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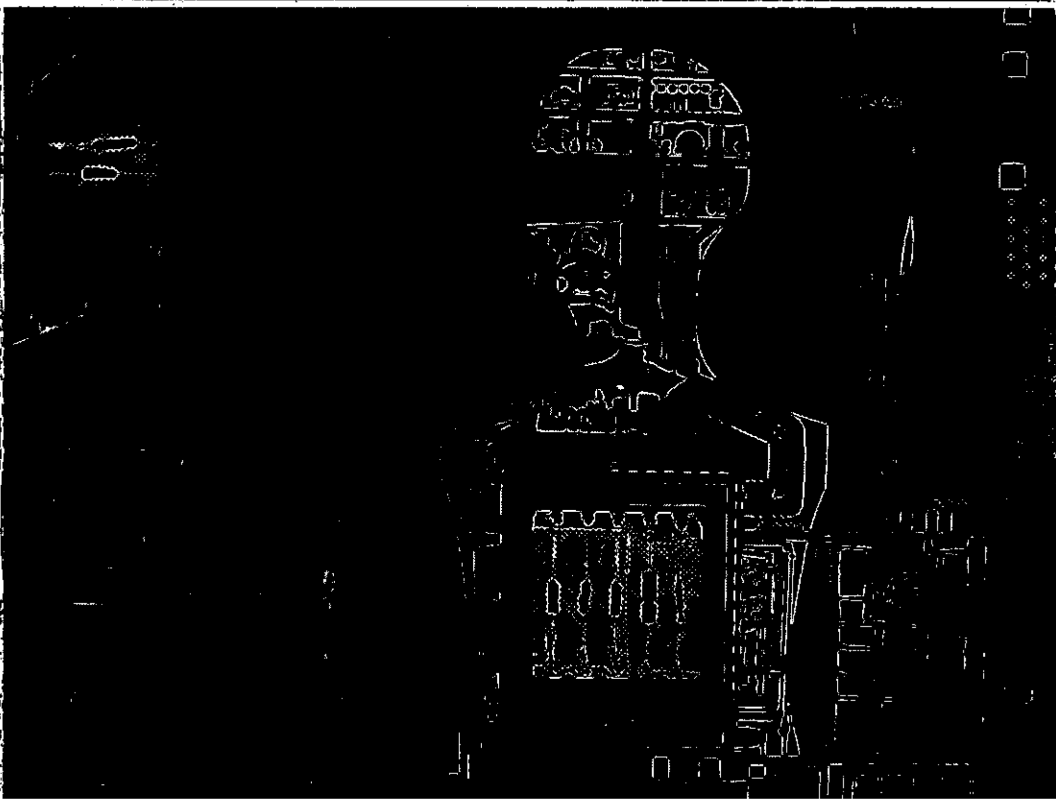
Industrial Adjustment and [illegible]

Technical Change and Survival : Europe's semiconductor industry

Giovanni Dosi



Front cover: Eduardo Paolozzi, *Wittgenstein in New York: As Is When*

TECHNICAL CHANGE AND SURVIVAL: EUROPE'S SEMICONDUCTOR INDUSTRY

by

Giovanni Dosi

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The Sussex European Research Centre (SERC), formerly the Centre for Contemporary European Studies (CCES), set up in Sussex University in 1965, primarily carries out policy-oriented research on political, economic and social affairs of any part of contemporary Europe. It is concerned with comparative, transnational and integration studies rather that with individual countries and there is a particular but not at all exclusive focus on the European Community.

The Schools Unit in the SERC helps staff in British secondary schools teach about contemporary Europe either within established subjects or through multidisciplinary studies.

Research at the SERC currently being completed concerns government intervention in industry; long-term food policy options; inflation and income distribution; labour markets; and the enlargement of the European Community.

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FOREWORD

This Sussex European Paper is one of the first two members of a series of industrial sector studies resulting from comparative research on International Implications of Industrial Policies in Western Europe. We gratefully acknowledge the help given by the Anglo-German and Volkswagen Foundations, who have made the project possible by funding the salaries for two fellows in the Sussex European Research Centre as well as the related operational costs. The studies are being carried out by authors from five countries - Britain, France, Germany, Italy and Japan - working to common specifications.

Most of these studies are sectoral, covering the major Western European countries within the international context. The branches examined span the range from new to mature industrial activities as follows: semiconductors, telecommunications, process plant, heavy electrical power equipment, machine tools, motorcars, white goods, steel, shipbuilding and textiles. These are representative of most of the sectors where international trade is important. This makes it possible to draw some general conclusions about the range of problems confronted and policies pursued. The studies conform, as much as the conditions of each sector permit, to a common pattern. In each, the responses to adjustment problems of industry and government are analysed and major policy issues are discussed.

Another study, on the automobile industry, is being published simultaneously. In addition, monographs are being prepared on the development of industrial policy making in Germany, France, Italy and Britain and the characteristic institutional frameworks within which it operates. A special study on Japanese adjustment policy has also been carried out in co-operation with the industrial Bank of Japan. Here again, the studies are designed to encourage useful comparisons between different countries and industrial branches.

It is hoped eventually to publish the results of the research in book form, including chapter-length summaries of the industrial sectoral studies.

ACKNOWLEDGEMENTS

I am grateful to Fondazione Einaudi, Turin; Ente Einaudi, Rome; and Consiglio Nazionale delle Richerche (CNR) for the research grants and to SERC for additional, and indispensable financial support. It is impossible to mention all the experts, colleagues and industry representatives whose comments, criticisms and stimuli contributed to the research. In particular, I would like to thank Professor François Duchêne, my supervisor Professor Tibor Barna, and my colleagues at SERC, Geoffrey Shepherd, Daniel Jones and Jürgen Müller. Valuable support in the form of ideas, data and suggestions came from the Science Policy Research Unit, University of Sussex (SPRU), especially from Professor Christopher Freeman, Keith Pavitt, and Ed. Sciberras. Mick MacLean, Director of Electronics Times has been a continuous, valuable source of comments, contacts and criticisms. Finally, a special mention for Professor Michele Salvati, without whom this research would not have been possible. Needless to say, none of them bear any responsibility for the opinions, and the possible mistakes, expressed here.

I. INTRODUCTION[1]

A BRIEF INTRODUCTION TO THE SEMICONDUCTOR INDUSTRY

One of the most impressive features of the economic and technological history of the last three decades has been the emergence and fast growth of the electronics industry. Its impact on the structure of industry and the broader social environment has been compared to that of the fundamental technological innovations of the past such as the steam engine, electricity, or the internal combustion engine.

A great deal of technical progress in electronics was made possible by the discovery and development of semiconductor components that substituted for traditional thermionic valves and allowed the introduction of an entire cluster of new products and components, ranging from mini- and microcomputers to electronic games, electronic telecommunications equipment, numerical controls for machine tools, digital watches, TV remote controls, etc. Semiconductors are materials (such as silicon, germanium, or gallium arsenide) whose electrical property is to act under certain conditions as insulators and under other conditions as conductors. Due to their properties of alternatively conducting or insulating, semiconductors can therefore perform the tasks of active components in electrical circuits, i.e. they can modulate, rectify or amplify electrical signals, (and, to a much lesser extent, the tasks of passive components, such as resistors or capacitors). For the purposes of this study, the industry is taken to include: discrete devices (diodes, transistors and special items like thyristors, triacs, etc.); integrated circuits; optoelectronic devices and solid state magnetic memories. Also belonging to this third category are some devices that are not semiconductors in physical terms. They have been included on economic grounds since they are generally produced by the semiconductor industry. Figure 1 provides a classification of types of semiconductor and of related electronic components.

Although some semiconductor properties have been known since the end of the last century, the birth of the semiconductor industry is usually placed in 1948, when Shockley, Bardeen and Brattain developed the first transistor (i.e. a semiconductor amplifier) at Bell Laboratories. The next landmark was the development of the integrated circuit (IC) by Texas Instruments and Fairchild in 1961. This is a device performing on a single chip more than one function, by having more than one component, either active or passive. Finally, a recent (1971) development of the integrated circuit is the microprocessor (MPU), which summarizes all the logical functions of a complete computer on a single chip.

The major technical classification of ICs is based on function: analog ICs operate on the same input signals, while digital ICs operate on the basis of binary logic. Though there appears to have been some limited tendency for these two types of device to specialize in different applications, it is expected that they will also continue to compete on some applications. Nonetheless, demand for digital ICs is expected to grow faster. A secondary classification is based on technology, for instance MOS (metal-oxide silicon), CMOS (complementary metal-oxide silicon), bipolar, or ECL (emitter-couple logic)

An important economic distinction in semiconductors is between standard and custom devices. A definition of a custom device is one that is produced to order for a customer or group of customers (without reference to the technological characteristics of the device); another definition is of a device whose technological characteristics suit it only to a narrow range of applications. This study is mainly concerned with the standardized, or high volume, part of the market.

The process of manufacturing semiconductors consists of a) the design of the circuit required on the chip; b) the production of a mask through which the circuit pattern is reproduced, by a process similar to photography, on the silicon wafer; c) the actual fabrication of the circuit, through this photolithographic process, and the diffusion on the wafer of the necessary impurities to obtain the required components and circuit patterns on the silicon chip; d) assembly; and e) testing.

The history of semiconductors is characterized by extremely fast technical change, a profound impact on downstream (end-user) sectors, and different capabilities of the various industrialized countries to compete in and commercially exploit the technology. If we refer to industrialized countries, this is because developing countries appear to have been left out of the game altogether. The industry provides an excellent case

study of transformation and adjustment in a growing and strategically vital sector. Rapid and continuous innovation, both in products and processes, and the fast rate of substitution between old and new products, constantly put competitive pressure on each individual company and country.

THE FRAMEWORK OF ANALYSIS

The process of technical change and growth in this sector also affects the transformation of related industries. This happens mainly through: a) the diffusion of technological knowledge, more often embodied in people than capital; b) the diffusion of product-embodied technical progress, for semiconductor output is an input in downstream industries; c) changes in relative prices due to the effect of technical advances on productivity; d) the transformation of industry and market structures brought about by the emergence of innovative companies, the diversification of some old companies in growing markets, and the disappearance of others; and e) the job-creation and displacement effect of technical progress. These are the core of the mechanism through which the process of growth and transformation of the economy takes place. Public intervention in this area, unlike public intervention in more mature sectors, is essentially growth-related, therefore, and all the arguments for public involvement refer to the reaping of benefits from the process of technological change.

There are some crucial issues to be dealt with in analysing a fast growing innovative sector which are relevant to any discussion of public intervention. These issues concern the determinants and direction of technological change, the effects of competitiveness in semiconductors on competition in other sectors (with their implications for employment and the balance of payments), national competitive differences and, by extension, ways of altering these.

The first two issues are dealt with only in summary form here, for they are treated in greater detail in a longer study in preparation. Because of the effect of semiconductors on competitiveness in other sectors and because, as we shall argue, market forces alone are under certain conditions insufficient for the achievement of national competitiveness, we shall focus on the third issue and attempt to assess the relative importance of markets and institutions in explaining national competitive differences. National differences in institutions will be reflected in actual differences in industry structure and in differences in policies of intervention. In terms of <u>structure</u>, we propose to examine the effects of foreign investment and the role of established companies versus new companies in the generation and diffusion of innovation. In terms of <u>intervention</u>, we shall be interested in the potential effectiveness of national policy given the limitations imposed by i) the competitive capacity of domestic industry, ii) the ability of domestic industry to affect government decision making, and iii) the social envionment - i.e. attitudes of the companies, degrees of industrial consensus, etc.

