72) OECD - "North-South Technology Transfer...", p. 79

(73) For empirical evidence see: OECD-Interfutures - "Capital Goods: Structural Evolution and World Prospects", Paris, 20 December 1979 and OECD - "North-South Technology Transfer - the Adjustment Ahead", Paris 1981, particularly chapter VI.

(74) For background information on GE see: "General Electric. The Financial Wizards Switch Back to Technology", Business Week, 16 March 1981, pp. 74-79; "General Electric Triumphs in Adversity", Financial Times, 17 June 1981 and Cox, James A. - "A Century of Light", New York, 1979

(75) Quoted from "General Electric Triumphs in Adversity", Financial Times, 17 June 1981

(76) For details see "General Electric Triumphs...", Financial Times, 17 June 1981

(77) Quoted from "Where Will the Jobs Come From?", The Economist, special report, 3 January 1981, p. 53

(78) See for instance: UN - "Transnational Corporations in World Development - A Re-examination", study prepared for the Commission on Transnational Corporations", E/C.10/38, New York, 20 March 1978

(79) OECD - "Technical Change and Economic Policy. Science and Technology in the New Economic and Social Context", Paris 1980 and OECD - "North-South Technology Transfer...", op.cit.

(80) OECD - "Technical Change...", p. 98

(81) OECD - "North-South Technology Transfer...", op.cit., p. 101

(82) OECD - "Technical Change...", p. 99

(83) ibid.

(84) ibid.

(85) OECD - "North-South Technology Transfer...", op.cit., p. 112

(86) Hill, C.T. - "Technological Innovation, Agent of Growth and Change", manuscript, Centre for Policy Alternatives, MIT, December 1978

(87) IMF - "World Economic Outlook 1981", Washington, D.C., July 1981

(88) Ernst, D. - "High Technology Investment and the Crisis - Recent Trends in the U.S.", chapter 6 of the author's forthcoming book "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982

(89) OECD-Interfutures - "Facing the Future: Mastering the Probable and Managing the Unpredictable. Final Report", OECD, Paris, June 1979

(90) See for instance Lorenzi, J.-H.; Pastré, O.; Toledano, J. - "La crise du XXe siècle", Economica, Paris, 1980, particularly chapters I and VI

(91) OECD - "North-South Technology Transfer...", p. 112

(92) See OECD - "International Cooperation in Science and Technology in the OECD Area. Trends, Problems, Prospects", background report to the Meeting of the Committee for Scientific and Technological Policy at Ministerial Level, SPT/Min (81)6, Paris, 23 February 1981

(93) See Ernst, D. - "Industrial Redeployment and Control over Technology - Consequences for the Third World", op.cit

(94) See the article by Weeger, Xavier - "Un nouveau complexe americain", Le Monde, 7 April 1981, describing the failure of the March 1981 OECD conference

(95) See reports on the conference in Le Monde and the Financial Times, particularly "Western Summit Ends with Some Closing of the Ranks", Financial Times, 22 July 1981

(96) UNCTAD - Geneva, August 1982, 280 p.

Notes

Chapter 7 - Innovation and International Restructuring of Industry in a Period of Crisis- Some Tentative Conclusions Drawn from the Experience of Semiconductor Manufacturing

(1) For a concise summary see Keesing, D.B. - "Trade Policies for Developing Countries", World Bank Staff Working Paper No 353, Washington, D.C., August 1979

(2) See the pioneering study of Fröbel, F.; Heinrichs, J. and Kreye, O. - "The New International Division of Labour", Cambridge University Press, 1980 (Originally published in German in 1977)

(3) Posner, 1961; Hufbauer, 1965 and 1970; Vernon, 1966,1970, 1971 and 1977; Tilton, 1971. For an excellent critique of these theories see Madeuf, 1977.

(4) Freeman, 1977. For a stimulating theoretical critique of "technological determinism" and an attempt to reconstruct neo-Schumpeterian innovation theory, see: Dosi, 1981

(5) McLean, 1980; Rada, 1980; Kaplinsky, 1981.

(6) See for instance: Fröbel, Heinrichs, Kreye, 1980.

(7) For a stimulating critique see Truel, 1980a and b.

(8) ibid.