Part II provides a brief history of the growth of the Western world's semiconductor industry and a theoretical framework for describing the nature and direction of technical progress and the role in this of market and non-market factors. It suggests ways in which non-market factors have differed on either side of the Atlantic. Subsequently it describes the evolution of Western Europe's semiconductor industry and the emergence of a problem of international competitiveness and technological lags and then briefly reviews the arguments related to public intervention in Western Europe.

Part III is a historical picture of industrial policies in European countries in the last two decades, with a tentative chronology of, and sub-division by, policy instruments. Differences and similarities in industrial policies among European countries are analysed, together with a comparative evaluation of their timing, size, comprehensivensss and effectiveness. Part III then examines the Japanese case as a source of comparison. Fortunately for an observer of the industry, Japan experienced many initial conditions similar to Europe in terms of technological level and industrial structure, so that very different outcomes may be ascribed either to different public policies and/or to a different socio-industrial environment.

Finally, Part IV is an effort to define a hypothetical range of industrial targets and policies in Europe, together with a discussion of some political pre-conditions for their implementation and their likelihood of selection. This section also attempts to provide some conclusions with respect to future trends in the industry and some tentative generalizations of the case of semiconductors to other high technology sectors.

II. TECHNOLOGY AND INTERNATIONAL COMPETITION

THE GROWTH OF THE WORLD INDUSTRY

Commercial production of semiconductory devices started around 1950. Since then, the industry has experienced impressive growth rates: in the period 1958-76, the American industry grew in monetary terms at an average annual compound rate of 18.5% and in real terms at a rate of 44% (Table 7). These meant that semiconductor prices came down at a vertiginous rate. Similar but somewhat lower rates of growth were achieved by the European industry. Tables 1-3 chart the growth in markets, output and employment in the non-Communist world's semiconductor industry; this growth was particularly high in integrated circuits (including microprocessors), by far the most dynamic segment of the semiconductor market.

Despite such impressive rates of growth the size of the industry, in terms of output and employment, remains limited: estimated world semiconductor output in 1978 was around $10,400m. (Table 2) and employment around 260,000 people (Table 3). European output and employment can be estimated in the same year at around $1,700m. (including US-controlled production) and around 50,000 employees. Employment grew more slowly than output; in the US, the only country where historical data are available, total employment grew at an annual rate of 9.5% over the period 1958-78. Productivity growth has been strikingly high: we estimate for the US (1958-76) a compound rate of around 33% (Table 2).[2]

Despite the relatively small size of the industry, semiconductors represent a technologically vital input in a great and growing number of electronics and electronics-related industries. Table 9 provides a disaggregation of the major end-user sectors in the US and Western Europe.

Production is US-dominated: US companies, either directly or through foreign subsidiaries, controlled in 1976 around 69% of world production, while the US market accounted for around 40% of the world market for semiconductors (Tables 1 & 2). Western Europe, on the other hand, accounted for 27% of world consumption and for around 17% of world production (of which 13% was European-controlled). After a large catching-up effort from the mid-60s onwards, the Japanese semiconductor industry has come to account for around one-quarter of world production as well as of world consumption. (See Part III for a lengthier consideration of Japan).

The world semiconductor industry is dominated by a relatively small number of firms, resulting in a level of concentration that is high if one takes into account the remarkable number of new entries (see Table 5 for the world market share of the top ten firms in 1978 and Tables 10, 14 and 24 for basic data on the major activities of the largest firms of the US, Western Europe and Japan respectively). Until recently, however, there has been no indication of increasing concentration (see Table 6)[3].

The degree of concentration reflects the importance of pronounced dynamic economies of scale: other things being equal (including manufacturing technologies), productivity appears to be a direct logarithmic function of the cumulative volume of production. This is the well-known "learning curve" effect.[4] Increasingly, also, static economies of scale appear to be relevant - that is, an increasing minimum scale of investment and production. To the extent that static and dynamic economies of scale are captured in indicators of labour productivity, the estimates of value of shipments per employee in major producing countries in Table 4 show the relatively strong position of Japan and the US (though one must keep in mind that the figures in this Table are biased by the different accounting procedures).

THE NATURE AND DIRECTION OF TECHNOLOGICAL CHANGE

The pace and direction of technical change are seen to be the most important factors in an explanation of the structure of the semiconductor industry and the differing strengths of countries and companies. Technical change has produced a stream of new products; it has induced fast substitution between old and new products; it has brought about a continuous fall in prices, especially in real terms (see Table 7 for evidence from the US); and it has resulted in new applications and markets.

For both economic theory and technology policy, it is important to establish the determinants of technical change,

particularly the relative roles of market factors (that is movements in prices and quantities) and institutional factors (ranging from pre-existing scientific and technological capabilities of companies and countries to political decisions and actions). The literature contains a lengthy discussion between those who claim that needs, via market signals, direct technical change (demand-pull theories), and those who maintain that the driving forces have generally been autonomous technological and scientific break-throughs (technology-push theories).[5]

The hypothesis advanced here is that technology, broadly defined as a "bundle" of theoretical knowledge (whether embodied in people or machines), practical experience and established methods, has similar characteristics to those attributed by contemporary epistemologists to science (see, inter alia, Kuhn (1962) and Lakatos (1978)). Just as a scientific paradigm determines the problems, procedures and tasks for science (the "puzzles", in the words of Kuhn), so too does a technological paradigm for technology. Our suggestion is that, as one moves from science to technology and then to production, market factors and institutional factors operate as <u>selective mechanisms</u> within the whole field of scientific and technological possibilities. Once a path of technical change has been established, however, it has a momentum of its own, defining the directions toward which problem-solving activity moves. (These paths are what Nelson and Winter (1977) called the natural trajectories of technical change.) Furthermore, there appears to be a continuous feedback from markets and production to technology and science, which accelerates or slows down technical progress along a given trajectory and which could eventually facilitate or hinder the emergence of alternative paths. A lengthier discussion of this hypothesis appears in Dosi (1980).

The history of semiconductors might, then, be read as the emergence of a defined technological trajectory. The 1950s and '60s saw the establishment in the field of active components of a semiconductor-based technological paradigm. Among the possible alternative solutions to the problem of switching, amplifying and rectifying, the dominant technology that emerged was based on a few specific physical properties of semiconductors - the so-called transistor and field effects. Based on this paradigm, the dimensions of the technological trajectory can be defined in terms of product costs and characteristics (miniaturization, density, reliability, speed, frequency, dissipation, noise and heat-immunity, energy consumption, maximum power change, etc.). Progress along such a path has led to increasing applications of semiconductors substituting for existing electronic and electro-mechanical devices and new applications.

This view of the innovatory process has important theoretical and policy implications. The process of producing, exploiting and diffusing innovations, especially when technological paths are not yet well defined, derives from an interplay between institutional and market factors. In capitalist economies, profit expectations provide an incentive to innovate, but this by itself explains neither the actual trajectories chosen nor the different technological capabilities of companies and/or countries. In particular, an important feature of the innovatory process is uncertainty: one of the explanations of differing innovative behaviour among individual firms is the way they discount the future and evaluate uncertainty. This depends on structural and social factors such as the size of the company, its technological level, its labour relations and the industrial culture of the country where it operates.

In this view there is clearly a role for science and technology policies. First, policies affect the structural conditions in which firms operate, influencing the incentives and behavioural responses of the latter through well-known means like R & D financing, procurement policies, etc. Second, policy may often affect the choice of the technological trajectories themselves. The view put forward here, is, indeed, that institutional factors played a central role in the establishment of the American lead in the late '50s and the '60s vis-à-vis the European industry.

At this point, it is useful to introduce the concept of technological frontiers. A trajectory is in fact not a single-value path but a scatter of points within bounds defined by its technological and economic trade-offs. The technology frontier is defined as the upper band of these points. In our view, once a country is at the technological frontier, there are cumulative forces which help to keep it moving along the frontier.[6] In the following paragraphs we attempt to explain why the US semiconductor industry is at the technology frontier and how it manages to stay there.

FACTORS IN THE US TECHNOLOGICAL LEAD

Two factors stand out in explaining the US lead: bridging institutions and military and space programmes. First, research institutions, particularly Bell Laboratories, bridging the divide between pure science, applied science and technology, have been strong in the US. A similar bridging role was played in the early history of the US industry by some of the very big

electrical companies such as General Electric, Westinghouse, and RCA.

Bell Laboratories and big established companies played a major role in the production of innovation, though not in the diffusion and commercial exploitation of the innovations themselves. In the period 1952-61, big established electrical firms accounted for 32% of total major product innovations and 22% of process innovations, while Bell Laboratories alone accounted for 40% and 56% respectively.[7] Commercial exploitation and diffusion have often occurred through new firms, often spin-offs from established companies, which were to become the industry leaders. The emergence of new firms was made possible by two factors. First, technology was essentially embodied in people and not equipment. (Nowadays, without losing its people-embodied features, it is also increasingly equipment-embodied. This brings about the emergence of size-related barriers to entry. Significantly, in the '70s the number of new spin-off companies progressively decreased.) Second, the reason why American firms alone could successfully enter on the US market was that the industry was on the technological frontier. In the unique "virgin territory" created by its technological advantage, market mechanisms in the form of the emergence of new firms and a high mobility of scientists and engineers have shown an advantage until recently over internationalization and vertical integration. The big established firms, which were responsible for most of the major early innovations, have on the contrary performed poorly (see Dosi (1980) for an analysis of the possible reasons for this).

Contrary to experience in the 'first-comer' American economy, size and vertical integration have played an important role in the survival and growth of the (imitating) European industry (not to mention Japanese). Nonetheless, the small number of big electrical companies meant a correspondingly smaller effort to undertake long-range, high-risk research. In terms of size, only Siemens and Philips could compare with the biggest American companies. The other companies involved in this field were big by European, but small by US, standards: AEI, Marconi, GEC and Plessey in the UK; AEG and Telefunken in Germany; Thomson, CSF and CGE in France; Olivetti in Italy, which entered the field later with the partly-owned SGS.

A second difference between the two sides of the Atlantic has been the role of the military. Table 8 shows the importance of the military involvement in research financing and semiconductor procurement in the US. Military and space programmes deeply affected both the supply and the demand side of the semiconductor industry.

On the supply side they involved:

- stimulation towards precisely defined technological directions and areas in which to allocate R & D efforts;
- the incentive towards and the direct financial support of the exploration of alternative paths of technical change;
- the speeding up of technical change to the maximum rate possible;
- the subsidy of the expansion of productive capacity to certain target levels considered necessary for national defence requirements;
- a push towards standardization of production.

On the demand side they resulted in:

- a guarantee of a future market for any innovation corresponding to required needs, i.e. public assured demand played a risk-taking role;
- the expansion of demand, with associated learning effects on productivity.