(9) The following owes much to some stimulating ideas presented by Susan Paine in "International Investment, Migration and Finance: Issues and Policies" (Draft), University of Cambridge

(10) Gèze, François - "Le Redéploiment Industriel et le Transfer de Technologie. Le cas des grandes entreprises françaises", in: Ernst, D. (ed), 1981

(11) This concept has been developed from Björkman, Torsten; Lundquist, Karin; Himmelstrand, Ulf - "Work Relations, Capital Accumulation and Technological Change", paper presented to the Round Table '81 "Socialism, Science, Technology, Development Strategies", 21 - 26 September 1981, Cavtat, Yugoslavia, who distinguish two classes of capital accumulation: rationalization of variable capital, i.e. labour, versus rationalization of constant capital. For a detailed discussion see: Ernst, D., - "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming). See also the author's future work on "Automating Capital Goods Production in a Period of Crisis - the Impact of Microelectronics and Implications for Industrial Restructuring and International Location Patterns", study to be prepared for UNIDO, 1983 (forthcoming).

(12) See in this context some documents prepared for the OECD-Working Party on Information, Computer and Communications Policy (ICCP), particularly Antonelli, Christiano - "Transborder Data Flows and International Business - A Pilot Study", prepared for the OECD - ICCP (DSTI/ICCP/81.16), OECD, Paris, 2 June 1981 and "Microelectronics, Productivity and Employment", proceedings of a special session of the OECD - ICCP (27 - 29 November 1979), OECD, Paris, 1981. Thoughtful reviews of possible future trends can be found in: Wise, Kensall D. et al - "Microcomputers: A Technology Forecast and Assessment to the Year 2000", John Wiley &

Sons, New York etc., 1980, and Miskell, Ronald V. - "Machine Tool Controls. Introduction and Summary", in: "Technology of Machine Tools. A Survey of the Art by the Machine Tool Task Force", Vol. 4. "Machine Tool Controls", Lawrence Livermoore Laboratory, University of California, October 1980, pp. 1 - 12.

(13) For a vivid account of this type of internationalisation strategy see Fröbel, Folker et al - "The New International Division of Labour", Cambridge University Press, 1980

(14) For the original presentation of this concept see: Babbage, Charles - "On the Economy of Machinery and Manufactures", London, Charles Knight, 1835 (reprinted 1971 by Augustus M. Kelley-Publishers, New York)

(15) Marx, Karl - "Capital" (english edition), Penguin, Vol I, p. 534

(16) Quoted from Björkman et al, September 1981, p. 4. See the classical studies: Braverman, Harry - "Labour and Monopoly Capital. The Degradation of Work in the Twentieth Century", Monthly Review Press, New York etc. 1974; Coriat, Benjamin - "L'atelier et le Chronomètre", Christian Bourgois Editeur, Paris, 1979 and Freyssenet, Michel - "La division capitaliste du travail", Savelli, Paris, 1977

(17) See for instance: Ansoff, H. Igor et al (editors) - "From Strategic Planning to Strategic Management", John Wiley & Sons, New York, 1976

(18) See chapter IV "Energy Requirements in the Manufacturing Sector" of UNIDO - "World Industry in 1980. Regular Issue of the Biennial Industrial Development Survey", Vienna, 1981 and UNIDO - "Industry 2000.New Perspectives" (ID/Conf 4/3), Vienna, 30 August 1979, p. 4

(19) PIW = products in work. For details see Lamborghini, Bruno and Antonelli, Christiano - "The Impact of Electronics on Industrial Structures and Firm's Strategies", in: OECD - "Microelectronics, Productivity and Employment", Paris 1981

(20) Björkman, Torsten et al - "Work Relations, Capital Accumulation...", op.cit. The following quotation is from page 5.

(21) See the standard study by Engelberger, Joseph F. - "Robots in Practice. Management and Applications of Industrial Robots", Kogan Page, London, 1980, particularly chapter 7 - 9 For a critical assessment see Coriat, Benjamin - "Robots et automates dans les industries de série. Esquisse d'une "économie" de la robotique d'atelier",paper presented to the ADEFI (= Association Pour Le Developpement Des Etudes Sur La Firme Industrielle) conference "Les Mutations Technologiques", Chantilly, 18-19 September 1980

(22) The "parallel units" or "dual sourcing" approach today is an established practice for major multinational corporations. Two prominent cases are Ford and IBM. It was Ford that introduced this management technique into the car industry as a

means of protecting itself from labour disputes in its own plants or that of its suppliers.
And IBM has made this "parallel units" approach a basic element of its business philosophy: for each product there should be at least three plants within IBM which share responsibility. This would apply for instance to IBM's captive production of VLSI memories which is divided between two U.S. based plants and the plant of IBM Deutschland GmbH, Stuttgart; located at Hulb near Sindelfingen. See: archives, Projekt Technologietransfer Hamburg.

(23) "The New Industrial Relations", Business Week special report, 11 May 1981, pp. 58 - 68. For an excellent critique see Plotke, David - "Technology and Social Development in the Contemporary United States: Political and Theoretical Issues", paper presented to Round Table '81 "Socialism, Science, Technology, Development Strategies", 21 - 26 September 1981, Cavtat, Yugoslavia

(24) Definition taken from Barron, I. and Curnow, R. - "The Future with Microelectronics. Forecasting the Effect of Information Technology", The Open University Press, London, 1979, pp. 28, 29. The most comprehensive study available is: Nora, S. and Minc, A. - "L'informatisation de la Sociéte", Paris, La Documentation Française, 1978 (also available now in English as: "The Computerization of Society", Cambridge, Mass., MIT Press, 1980).

(25) Micro-processor = the central processing unit of a computer implemented on a single silicon chip.

(26) Telematics = telecommunications plus informatics.

(27) Bubble memory is a memory system in which data are stored on moving bubbles of magnetism on a semiconductor, this storage being nonvolatile.

(28) See, for instance, Buchanan, J.R. and Linowes R.G. - "Understanding Distributed Data Processing. What Managers Need to Know to Make the Most of the Coming Developments in Information Processing", in: Harvard Business Review, July - August 1980.

(29) See, for instance, "Chipping a Way towards Total Control Capability. Special Report on Computer Numerical Control", in: Metalworking Production, April 1979.

(30) See the market survey of Dataquest, Inc. - "Systems of Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Integrated Management (CIM)", Cupertino, California, October 1979, 300 pages.
See also the author's forthcoming case study "Automating Capital Goods Production in a Period of Crisis - the Impact of Microelectronics and Implications for Industrial Restructuring and International Location Patterns", study to be prepared for UNIDO, 1983 (forthcoming).

(31) Shaiken, H. - "Computer Technology and the Relations of Power in the Workplace", Wissenschaftszentrum Berlin IIVG/dp/80-217, Berlin, October 1980, p. 44. For similar examples see: "Report on the TIE (= Transnational Information Exchange) Seminar on the Telecommunications Industry",

in: TIE, No. 6, July - September 1980, especially the report on the attempts of both Siemens and Daimler Benz to introduce "Longterm Personnel Planning" systems, i.e. sophisticated data bases which develop complete profiles of individual workers (up to 900 different information elements for each worker).

(32) Antonelli, Christiano - "Transborder Data Flows...", op.cit.

(33) ibid., p. 6

(34) ibid., p. 7

(35) ibid., p. 8

(36) "Singapore Determined to Secure Place in World Aviation Industry", Financial Times, 25 September 1981

(37) Antonelli, Christiano - "Transborder Data Flows", op.cit. p. 8

(38) This would apply particularly to the "New International Division of Labour" school, as formulated for instance in Fröbel et al - "The New International Division of Labour", op.cit. For an in-depth discussion see Gèze, François - "Le Redéploiement Industriel et le Transfert de Technologie. Le cas des grandes entreprises françaises", in: Ernst, Dieter (editor) - "Industrial Redeployment and International Transfer of Technology: Trends and Policy Issues", special issue of Vierteljahresberichte. Probleme der Entwicklungsländerforschung (Friedrich Ebert Foundation), Bonn, March 1981

(39) For a detailed theoretical and empirical treatment see Ernst, D., - "Crisis, Innovation and the Transition to New Patterns of Industrial Production - the Impact of Microelectronics", 1982 (forthcoming). See also the author's forthcoming case study on "Automating Capital Goods Production in a Period of Crisis - the Impact of Microelectronics and Implication for Industrial Restructuring and International Location Patterns", study to be prepared for UNIDO, 1983.