In Europe, on the other hand, military policies were not comparable in size or comprehensiveness. We are not arguing that military intervention was the most efficient means to foster innovation and growth in the sector, for the history of military-sponsored research projects has witnessed an impressive record of failures.[8] Nor are we saying that technological fall-out effects from the military to the civilian sector are the rule. The high fall-out effect experienced by the semiconductor industry can be attributed to the coincidence, at least in the early history of the industry, between the military trajectory and the civilian trajectory (e.g. computers) in terms of many common technological requirements. It appears that military and space programmes had a decisive role in this particular industry in its early stages in shaping the direction of technical change, 'planning' the expansion of demand and in inducing a huge accumulation of knowledge, expertise, etc. Together, these factors resulted in the establishment of a technological frontier on which the American industry was firmly placed in the '60s and '70s, although certainly at a high cost in terms of research expenditure and of frequent inefficiencies in publicly financed R & D efforts. It must be noted that market forces were essentially responsible for a swift reaction to the technological and market planning brought about by the above institutional factors. Furthermore, as technological trajectories became more defined, the military role - starting in the late '60s - decreased and the factors

fostering innovations and their diffusion became increasingly an endogenous product of normal economic mechanisms.

In the absence of similar institutional factors in Western Europe, the development of the semiconductor industry was slower and more haphazard. The large European companies entered the field at different times, with different technological capabilities, and devoting different financial and technological resources. With few exceptions, the resources devoted to semiconductors by European companies in the '50s and '60s were considerably lower than those of their American counterparts. Those companies entering the field generally focussed on the technological directions and applications in which they were already concerned. Since most of them were involved in consumer electronics (Philips, Thomson) and heavy electrical engineering (Siemens, AEI, etc.), the result was a much greater stress on advances fitting those applications and a relative neglect of military and computer-related applications, where the greatest technical advances were being made. Even in some of the areas of European specialization, progress was slower than in the US.

Up to the mid-60s the industry generally followed a pattern of technological imitation with significant, but not increasing, time lags vis-à-vis American innovations. In the late '60s to early '70s the lag in the newer or fastest-growing products and technologies (MOS-ICs and MPUs) appears to have somewhat increased.[9] The existence of these lags is, in our view, the explanation for the relative absence of new spin-off firms from the European industry.[10]

Other things being equal, the process of innovation on the technological frontier is likely to be cumulative and tends to act as a structural constraint: the probability of advancing with respect to the frontier is somewhat proportional to the position already occupied. This tends to explain, on the technology side, the relative stability of European lags. In the long run, of course, the ceteris paribus assumption cannot hold, and in the following pages an analysis of the changes in structural and behavioural conditions in the European industry will be attempted.

The American technological lead has created a significant American trade surplus all through the history of the industry, and a corresponding deficit in all the major European countries. (The exception was France in the '70s. This can be explained by a relatively high American investment, located there in an attempt to overcome a significant non-tariff protection of that market.) Figures 2 to 7 show the trends in exports and imports in the major Western countries.

During the late '60s and early '70s a process that can be described as the unification of the world market took place. A unified market implied a (relatively) unique price. When the latter was brutally brought about in the middle of a slump in demand by American companies (primarily Texas Instruments), during the so-called price war of 1970-71, all the European producers were forced out of the mass-standard market, with barely five exceptions. Other European companies which maintained their semiconductor facilities withdrew to more specialized and protected markets.

Another important part of the process of unification of the world market was very substantial direct American investment in Europe. Although the case of semiconductors cannot be generalized, the evidence suggests that the net consequences in semiconductors have been significantly negative for the indigenous industry.

Foreign investment helps to break the relationship of lag in production to lag in demand which is one of the factors allowing backward industries and companies to survive at a lower stage in the product cycle. Thus, the US companies on the technological frontier pre-empt the market of the most advanced devices which the indigenous companies cannot yet produce, and, in doing so, make it more difficult for national companies to imitate at a later stage. This process, though damaging the local semiconductor industry, could benefit end-user industries by decreasing their delay in the adoption of the most advanced components. It seems likely, however, that the process is strong enough to jeopardize the survival of national semiconductor manufacturers but not enough to eliminate the diffusion lag in consumption of the most advanced products.

Some evidence in other sectors suggests that increased domestic competition from foreign-owned companies might sometimes encourage local producers to be more aggressive and innovative; it could be defined as a policy of throwing the child in the water to teach him how to swim. In our case, the children were weak, the water cold, and most of them drowned. Some recent trends in company strategy suggest, however, that in the few surviving companies, the threat of being totally forced out of the market has induced some competitive reactions.

There is also evidence from our interviews that the transfer of semiconductor technology within the domestic market through direct US investment in Europe is not over-

whelming. Despite the volume of these investments, most of the R & D facilities have remained in the US, including, generally, design and mask-making for the circuits. (ITT is a notable exception.) Furthermore, the production of the most advanced devices is normally located in the US. There are some recent signs of plans by some American companies to manufacture a few of the most advanced ICs and memories in Europe (e.g. the investment planned by National Semiconductors in Scotland), but such plans are likely to remain exceptions.

It has already been mentioned that technology represents a crucial factor in explaning the economic performance of companies and national industries. The technological frontier in itself presents the most powerful barrier to entry. From the point of view of market structure, the technological position of the US industry permitted innovative firms to overcome this barrier through new products and processes. One can see the asymmetric nature of these entry barriers, very formidable for technologically lagging firms, but slight for companies operating at the forefront of the technology. It appears that static economies of scale and minimum efficient scales of production have been increasing over time and that now, even leaving aside technological barriers to entry, they constitute a significant obstacle to the emergence of new companies on the standard market. Company estimates placed the minimum level of production in 1979 at around £70-80m. and the minimum required investment, including fixed capital and R & D expenditure, from £25m. to £100m. for a fairly complete range of semiconductor devices.

Finally, it is useful to make it clear that, while the US has enjoyed, till recently at least, a commanding lead in world semiconductor technology, the industry nonetheless faces a continuous adjustment problem. Uncertainties about the outcome of research in a fast moving technology are faced by each firm; generalized to the whose sector this uncertainty can be termed "the burden of the first-comer" (to be offset, of course, against the first-comer's advantages). Indeed, the uncertainties involved in making strategic technical choices strongly suggest that the governments of first-comer countries should pursue "offensive technology" policies in semiconductors. As we shall see in the following discussion, however, policies related to this "burden of the first-comer" might be radically different from policies in lagging countries, aiming at reaching the technological frontier.

EUROPE'S ADJUSTMENT PROBLEM: THE STRATEGIES OF EUROPEAN FIRMS

A fast rate of technical change, with fast substitution between old and new products, rapidly expanding markets for the latter, shrinking markets for the former, and temporary monopoly/oligopoly positions that can be exploited, is bound to bring about continuous adjustment pressures on each company. These pressures are at the core of the mechanism by which technical progress diffuses throughout the economy and induces incentives to innovate.

There is a basic asymmetry in the nature and the degree of adjustment pressures placed upon countries, industries and companies. This asymmetry reflects their relative distance from the technological frontier (including both product and process technology). It also affects the set of possibilities that the country, industry or company has in adjustment itself. Purely imitative responses and attempts to catch up are more likely to succeed in industries characterized by a stable basic technology, fairly easy transferability of that technology (for instance, embodied in equipment and not people) and a low degree of international oligopolization. In the opposite case, as in the semi-conductor industry, the continuous adjustment induced by technical change seems to penalize imitators and reduce their degrees of freedom. This appears to be the core of the adjustment problem facing European semiconductor industries.

The most immediate problem for many of the existing firms in Europe remains that of survival in the markets where they are already operating. Capacity to survive in the face of American competition has been partly determined by the cumulative efforts of each company in this field and continues to depend on the capacity to finance both a considerable amount of research and increasingly high fixed investment costs in a situation where most companies can expect to continue making losses in semiconductors for a long time.[11] For each company in isolation, technological and financial constraints are so powerful as to prevent any possibility of catching up; at the same time foreign competition and a high elasticity of substitution between new and old products prevent an easy survival on more mature markets. This situation will continue to prevail as long as the rate of technical change remains high. Table 18 provides an impressionistic overview of the relative strengths and weaknesses of Europe's national electronics industries, while Tables 16 and 17 indicate some of the time lags in first commercial production that are behind these strengths and weaknesses.

Given the factors that contributed to the original US technological lead, the rate of technological progress in the industry and the consequent problems for European firms of surviving, let along closing the gap, we are arguing that these problems are not primarily the result of poor decisions that are being made today. Indeed, European firms can be argued to be acting rationally within the constraints they face. The outcome may well have been different had these firms made different decisions in the earlier days of the industries - in the '50s and '60s - when foreign penetration of national markets was smaller. The following paragraphs recall some of the major aspects of company strategies which have led to the present structure of the European industry. There are now five major European producers: Philips (by far the largest, with subsidiaries in Holland, the UK, Germany, France and the US), Siemens (Germany), SGS (owned within IRI by STET, the Italian telecommunications holding company), Thomson (France) and AEG-Telefunken (German).

The salient size and product characteristics of the major European-owned firms and recent developments in the shares of producers in the European semiconductor market are detailed in Tables 14 and 15 respectively.

In the early stages Philips (Netherlands) and Siemens (Germany) had a significant involvement in the new semi-conductor technology; Philips is reported to have developed its first transistor just a few weeks after the announcement of its discovery by Bell Laboratories. AEI (purchased by GEC in 1967) and English Electric (merged with GEC in 1968) in the UK were also relatively strong. Nonetheless, the hallmark of the European industry strategy in the '50s and '60s was to follow an imitative path. Each company generally focussed on the range of applications in which it was already specialized. As a result, Europe's relative strength in semiconductors lay with consumer electronics and industrial applications.

A major shake-up of the industry occurred with the emergence of ICs and their diffusion in different areas of application from the mid-60s. Europe's lag in ICs was very long and the effort of catching up particularly expensive, while competition from American companies was bringing the price down to American levels. Faced with this situation, European companies had the choice of withdrawing from production and buying ICs on the market - a cheaper option in the short to medium run - or trying to seize a share in the new and fast growing market despite the high costs and high risks to be borne for a long time. Conventional, shorter-run, profitability criteria would have suggested the withdrawal of all European companies. Thus, GEC is hardly to be blamed for leaving the standardized semiconductor market in 1970-71, despite its fairly strong technological capability (in European terms) and significant British market. Thomson (France) also partly withdrew and, indeed, would have withdrawn further but for the intervention of the French government (see below).

On the other hand, ICs were rapidly substituting for many other electronic components that the big integrated electric companies of Europe were already producing: in these circumstances getting out of semiconductors would have represented not only a missed opportunity for growth, but also a net loss of existing markets. This factor, plus the possibility of internalizing the benefits from advances in that far-reaching technology, helped explain the difference between the strategies of GEC on the one hand and those of Philips and Siemens on the other. The size, vertical integration, and technological inter-relatedness among different activities enjoyed in large firms like Philips and Siemens are together likely to allow a firm, in a situation where the timing and nature of future profits are far from certain, to move into growth areas on the assumption that profits are likely to follow growth; they also allow a firm to manufacture clusters of interlinked products in order to exploit demands that one product creates for another. It is significant that the European companies remaining in the high volume semiconductor market maintained a relative specialization in the devices for which they alread had an in-house demand. (The Italian producer SGS, which is not de facto integrated inside its parent company, STET, is an exception.)

It is probable that size and vertical integration do not provide the entire explanation for the extent of a firm's horizons or its growth orientation. These might also be influenced by the general environment in which the company operates, for instance, the far-sightedness of national financial markets, the role of banks, and more sociological and political variables such as relationships with labour and government.

Philips and Siemens have clearly emerged as Europe's strongest semiconductor producers. If production in its American subsidiary Signetics is included, Philips was among the world's five largest semiconductor producers in 1978. It has made a huge effort since the late '60s to improve its technological capability in ICs: now it can be considered to be on the technological frontier in many areas, although it is still relatively weak in some crucial fields like microprocessors and general MOS technology. Philips has important semiconductor facilities in Holland, the UK (Mullard), Germany (Valvo), and France (RTC-Compelec). These companies

obtained considerable government help in the UK, Germany and France (but not in Holland), although the percentage of government support to total R & D has probably been lower than for other European companies. Philips' pursuit of the technological frontier in semiconductors has basically been independent of national government policies.

As a result of its size and experience in the field since the beginning of the industry, Siemens would probably have been able to undertake the cost and effort of expanding and improving its semiconductor activities alone. As a matter of fact, it has been considerably supported by the German government over the last decade (see below); yet even now it still lags behind its American competitors in the field of ICs and microprocessors.

As might be expected, radical technical change has had important effects on the structure of the semiconductor industry. The emergence in the US market of new innovative companies during the '50s and '60s, among them today's market leaders, is the best known feature. Another aspect is the threat posed to vertically integrated companies whose oligopolistic market power is based on the success of previous, and competing, technologies.[12] This process of erosion and the emergence of new vertical integrations on the basis of new technologies has become evident very recently and must be expected to have an increasing impact upon companies and industries.

A first aspect of this structural trend is the attempt of existing electronics/electro-mechanical groups to maintain their leadership in the new technology. The examples of Philips and Siemens have been cited. Very recently, in the late '70s, a strong tendency has emerged in the US towards the upward integration of computer, electrical and automotive companies, among them Honeywell, Sperry Univac, Xerox and General Motors.[13] Part of the same process is the buying up of existing semiconductor companies: in the US "out of 36 semiconductor startups since 1966..only 7 remain independent".[14] In this acquisition wave, an important role has been played by European companies, principally Philips, Siemens, VDO and Bosch from Germany and Schlumberger from France (see Table 11).

A second aspect of the same trend towards vertical integration based on the new technology is the downstream expansion of semiconductor companies (examples among many are Texas Instruments in micro and mini computers and watches, and Fujitsu in industrial control).[15] Since there is no evidence that the process of expanding applications and substitution for old technologies is slowing down, it is reasonable to forecast that these kind of adjustment pressures, and with them the vertical integration trend, will continue. Several European consumer electronics, telecommunications and heavy electrical engineering companies are already following this trend, though with different degrees of commitment and technological capability. In addition to Philips, Siemens, SESCOSEM (a subsidiary of Thomson-CSF), and AEG-Telefunken, these include: Plessey, GEC and Lucas (UK); Ericcson (Sweden); Brown-Boveri (Switzerland/German); Bosch, VDO (Germany); and, with a more recent involvement, Ansaldo (Italy). The next drive towards vertical integration will probably involve the automotive sector, following the early lead of General Motors. An active interest already exists among the major European car companies.

The industry's increasing fixed capital requirements per unit of output (by all appearances a recent phenomenon) has led it to rely more than before on outside capital to finance its rapid expansion.[16] This has encouraged the integration of semiconductor producers with established cash-abundant companies. Thus American semiconductor firms have shown a greater willingness to set up joint ventures with European companies in such cash-against-technology deals as: Fairchild-GEC in the UK (a deal which may be in jeopardy after Schlumberger's takeover of the former); Harris-Matra, National Semiconductors - Saint Gobain Pont-à-Mousson in France; Fairchild - National Oil Company in Austria. Financial constraints on the growth of US producers since 1979 have also provided one of the main explanations of increased Japanese penetration of their domestic market.

It has also been argued that financial motives underlie the recently more liberal licensing of US technology to European countries, especially from those firms without productive facilities in Europe, such as Intel (licensing to Siemens) and Zilog (licensing to SGS), both in micro-processors.[17] It is noticeable that the Zilog-SGS deal covers a very early stage in the product's development and involves a substantial technology transfer. It allows SGS to compete on the American market in slightly more mature licensed devices, while giving it the sole manufacturing rights in Europe for the most advanced device.

The acquisition of existing American semiconductor companies, the establishment of joint ventures in Europe - especially for European firms that are newcomers to the field - and the licensing of American technology are all part of a defensive adjustment strategy for existing European semiconductor companies or big conglomerates, electrical or not, looking for diversification opportunities. This strategy might be defined as defensive because, although it will improve the competitiveness of existing companies vis-à-vis American and Japanese companies and provide growth possibilities for a few other large new companies, it will neither completely bridge the technological gap nor reduce the relative imbalances between European countries.

A prevailing opinion is that joint ventures are not likely to bring about a marked transfer of technology; they leave little freedom of action in technology or strategy to the European partner. (This also seems to have been the French experience in computers.) A possible exception was the joint venture of Olivetti, Telettra and Fairchild establishing SGS, though controversy over strategies was among the reasons which broke the marriage. This experience is commonly believed to constitute a very particular case, but a more empirical judgement on the issue is impossible since we do not yet know the outcome of the recent joint ventures of Saint Gobain and National Semiconductors, and Matra and Harris.

ARGUMENTS FOR PUBLIC INTERVENTION

Before the '70s, the European semiconductor industry operated in a broadly free market environment. (The public intervention that developed in the '70s is the subject of Part III.) We have sought to show in the preceding pages that this free market environment has resulted in no more than the survival of the industry which is, in effect, only running fast enough to stay in the same place. The Japanese strategy of catching up through a sequence of licensing, creative imitation and improvement has proved beyond the financial and technical capacity of most European firms. These circumstances justify a consideration of the ways in which public intervention could be used in European countries to relax the constraints on catching up that the free market has imposed.

Before we present a range of possible policy options, we must first consider the reasons for a country wishing to have its own competitive semiconductor industry. These principally concern the general effects of the characteristics of the industry on competitiveness in other related sectors, on employment, on the balance of payments, and on national independence. These arguments for public intervention, which we consider below, bring about strong adjustment pressures, not so much on the companies involved with semiconductors, but directly on governments and public institutions.

The Relationship of Producers and Users

In our view, the key argument favouring the existence of a technologically advanced domestic semiconductor industry, which partly subsumes other arguments we shall consider, concerns the relationship between technical progress in semiconductors and that in component end-uses - computers, industrial automation, consumer electronics, telecommunications, automobiles, etc. There are few doubts that a strong and consistent relationship exists, but is a domestic, or even more a nationally-owned, semiconductor industry necessary to reap its advantages? This question can be broken down into two parts: first, to what extent is it possible to benefit from technical progress in semiconductors by buying the most advanced devices on the international market and second, is it possible for a country successfully to specialize downstream relying solely on the market mechanism? Past studies on the sector are not unanimous on these questions.[18]

The efficacy of the international market mechanism is strongly obstructed by the increasingly systemic nature of IC technologies, by which we mean the embodiment within the IC itself of specific functions related to particular end-uses. This view is supported by much work that has been carried out at the Science Policy Research Unit.[19] The greater the geographical and economic distance between producers and end-users, the greater the difficulties in the free flow of knowledge, technicicans and scientists, technical information, perception of new technical possiblities, etc.

Even in the absence of geographical and economic distance, it is not clear that market mechanisms alone will fully allow the downstream diffusion of technology. Certainly, traded aspects - changes in relative prices, product-embodied technical advances, incentives and disincentives via the allocative mechanism by means of changing profitability, etc. - are central to the transmission of technical change throughout the economy. The limits of traded technological transfer as incorporated in licensing have been briefly discussed above and they apply to an even greater extent to other forms of technology transfer, such as second-sourcing.[20] Equally essential, however, are the non-directly traded aspects - generally termed 'externalities' in orthodox economics. One example of these non-market aspects is Silicon Valley, the area south-east of San Francisco where a great number of semiconductor firms are concentrated. Mobility of technicians and managers, daily interchange of information, and the ease of producer-user contacts are among the effects of this concentration. Another example is the training effect for national electronics industries. This has been mainly the

result of the research and manufacturing activities of firms like Siemens in Germany and SGS in Italy. Texas Instruments has played a similar role in Europe, especially in the UK. In some respects the attempt to integrate vertically into semiconductors by diversified electronics companies can actually be seen as the effort to internalize within the companies part of the gains from technological progress that the invisible hand of the market cannot transform into tradeable commodities. These are not cases of an exceptional market failure in an otherwise smoothly working mechanism; on the contrary, they are a permanent feature of the process of technical change. In some respects an industry like semiconductors can be considered as a service activity whose output goes beyond the simple measurable hardware it produces.

Our argument for the importance of non-market aspects relates to a cluster of industries actually or potentially affected by microelectronic technologies, and not so much to individual companies (which might very well waste no time in following new technologies) or even to individual industries. There are examples, especially from small countries, of successful electronics-related industries with no significant local production of semiconductor components - for instance, the Norwegian robotics industry. Our argument applies especially to big countries with a large number of inter-related sectors and companies and refers to the effects of local semiconductor production on average rates of downstream diffusion.

The Employment Argument

It is necessary to distinguish between direct employment effects in the semiconductor industry itself and indirect effects through the adoption of new technologies in end-user sectors. Direct employment in semiconductors accounts for a very small proportion of total manufacturing employment (about 0.2% in the major European countries in 1978 compared to 0.6% in the US -see Table 3). The only truly labour-intensive phase undertaken domestically in the industry is R & D, which tends to be concentrated in the country of ownership. (The ratio of R & D expenditure to value of sales for European firms generally ranges between 10% and 15%. The equivalent ratio for American subsidiaries in Europe is generally below 5% and is between 5% and 10% in their US parents.[21]) Assembly is still partly labour-intensive, but it is performed largely in South-East Asia or European peripheral countries such as Portugal or Malta. The biggest European producers, Philips, Siemens, SGS, SESCOSEM all assemble off-shore.[22]

Potentially the most powerful employment effect is the indirect one which in turn crucially depends on the interrelationship effect discussed above. There is some evidence of labour-saving effects in microelectronic technologies.[23] However, the net total employment effect of the adoption of the new technology might logically be categorized as follows: (a) labour-displacement in downstream industries; (b) (b) domestic employment-creation in semiconductors and in downstream sectors as a result of new products and new activities; (c) domestic employment-creation as decreasing costs increase domestic demand in semiconductor and downstream activities; and (d) effects on international competitiveness, i.e. on foreign demand, foreign penetration on domestic markets and the maximum rate of growth compatible with the balance of payments constraint. The first three effects relate to the adoption of the new technology as such in one country, while the fourth relates to the relative speed at which the technology is adopted vis-à-vis other countries. In the short run the net total effects are difficult to assess a priori. Nonetheless, in the long run, other things being equal, the effect is certainly positive. If a country does not choose to close itself off completely from international trade, a permanent lag in the adoption of a superior technology implies declining shares of foreign markets and an increasing foreign penetration of the domestic market. Both would result in a declining maximum rate of growth compatible with the balance of payments constraint.[24]

The Trade Argument

There is convincing evidence of a strong positive direct and indirect relationship between international trade performance and domestic technological levels. This evidence can be seen both in a micro analysis of the relative success on export markets of countries (and companies) in relation to their technological strength and weaknesses and in econometric tests of the relationship between countries' export shares and their patenting activity (used as a proxy of innovative output).[25] In terms of direct effects, the trade balances of most European countries, as a ratio of total internal demand, showed an increasing deficit around the mid '60s, a decreasing deficit around the turn of the decade (associated with the big wave of American investment in Europe), and a deficit worsening in absolute terms, while rather stable again thereafter, as a ratio of internal consumption. (See Figures 2 to 7 for the evolution of output and trade in semiconductors for the major producing countries from the '50s to the '70s.)