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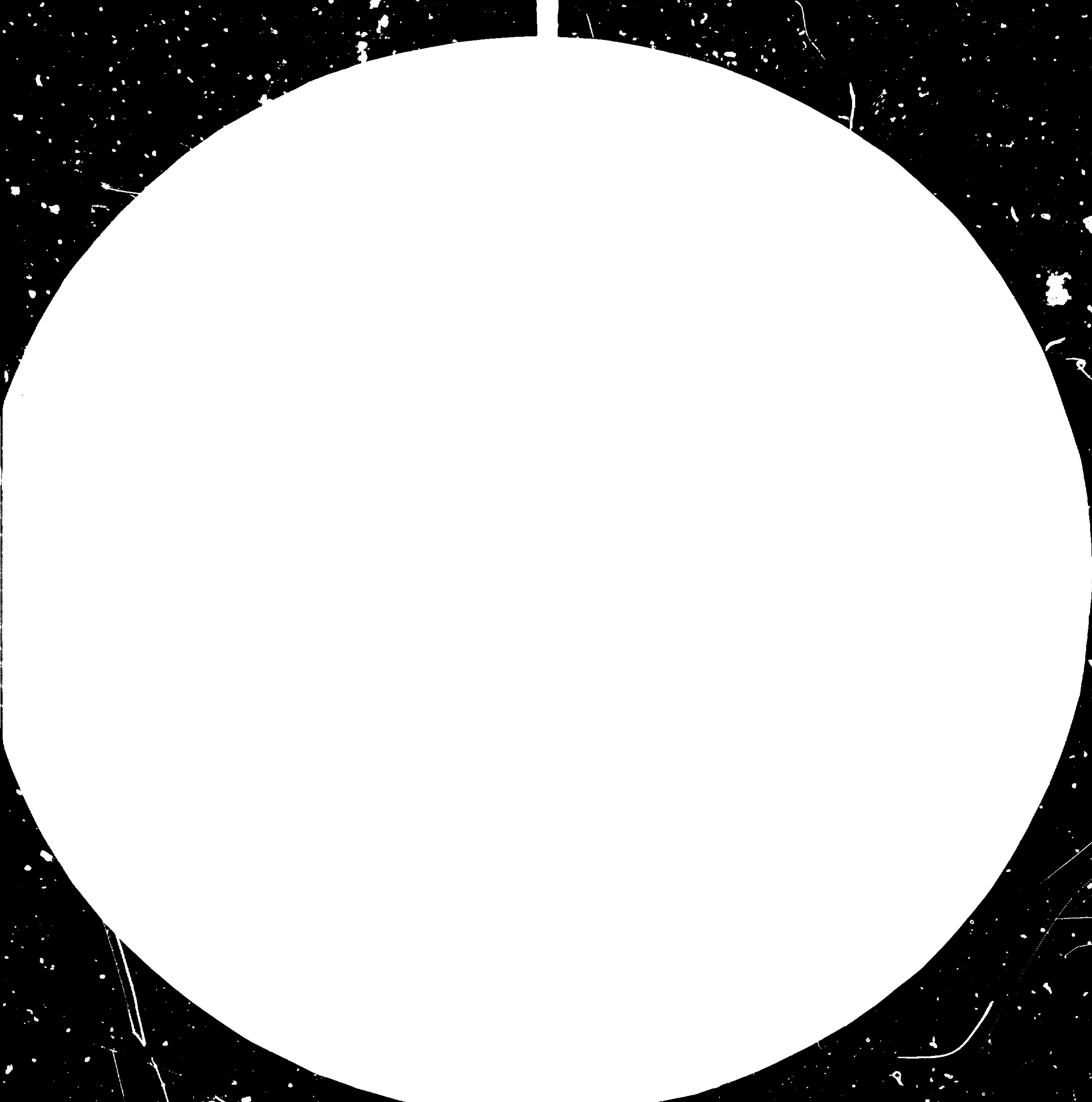

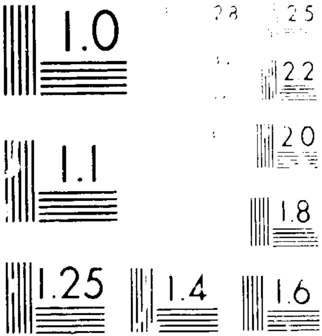
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