The impact of competitiveness in semiconductors on national trade balances is obviously strongest in its indirect effects but a precise assessment is difficult. Competitiveness in semiconductors is certainly not a necessary or sufficient condition for competitiveness in electronics more broadly, even if it appears to have a strong facilitating effect.

There are other important adjustment pressures which cannot easily be located in an economic framework. One of the basic driving forces for industrial policies in electronics has usually been a national perception of the strategic importance of the industry in terms of military objectives, national prestige, a desire for technological autonomy, etc.[26] This national drive, which has certain important connections with our interrelationship argument, does not necessarily introduce distortions or inefficiencies as compared to situations in which the strong political objective is absent; but it does contribute to shaping the patterns of intervention in certain directions rather than others.

The development of a strong electronics industry has been seen by many governments as a form of long-run insurance enabling the domestic industry to reap the benefits of a fast changing technology throughout the economy. The importance of electronics has been compared to that of steel in the last century and a half in industrialized economies (see OECD, 1968). Nobody could have quantified the eventual returns from the development of that industry, i.e. the trade-offs implied in developing a heavy industry or a more traditional pattern of specialization. While the steel industry turned out to be an important ingredient of industrialization, the prime motivation for its expansion was often political.

Finally, the case of semiconductors could be taken to be representative of other high technology industries such as computers, electronic instruments, or even some chemical sub-sectors. Together, these industries may account for an important part of future developments in trade balances and employment. National performance in these industries will have an important effect on national industrial structure and position in the international division of labour.

Options for Intervention

If one accepts the arguments for the need for a domestic semiconductor industry and the inability of market forces alone to achieve this end in a satisfactory manner, some of the options for a strategy of intervention can be briefly considered. These options are essentially related, in the first instance, to the electronics industry as a whole because of the interrelationship argument. We can rank the possible options from the first to the n-th best in accordance with some criterion of technological capability and strength in the set of user sectors: the ambitiousness of the policy targets contributes to defining semiconductor policy. Three strategies can be tentatively defined:

i. an across-the-board offensive strategy aimed at the technological frontier in most of the related electronics industries. The implication is a forced accumulation of knowledge and manufacturing capabilities and a substantial catching-up effort in semiconductors. This strategy appears well beyond the reach of European firms in isolation and would involve a comprehensive set of industrial policies almost necessarily at a European level. With regard to semiconductors, it would imply the maximization of the technological fall-out from semiconductors upon the related sectors and the taking on European shoulders of part of the burden of the first-comer;

ii. a strategy of picking the winners in electronics-related sectors and a substantially imitative strategy in the others. This would still imply an effort to improve the technological levels and size of the European semiconductor industry, but on more selective grounds - for example, with greater stress on industrial and consumer applications rather than computers. A set of research and structural policies would almost certainly still be needed but on a lower scale and with different degrees of intervention in the various countries. This strategy could be implemented on a national, not necessarily European, level;

iii. a strategy of fostering the already existing market forces. In many respects this is similar to the previous strategy. Here, however, neutral trends already existing in the industry (in some sense the industry's revealed comparative advantage) are stressed rather than exogenously defined objectives. There would still be a need for policies regarding both semiconductors and applications, but on a more limited scale, aiming at incremental improvements of the existing situation.

As a qualification of these intervention strategies, it is important to discuss the relative role of national ownership and foreign investment in Europe. Quantifiable evidence on this issue is difficult to obtain and conflicting answers can be advanced. On the one hand, if we assume that the technological lag of the European industry is given and unchangeable, then American direct investment will, other things being equal, make a positive contribution to the speed of diffusion and consumption of the most advanced technologies. US direct investment in Europe is partly motivated by the use of direct manufacturing as a point of sale which allows greater market penetration.[27] This and the very short lag in the commercialization of new US products in Europe suggest that US foreign investment accelerates the consumption of the most advanced items, compared to a situation in which there is no foreign investment and local industry still lags in manufacturing. On the other hand, if we assume as one of the main policy targets a successful national or European industry on the technological frontier, foreign investment may appear a second best alternative: a fully national or European industry will locate more R & D at home, and will have higher feedbacks of innovative stimuli, flows of information and technologies. Whether this first best alternative is a practical one is, of course, a different matter.

III. PUBLIC POLICIES

A HISTORY OF PUBLIC POLICIES IN EUROPE

Public intervention in semiconductors has grown significantly in the UK, France, Germany and Italy. Table 19 provides a record for each country of public money earmarked for major relevant programmes in 1964-82 (in national currencies and US $), while Figure 8 records the major events in structural change and government intervention in 1964-79. Despite considerable national differences in timing and scope, the history of intervention divides into three phases.

Three Historical Phases of Public Policies

First phase: laissez-faire and (limited) military-related policies (UK and France), 1950 - mid'60s.

This non-intervention phase occurred precisely during the period when the technological trajectories of the industry were being established on the American market. European industry, broadly speaking, followed an imitative pattern, with fairly stable imitative lags and substantial imbalances among countries (see Table 16). In the UK and France, accompanying a non-interventionist attitude toward industry as a whole, military-related R & D support and procurement policies date back to the '50s. The limited size of such measures in European countries in general as compared to their American equivalents seems to have produced little effect in improving innovative capacities.

In imitating countries where military-related intervention fails to reach the comprehensiveness of the American model, it does not allow any leap-frogging but, if anything, helps a quicker imitation in the military field, without any substantial effect on other sectors of application. Many industry representatives still advocate an increased military involvement as part of the cure for the European industry. This is understandable, since it guarantees riskless R & D funding and a strictly protected market, but the entire argument seems somewhat suspect. If the final aim is to develop civilian technologies, a much more straight-forward way seems to be to apply efforts directly to them. Japan provides an example of a successful effort concentrated directly on civilian applications, without any military involvement. It must be said, however, that military-related policies, especially in the UK, probably gave a significant stimulus to companies to remain in the industry and encouraged the maintenance of R & D activities in the most advanced fields.

Until the late '60s, among the four countries considered, only the UK and France show any significant R & D funding and procurement; in Italy and Germany public support was irrelevant.

Second phase: computer-related policies (UK, France, and Germany), mid '60s to mid '70s.

Besides the military, an additional reason for public interest in semiconductors in the UK (since 1964), France (since 1966) and Germany (since 1967) has been a by-product of government intervention in the computer industry.

Concurrently with the creation of a Ministry of Technology in 1964, the UK started an Advanced Computer Technology Project, with finance of £5m. (US $14m.), to share on a 50-50 basis the cost of applied research in computers and computer-related technology, a little of it for semiconductor research (see Table 20). All through the '60s most of the publicly funded research came from military programmes. In France the Plan Calcul (1967) provided FF91.6m. (about US $18m.) for the period 1967-70 to the component industry (Table 22), mainly to the semiconductor company SESCOSEM, belonging to the Thomson group and constituted in 1968 through the government-fostered merger of SESCO (Thomson) and COSEM (CSF).

Germany's first Data Processing Programme (1967) provided some minor R & D support to the semiconductor industry. Only in 1969 did state support become important, with the second programme. All through the '60s Italy had no specific plan for electronics, the only public provision being the technological evolution fund (1968) aimed at providing long-term low interest loans and R & D subsidies to the entire manufacturing industry. The semiconductor industry (i.e. SGS and Ates) obtained over 10 years (1968-78) as little as L3.6bn. (about $5m.), comprising L3bn. as a 5% interest loan and L600m. of subsidies. All through the

'60s a state-owned company operated in the semiconductor industry (Ates belonging to STET, i.e. IRI). It merged with SGS in 1972-73.

In fact, public policies seem to explain few of the differences in innovative capacity existing among European countries in the '60s. A more convincing explanation is the technological strength of the companies involved in the sector and their autonomous research efforts, etc.

<u>Third phase</u>: semiconductor-specific policies and application-related policies in all four countries from 1975

As the pervasive effect of semiconductor progress beca clearer, public institutions started to focus on technologic inter-relatedness within the electronics industry.

In Germany, with the second Data Processing Programme (1969-70), the scope of intervention came to cover the major areas of high technology and of fast development (semiconductors, computer hardware, peripherals, software, comput applications). Table 21 gives an impression of the wide sco of industrial policies in electronics, which, in terms of activities, cover basic research, applied industrial researc applications of both computers and semiconductor components, and education and training. Beginning in 1974, the provisions for semiconductor components were separated in a specific plan (1974-78). A comparison with other countries shows the much bigger size of German support to the electronics industry in general and the semiconductor industry in particular (see Table 19).

In the UK a specific programme related to semiconducto was introduced in 1973 to support R & D projects in the nationally-owned semiconductor industry (see Table 20). In 1977 and on a bigger scale in 1978, the Department of Industry introduced two support programmes, to the component industry in general (1977 - Component Industry Scheme), and to semiconductors specifically (1978 - Microelectronic Industry Support Program-MISP). In 1978, the National Enterprise Board (NEB) launched a new company (INMOS), meant to establish R & D and production facilities both in t US and UK and to enter the standard VLSI market. Another measure taken in 1978 related to semiconductor applications in the Microprocessor Application Scheme, financed with an estimated £55m (about US $110m.) available for training programmes, industrial consultancies in microelectronics applications, and R & D projects involving the use of microprocessors.

The strategy of the present Conservative government towards industrial policies in electronics is not completely clear. There are signs that the basic provisions of the previous administration will not be radically reversed. The new government has fulfilled the engagements of the NEB towards INMOS and intends to pursue a policy towards new investments in semiconductors similar to the previous one: the new National Semiconductor plant in Scotland will be financed for £12-14m. (about US $30m.) and so will the joint venture of GEC-Fairchild for £7m. (about US $ 7m.) if the investment plan will ever come through.[28] These measures add to the support already given to ITT in 1978 (£7m.). Both the Microprocessors Application Scheme and the Microelectronic Industry Support Programme will be retained.

France did not have a specific programme related to semiconductor components until 1977. Actually, what were sometimes referred to as "Plan Composants" in the late '60s and early '70s were essentially a series of measures related to the Plans Calcul (see Table 22) and primarily concerned with the subsidy of semiconductor activities in the Thomson group. A comprehensive plan specifically aimed at the development of IC technologies and production was introduced in 1977, giving finance for R & D activities in both French companies and joint ventures. In addition, inside the plan 'Informatisation de la Société' there is a part devoted to the applications of microprocessors in end-user sectors. The plan 'Circuits Intégrés' involves a total of FF600m. (about US $130m.) over four years. The plan 'Informatisation de la Société', net of the amount also appearing in the IC plan, is around FF400m. (about US $90m.) per year, for four years. Inside the latter there are provisions, for FF10-15m., for MPU applications. These figures do not include the regional development grants for new investments and the long-term interest loans by the Credit National.

Finally Italy, as mentioned, did not have any major intervention in the electronics sector until 1978. At this time, the electronics sector was among those sectors affected by the Industrial Restructuring, Rationalization and Development Law (Law 675/77) which was meant to provide guidelines and financial support, in terms of R & D and investment grants and long-term low-interest loans, to a dozen industrial sectors, either because they were technologically strategic or because they were facing strong adjustment pressures. Among the sectors are electronics, machine tools, food processing, paper, steel, chemicals, fashion garments, anti-pollution plants, energy saving and alternative energy sources and materials recycling.

Inside the electronics plan, one of the sub-sectors considered is electronic components, of which semiconductors are the most important part. Table 23 details the public financial commitments over four years (1978-82). Although there is no special provision for micro-electronic applications, the other parts of the electronics plan (concerning computers and office equipment, telecommunications, consumer electronics, automation and industrial electronics), as well as the machine tools plan, may be understood as fulfilling this task.

At the time of completing this work (February 1981), however, none of the financing has reached the industry yet, due to the lack of administrative procedures and the chaotic state of Italian civil service. Moreover, one must notice that the amounts proposed and approved - shown in Table 23 - significantly exceed the actual cash at the moment available.

A Comparison of Instruments

There is an obvious relationship between the objectives, instruments and effectiveness of policies. It is useful, therefore, to undertake a brief survey of policy instruments. Generally, European industrial policies for semiconductors take six forms:

i. R & D support through subsidies, research contracts or low interest loans.

This has been by far the most important instrument of intervention in all European countries. In addition, some research activities have been undertaken directly in public institutions and government agencies. This was especially important during the '50s and '60s in the UK (military research establishments) and France (military research, Centre National d'Etudes des Telecommunications and Atomic Energy Agency). In the '70s, the Atomic Energy Agency itself set up a manufacturing activity (EFCIS) in a joint venture with the Thomson group. In Germany, a significant amount of research (pure and applied, generally non-military) is undertaken by the institutes of the Fraunhofer Gesellschaft. The Association of German Engineers (VDI) has recently established a technology centre in Berlin, mainly operating as an advisory/consultancy body for small and medium firms. A similar role is performed by the Technology Advisory Services of the Chambers of Commerce and by the RKW (das Rationalisierungskuratorium der Deutschen Wirtschaft). In Italy some research projects have been undertaken

by the National Research Council (CNR), either autonomously or in collaboration with private firms.

Custom design centres, available for research and design contracts from private firms, publicly sponsored either through universities or government agencies, exist in the UK (WMI), Germany (Aachen High School and Dortmund University), France, Belgium, Denmark and Switzerland.[29]

ii. Procurement policies, mainly in the military and telecommunication fields.

Military procurement has been relatively important in the UK and France, much less so in Germany and Italy. Its impact as a percentage of total demand shows, however, a general declining trend. Telecommunication procurement generally follows a buy-national-whenever-possible policy in all the major European countries. The telecommunications market is following a fast growth trend due to the drive towards fully electronic equipment. It must be noted, however, that total public procurement (military, aerospace and telecommunications) in Europe is around 20% of the total market, although there is some variance among countries. France is at the top, due partly to military procurement, but primarily to telecommunications, followed by the UK, Italy and Germany. Inside IC markets the percentage of total procurement is, on average, below 20%, again with some variance, following the same ranking as the total semiconductor market.

iii. Investment grants and subsidies, transfers on capital account.

These policies are not generally related to semiconductors but mainly to macro-economic policies of investment incentives and regional policies. For the semiconductor industry they seem to play a substantial role in the UK, especially with regard to location in Scotland. Recent semiconductor investments in France, both nationally-owned and joint ventures, are believed to be financed on preferential terms and to be granted regional incentives. Italian electronics, as well as other manufacturing investments in the South, are generally aided on a fairly automatic base under the auspices of Cassa del Mezzogiorno. Regional (Länder) provisions are significant also in Germany, though it seems that they have not been of much relevance in semiconductors.

iv. Tariff and non-tariff protection.

All the EEC countries apply a 17% ad valorem tariff, which is the highest amongst industrialized countries. The EEC did not agree to bargain any reduction of this tariff in the recent Tokyo Round of GATT. However, the tariff does not appear to affect import flows of the most advanced devices not yet produced in Europe. Even with respect to devices also produced in Europe, it is well below the cost differentials between Japanese and American industry on one hand, and European industry on the other. More important, a high protection in components decreases the degree of effective protection in electronic goods. A form of non-tariff protection is the existence of national technical standards, especially for telecommunications and military components. A European set of technical standards is on the way to being approved by EEC members. Some American (and Japanese) producers claim that import licensing in France and Italy represents a protective barrier.

v. Promotion of structural change through mergers, constitution of new firms, nationalization, planning of the areas of activity of individual firms, etc.

In France, public institutions have always favoured merger policies. These led to the formation of SESCOSEM (1968) and finally to the concentration in the Thomson group of almost all French-owned semiconductor production by 1978. Furthermore, the government had an active role in first authorizing and then financing and bargaining the terms of the agreement in the joint ventures of Saint Gobain Pont-à-Mousson with National Semiconductors and Matra with Harris (both 1978). Both agreements resulted in a 51% share for the French partner and 49% for the American one. They are believed to imply the provision of the technology by the American companies and the financial backing by the French partners and from the government. Continuing public support is conditional on the achievement by the new companies of the targets agreed in advance with the DIELI (Direction des Industries Electroniques et de l'Informatique) in terms of transfer of technology and levels of production. St. Gobain and Matra are notably not electronics companies but diversified groups willing to expand into the most promising areas of electronics (recently St. Gobain acquired the majority share of CII-Honeywell Bull and more than 20% in Olivetti). Finally, the last IC plan provides a pattern of specialization among French firms, joing ventures and the Philips subsidiary (RTC): SESCOSEM in linear (and some digital) bipolar ICs ; EFCIS in MOS, CMOS and SOS; RTC in

ECL and fast TTL (both are bipolar ICs); St. Gobain-NS in MOS; Matra-Harris in CMOS.

In semiconductors the British government followed no explicit structural policy until the constitution of INMOS by the NEB. In the '60s it favoured the merger between the semiconductor divisions of Eliot and Marconi in Marconi Eliott Microelectronics. The attention of the British government has been, moreover, focussed for a long time on computers: there, it had a direct or indirect role in the series of mergers that lead to the constitution of ICL, in which the government itself kept a share until 1979.

In Germany, no significant structural policy took place and there does not appear to be a need for it.

In Italy, although any kind of conscious supply side policy has been absent for a long time, the most important action in this respect has been the purchase by STET (the telecommunications and electronics holding of IRI) of SGS, after Fairchild left the joint venture with Olivetti and Telettra. In the same period STET acquired other electronics companies, either from other holdings of the same IRI group or from third owners (SELENIA, ELSAG, ELTEC). These actions must be seen primarily as part of a strategy of a company acting largely independently from industrial policy considerations, like any other private company. It is doubtful, however, whether any other Italian company would have intervened in SGS and covered its persistent losses, were it not at that time in a great and financially solid holding. In the Italian electronics field only the state-owned telecommunications company seemed to have this character. In the SGS case, the STET acquisition met the willingness of the latter to expand in the electronics areas, that of the two other partners (Olivetti and Telettra) to find new funds and a risk-sharing partner, and that of the unions to achieve greater job security in a firm in financial trouble.

v. Policies towards direct foreign investments.

All these four European countries, with the exception of France, had a non-discriminatory policy towards American investment. France always tried to bargain the access to its market against some technology transfer (the establishment of local R & D facilities etc.) and to increase import substitution and export capabilities of foreign subsidiaries. More recently it favoured the establishment of joint ventures. In Germany and Italy foreign semiconductor investment has not been discretionarily controlled but foreign companies did not have any role in public plans. In the UK, the first scheme (1973) for microelectronics was limited to national companies, while the more recent ones are not. A unique feature of the UK (and Ireland) is that the regional development provisions represent a major incentive to foreign investment.

SIMILARITIES, DIFFERENCES AND EFFECTS OF PAST PUBLIC POLICIES

The analysis that follows will try to assess more exactly the degree of similarity or difference between national semiconductor policies and, at a more specific level, the relationship between policies and the behaviour and objectives of firms.

The conventional wisdom is that the electronics sector confirms a supposedly general pattern differentiating Germany's more market related policies from more interventionist and discretionary French and British policies, with Italy somewhat in between, having very interventionist policies in some sectors and no policy at all in others. The hypothesis proposed here is that beneath the differences there are strong similarities among European policies.

Leaving aside for a moment the timing and comprehensiveness of industrial policies in semiconductors, the actual philosophy that appears to be common to European policies seems based on two connected assumptions. The first could be summarized as 'you cannot tell firms what to do', and the second, related to the first, assumes the strategies of the firms as generally consistent with the public objectives themselves - 'the objectives of the companies are the objectives of the country.'

As far as semiconductors are concerned, there appears to be a correspondence between the strategies of domestic companies and the provisions of policy actions which to some extent have been acting as a reinforcement. The most striking example, not only in semiconductors but generally in electronics, of the inability of European governments to implement an autonomous strategy, is the French case. Here, the actual policies and their outcome can be represented as the result of a stalemate between part of the government (namely the Délégation à l'Informatique), expressing objectives and targets from a national point of view, and those of the companies themselves. In this stalemate the Délégation à l'Informatique seldom had the power to implement political decisions. Often the final government decision turned out as a compromise between conflicting

private interests.[30]

French electronics is sometimes taken as an example of the failure of industrial planning, in so far as it conflicts with the working of the market mechanism.[31] We would argue that, on the contrary, it represents the failure to pursue coherent planning, in so far as it conflicts with the strategies of each company. To put it in more orthodox economic terms, whenever there occurred a conflict between private and social returns, public institutions tended to show themselves incapable of pursuing the latter.

In other countries the conflict does not seem to arise, simply because the tasks and aims of industrial policies are, more or less, made to be coincidental with the already existing structures and strategies of the companies operating in the field. If we look at the main strategic options facing policy-makers in each country - i.e. (a) leaving the semiconductor sector altogether and concentrating on applications; (b) maintaining a design and custom manufacturing capability; (c) improving and/or developing technological and manufacturing capability in the standard, American-dominated market - we notice a fairly close correspondence between the chosen policies and the original structure and features of the industry itself. In this, we are trying to avoid any value judgement: it may well be that this choice is actually unavoidable, the other more offensive strategies being impractical or very difficult. The likely consequence of all this, however, seems to be the maintenance of the relative differences between the American and European industry and also among European countries themselves.

As shown at the outset, there is no great homogeneity among European companies and, furthermore, they can be subdivided between those operating in the standard markets and those operating in custom markets. This corresponds to the distinction made by Sciberras (1977) between firms belonging to the 'big league' and those belonging to the 'little league'. Of course, there is no sharp distinction between standard and custom markets since the various devices possess just a smaller or bigger degree of customization in terms of applications. Furthermore, all the 'big league' companies also produce customized devices. However, the distinction maintains its usefulness in terms of volume of production, competition faced from American companies and range of products which a company tries to cover. To apply the distinction in a restrictive sense, just three European producers belong to the 'big league', namely Philips, Siemens and SGS. For most of the European companies the only reasonable strategy is defensive, i.e. the maintenance of the relative distance from American competitors, followin a more or less imitative pattern. Broadly speaking, this is also the objective taken up by public industrial policies. Given these similarities in the philosophy of public intervention the differences are impressive. They mainly concern the comprehensiveness, the timing, and initial structural conditions industrial policies have to deal with, and the size of the intervention.

Germany

With respect to all four indicators, Germany emerges as the best placed. First, the comprehensiveness of German support programmes in data processing, components, applicati and software has already been mentioned. This feature appear extremely important given the strong interactive mechanisms between users and producers. Specifically, with respect to semiconductor components, German policies (primarily R & D support) have been implemented in an environment in which: (i) the relative specialization of the biggest German manufacturers is fairly clearly established; (ii) some companies (primarily Siemens and Valvo-Philips, but also AEG) have the possibility, due to their size and vertical integration, of internalizing to a greater or lesser extent the advantages of improvements in semiconductor technologies and they actually showed, since the '50s, a willingness to develop in the semiconductor field.

Second, the timing and the size of industrial policies: as already mentioned, R & D support in semiconductors, initia around 1969, has been substantial enough since 1972 to financ several projects in products, productive technologies and applications. Among the favourable conditions listed above, the necessary one was the existence of companies which seemed autonomously ready to remain and develop in the sector. An indirect indication of the relative willingness of the major German companies to undertake their own risks and financial burden might be the percentage ratio of company-financed to total R & D. There is evidence that in Germany it ranges fro between 60% and 80%. According to some estimates the percent in French industry is as low as 20% to 30%.[32] German strateg has not been that of an ambitious leap-frogging, as opposed t the recent Japanese targets, but of a pattern of quick imitat in a wide range of products and technologies, the speeding-up the rate of diffusion in applications, an advancement in basi research and in new and promising technologies, such as opto-electronics and solid state solar cells.

Some significant results have been achieved by German policies. The imitative lag of German industry is probably on average somewhat shorter; one of the firms (Siemens) is reaching the breakeven point; the coverage ratio in ICs defined as domestic German-controlled production over national consumption has increased. This ratio is an approximate indicator of the competitiveness of domestic firms in both internal and external markets. In the '60s to early '70s it decreased, to different degrees, in all the major European countries. (For each country the numerator of the ratio is production by national firms plus, for Germany, France and UK, the Philips subsidiary.) According to some estimates, it continued to decrease in the UK until recently, as well as in France. In Italy, after a decrease until the mid'70s, it is now slightly improving. In Germany, it passed from 26% (1974) to 38% (1978). For Germany no reversal of the initial situation of technological lag has occurred, but signs of improvement are significant.

United Kingdom

It is interesting to note the difference between the German case, which could be called a balanced path of technological advance, and the British. Having the bulk of intervention until the mid '70s concentrated on computers, British semiconductors had a secondary place in industrial policies. Our view is that given the British situation on the supply side, with a great number of rather small producers mainly interested in their own special applications, not much more could be done. Had more funds in any form been made available, they could hardly have been used by British firms. In fact, the limited Microelectronics Support Scheme (1973 - funding £10 million or about US $21m.) took six years to be used. The scheme provided support only for British firms and for projects which, it was believed, would not be undertaken otherwise. In other words, in the British situation before the constitution of INMOS, any greater and more ambitious policy would also have required some structural policy of merger and/or constitution of a new company. Some believe that the INMOS experiment is "too little, too late" (Grant and Shaw (1979)). In other fields, namely computers, a merger policy proved to be fairly successful in the case of ICL, although as the French semiconductor case shows, such a policy is only a necessary, not a sufficient, condition. On the other hand, if mergers simply mean a sum of two net liabilities for public institutions without any long-run commitment by private ownership, the outcome in terms of technological capabilities, etc., may not be very different.

In the United Kingdom, after the withdrawal of British companies from the big markets, the limited policies until recently probably just enabled the domestic producers to remain where they were, while military and telecommunications procurement protected two of the main areas of activity of British-owned semiconductor firms. On the other hand, the recent constitution of INMOS is a large, ambitious attempt to leap-frog into VLSI. The results cannot be evaluated yet, since INMOS will not sell its first devices before 1981. The risk is high, but, given the remarkable staff of technicians recruited on both sides of the Atlantic, the bet appears worthwhile.

France

The French case has already been discussed as a striking instance of conflict between national objectives and private strategies. Policies certainly had a decisive role in the survival of a French industry, although they largely failed to accomplish the more ambitious task of increasing its relative technological and market strength. It could well be that, in cases like the French one, where for a long time private companies did not show any deep commitment to sharing the risks and the costs of catching up, "the act of safe-guarding the appearances of a purely private solution, when it is an artifice since the beginning" prevented any more ambitious and/or more efficient industrial policy.[33]

There are signs that the situation is changing. First, the Thomson group seems much more committed than before to semiconductors. Second, the massive programme of development in the telecommunication network has provided a push toward technical improvements in the field and at the same time a profitable market, guaranteed through procurement policy. Third, big diversified companies such as St. Gobain and Matra are now entering the field. Fourth, there is renewed government interest with the Plan Circuits Intégrés (1977) and the institution of the co-ordinating and monitoring Mission pour les Circuits Intégrés.

Italy

Finally, there are the Italian industrial measures, which are probably not "too little" but certainly "too late". Italian planning confirms the impression that it is actually a self-planning of the industry itself. The STET group in general and SGS in particular, together with other private electronics firms, have been asking for some kind of industrial policy since the beginning of the '70s. Apart from the delay in their introduction, the central objective in semiconductors seems to be the strengthening of the technological and manufacturing capabilities

of SGS-Ates over the entire spectrum of ICs (and especially MOS and micro-processors, where the Italian company has been relatively weak). Two crucial issues are still unsolved. First, the structure, the strategies and the technological options of the STET group are totally nuclear (for example, the relationship between the utility and the manufacturing companies belonging to the group, which telecommunications system to adopt and the relationship with Olivetti). Any decision is actually held up by the disputes between the different involved industries and by the political fights over the attributions of the managing posts. Second, there does not seem to be any public agency capable of managing rather complex industrial policies. The provisions of Law 675 are meant to be administered by IMI, a public-owned long-term credit institution. It seems to be a technically efficient and competent body but is not meant to take political decisions on industrial strategies. Beside that, no part of the civil service seems to have an outstanding expertise in managing industrial policies.

In spite of differences in timing, administrative capabilities, etc., the Italian plan appears to aim in semiconductors at objectives similar to German plans - a stronger showing in the standard market, fast imitative reactions, etc. Furthermore, both are focussed on domestically-owned producers. Again, it must be stressed that this is allowed by an already existing structure which makes it possible. In other sub-sectors, like consumer electronics and electronic instruments, the lack of any supply side policy will certainly make the plan largely helpless.

The results of Italian policies, of course, cannot be judged yet. The impression is that they could somewhat reinforce the technological and manufacturing capability of SGS, which - by European standards - is already fairly good. The story of the electronics plan after its approval, however, is an interesting illustration of the total incapacity of the Italian state administration to implement consistently and efficiently any kind of complex industrial policy. After the approval of the provisions of each sectoral plan (for electronics, see Table 23), the total financial outlays on different sectors required under the Law turned out to be well below the sum of the amounts required in each sectoral plan. Moreover, the lack of administrative guidance on the procedures of application for the funds up till now (early 1981) prevented their utilization.

Another central feature of industrial policies concerns attitudes toward foreign (mainly American) companies. In some countries, especially the UK, there seems to be some kind of policy schizophrenia between national objectives and actual policies that appear very keen to subsidize foreign investment.

In the case of joint ventures the single most important explanation is probably the strong pressure that European firms themselves recently began to put upon public authorities in this direction. It cannot be denied that in some countries this second-best alternative might be the only practical one in cases where the development and/or establishment of a significant and independent industry appears too late or politically impracticable. It needs pointing out that there is in this case, and even more so in the case of 100% American direct investments, an apparent large waste in heavy public subsidy of investments which would have probably occurred anyway

This is almost certainly the case of the joint ventures of GEC with Fairchild (the former could be suspected of everything but of lacking liquid assets), St. Gobain with National Semiconductor and Matra with Harris. One estimate is that sometimes through various support schemes, public funds (in the UK case) can reach up to 60% of the total cost of the capital. With respect to investment decisions, however, capital costs are just one of the influencing factors, and often not even the most important one. Other important determinants are the proximity to an important market, the availability of technical staff, etc This net zero sum game is mainly played among the UK, France and Ireland, but with significant differences. France is ready to give special subsidy, besides the usual and fairly automatic regional development schemes, to joint ventures after a complex bargain on technology transfers and production targets. The other two seem ready to finance any electronic investments. Possibly in all this the only positive net outcome might be for Ireland, which, apart from differential labour costs, does not appear otherwise to have big allocative incentives. Germany does not seem to be in the race at all, the provision of its plans being confined to German firms and to Valvo, an honorary German firm. Neither is Italy. In the past Texas Instruments benefitted from Cassa del Mezzogiorno funds which are, however, available to investments in the South through a fairly automatic procedure. (Some Italian policy makers, however, have also been tempted to ride two horses and finance the expansion of Texas Instruments through the electronics plan as well. The net effect on national technological and manufacturing potential is probably near zero, the only apparent outcome being a substantial diminution of the cost of capital for the investing companies.

As already mentioned, the main policy instrument in Europe has been R & D subsidies to projects more or less defined by the firms themselves. As far as research objectives are concerned, European governments have at best been able to define the major areas of development to which public funding was applicable, and then monitor the actual implementation of the project

themselves. The effectiveness of R & D subsidies has been a topic of considerable discussion in the literature, especially in relation to their effectiveness in fostering innovation. The problem is whether subsidies are an appropriate tool of industrial policy for the acceleration of technological imitation and the development of competitiveness in Europe's national semiconductor industries. In the case under consideration, R & D policies alone seem to present various weaknesses. First, in our opinion, there is a paradox in R & D policies as they have been implemented in Europe: on the one hand, it could be argued that firms know better than the governments in which directions to develop technology; on the other hand, the technological tasks that each firm is likely to undertake, and their ambitiousness, is generally a direct function of the already existing strength of the firms concerned, the markets they are in, their past R & D efforts, etc. The slightly paradoxical result is that policies conceived to reduce relative technological lags are likely, in the end, to reproduce these same relative differences, i.e. to reinforce already existing trends.

Furthermore, R & D subsidies risk being substitutes for private financing, without adding substantially to what a firm would have achieved otherwise. The very limited evidence on the subject is contradictory. The French case suggests that it has been partly substitutive. In Germany, it seems to have had a positive net effect, although it could be argued that large companies like Siemens had the strength, if not the willingness, to pursue these tasks anyhow. The impression is that, in the Italian case as well, the provisions of the plan will produce a net increase in the R & D efforts of Italian industry (i.e. SGS). The problem of public policy in innovation becomes even more complicated when the aim is not to follow a well-defined imitative pattern, but to encourage innovations and developments in new fields. In this all European policies seem fairly weak.

THE JAPANESE SEMICONDUCTOR INDUSTRY

Starting from a position in the mid '60s that was, if anything, behind that of Europe, the Japanese semiconductor industry undertook a huge catching-up effort. By the very end of the '70s it had completely eliminated its technological gap with the US in some areas such as ICs for consumer applications and memories and significantly reduced it elsewhere. From the mid '70s, Japan's share of world production increased at a rate above the relative growth of its internal market. By the turn of the decade Japan had achieved substantial market shares in the US in some devices, especially memories. It is evident that the next stage of Japanese export growth will be a penetration of the European market, with resulting direct effects on European producers.

It is worth noting the similarities and differences between the targets, instruments and results of European and Japanese semiconductor policies. Similarities between Japan and some European countries do not seem to go beyond the common target of decreasing the lag in technological and manufacturing capabilities in the entire range of products composing the semiconductor industry and, till recently, followed an imitative pattern.

The similarities appear to stop here, for there exists a significant different in the philosophy of planning. While European planning seems generally to adapt to the existing structure and strategies of the industry, the impression is that in Japan, given certain long-term objectives, part of industrial policy is the task of removing the structural constraints which would make those objectives unprofitable for private companies. These kinds of institutional measures include: (a) very restrictive regulations on foreign investment (formally until 1974 and informally thereafter); (b) institutional definition and public monitoring of the terms of licensing agreements, which were required to benefit not one firm but the entire industry; (c) import controls (stopped in 1974); (d) setting of technological targets (for example the recent VLSI plan) and establishment of adequate research facilities to fulfill them (for example the institution of joint research centres between the major companies, with direct government participation).

Our argument is that these industrial and trade policies allowed a definition of company strategy consistent with the national objectives and not the other way round, as has often happened in Europe. Furthermore, to implement the policy objectives an extensive and discretionary role is played by the publicly controlled Japan Development Bank and a set of powerful, although seldom used, coercive measures exist.[34]

As has been noted elsewhere, Japan is also characterized by an apparent closeness between policy-makers (especially in MITI) and companies, which partly explains the success of Japanese industrial policies. This closeness, however, is not uncommon to some European countries (notably France, but also Germany). What is striking in the Japanese case is the capability of policy-makers and institutions to represent the long-term interest of Japanese industry as a whole - to a certain extent forcing it upon each individual company - rather than the sum of the interests of individual companies, as often in Europe. Here also the environmental conditions come into play. Japanese policy has generally succeeded in

making rewarding for each firm what is considered necessary for the country. One could, in fact, say that while most other countries have considered their place in the international division of labour as given at each point in time by the international market mechanism, the Japanese have conquered it. The Japanese case is notable as the only example of the success of industrial policies nearly eliminating the technological lag vis-à-vis the American semiconductor industry. In our view, very consistent and comprehensive policies are an important part of the explanation of the different performance of Europe and Japan, for the starting points were not very different. The choice of instruments has also been crucial: variables that in Europe had to be considered among the constraints (like foreign investment or licensing policies by American firms), in Japan could parly become instrumental variables subjected to institutional control. European policies, for their part, generally emphasized just one main instrument - R & D subsidies.

On the Japanese side, indeed, subsidies never played a major role until the recent four year (1979-82) VLSI plan, publicly financed for $360m. of which $250m was government loans (see Table 25). Much more important to Japan seems to have been non-tariff import protection, control over foreign investment and monitoring of technology transfers. On top of this came a process of building industrial consensus around technological and manufacturing targets, agreed in a detailed bargaining process between companies, state, and unions. In the Japanese scenario, it seems particularly difficult to assess who is the prime mover, i.e. how much of Japanese dynamism can be attributed to government policies and how much to private companies. One cannot attribute to MITI alone the general difference in performance between Japan and Europe: more correctly, the difference seems to consist in a strikingly effective relationship between institutional settings (including MITI) and an extremely competitive internal market environment (oligopolistic competition amongst the major Japanese groups).[35]

To some extent the problem is that of chicken-and-egg. Certainly Japanese companies have shown a strikingly aggressive attitude, both in technological and market aspects, together with a high degree of far-sightedness. However, one can be very entrepreneurial in a broad set of activities, ranging from marketing very sophisticated computers to selling oranges in Naples. The fact that the Japanese followed the first route certainly depends also on a set of structural and institutional factors. Government policies provided some of these. Others probably derive from the structure of Japanese society as such, and two features here are worth mentioning. First, the immobility of manpower and the system of life-time employment, instead of being paralysing factors, probably represent a strong motivation for strategies of long-run planning and a search for growth sectors. What in Western economies, especially in the US, is left to macro-economic mechanisms an at micro level to the working of some kind of Schumpeterian competition (individual entrepreneurship, emergence of new innovative companies, etc.) is internalized in Japan in the companies themselves in what appears to be both a social and economic commitment. Second, there is a more fundamental issue which relates to the degree of social acceptance of the rules of the game. It is, in our view, a crucial aspect of the definition of the relation of state, firms and social gro (and the relation of planning and market mechanisms) in the various countries considered: the greater the consensus on the basic rules of the game, the greater appears the consistency of individual (company) behaviour with a commonly accepted set of objectives. Generally, a cohesive social structure is associated with an entire set of institutions within a social hierarchy for managing shared objectives. At the same time, again not very surprisingly, planning does not need to show up in its authoritative form, but appears much more as natural harmony between social groups and between individual decisions. This apparent paradox emerges in a comparison of German and French electronics policy. If one defines planning as the conscious setting of goals, instruments, and behaviour, as opposed to the ex-post harmonization of behaviour induced by market mechanisms, then probably there has been much more planning in Germany than in France. In France, nonetheless, lower degrees of rule-sharing and target-sharing make planning more evidently an authoritati force, while in Germany it appears much more as an endogenous mechanism.

To summarize: with a European comparison in mind, Japan's electronics policies could perhaps be defined in three propositions: (a) "one country's position in the international division of labour need not be accepted but can be conquered"; (b) "what is good for the country has to be made profitable for the companies"; (c) "market competition is a positive stimulus, as long as it occurs among national companies on the domestic market or with foreign companies on foreign markets".

IV. THE FUTURE OF EUROPEAN SEMICONDUCTORS

The analysis of history, structure and past government policies in the semiconductor industry helps to define the long-run trends and the set of constraints that each company and each industry will have to face in deciding courses of action, strategies, policy targets and instruments. In other words, an attempt has been made to assess how the complex set of institutions, strategies and past policies have materialized in the present structure of the industry. This determines, so to speak, the limitation that companies and governments face in decision-making in the present and in the medium future, together with the nature of the incentives and forces that are likely to shape behaviour. Even under these limitations, however, some behavioural degrees of freedom exist.

CONSTRAINTS ON FUTURE DEVELOPMENTS

Possible future scenarios will depend on present constraints. Before some scenarios are proposed, it might be useful to summarize the important features that constitute constraints for the European semiconductor industry. These can be divided into technological conditions, structural features of the industry and policy trends.

Technological Conditions

A very rapid pace of technical change has been the main driving force in the process of growth and structural change in the industry. Moreover, as was argued above, technical change appears to follow along technological trajectories so that - so long as the rate of change remains very high - an industry which is already placed on the technological frontier is more likely to produce future advances than industries lagging behind. This factor will tend to reproduce over time a rather stable pattern of lags and leads among national industries. In the medium future, one can expect technical progress to remain as high as in the past, although somewhat more forecastable and incremental, e.g. the progress from 16K to 64K to 256K memories. Areas where major and radical breakthroughs still appear likely are superconductors, sensors, solid state magnetic memories and opto-electronics. Given these trends, one might expect the European average technological lag to remain. All this, of course, is under the ceteris paribus assumption: the discussion below will precisely concern the conditions which would allow a catching-up effort.

In recent years (the late '70s), static economies of scale increased in importance, due to increasing capital requirements and minimum R & D thresholds. This trend, which is likely to continue, will make it very difficult for new small firms to enter the industry. This barrier to entry will not apply to big conglomerate firms and one can expect the number of lateral entries to grow.

Microelectronics technology is affecting an increasing number of industrial sectors both inside the electro-mechanical industry and outside it. Today one can observe the beginning of a process that will develop extensively over the next decade.

Due to the increasingly systemic nature of semiconductor technology, linkages and interdependence between semiconductors and downstream sectors are becoming crucial. This factor also underlies the tendency towards vertical integration, both downward from semiconductors to user-sectors, and upward.

In many respects, semiconductor technology will remain the driving force of technical progress in downstream sectors. This feature, together with the above-mentioned technological interdependence, led us to argue (in Part II) that the existence of a domestic semiconductor industry represents a facilitating factor in the development of the cluster of downstream industries, although by no means a necessary or sufficient one.

Structural Features of the Industry

The semiconductor industry is, and will remain, a high growth industry. High market growth in itself allows the existence and development of a rather large number of firms. The pressures which lead towards changes in the industrial structure come from other sources. First, firms which cannot keep up with the pace of technical progress see their markets rapidly shrinking. Second, increasing financial requirements, because of higher marginal capital/output ratios, are allowing

take-overs of semiconductor firms by big and financially sound conglomerates - for instance Fairchild by Schlumberger, Zilog by Exxon and Mostek by United Technologies.

The semiconductor industry has been progressively unified in a world market. This process has two related features. First, international trade and aggressive penetration policies by the first-comers brought about, roughly speaking, a unified world price. Second, international investment forced a rapid international integration of the industry. As far as Europe is concerned, it is hard to conceive the existence of a semiconductor company purely inside one national market. It is much easier to conceive three regional markets (European, North American and Japanese) as the primary environment for the respective companies.

The technological trends outlined above, and in particular the dominant role of technical change in semiconductors and its impact on downstream sectors, are progressively disintegrating the old electro-mechanical oligopoly and permitting the slow emergence of a new electronics-based oligopoly. The semiconductor industry itself, after three decades of very rapid changes due to successive waves of Schumpeterian entries and temporary oligopolies in innovative products, appears to be heading towards a relatively more stable structure of supply.

One of the features of the industry is a somewhat dichotomous structure, between mass-market producers and specialized (custom) ones. Note that most of the discussion above has been concerned with mass-producers, under the assumption that they have a much greater impact on the competitiveness of downstream sectors, changes in the industrial structure, balance of trade, employment, etc.

The 1970s saw the Japanese attempt to catch up with US technology. In some fields they have been entirely successful (in, for example, memories) while in others they are still somewhat behind (for example, microprocessors). Over the next decade, one can expect a Japanese sharing of world technological leadership with the American industry, although the US probably will keep some lead in the most innovative and sophisticated products. One effect will probably be a wave of Japanese investment in Europe, if European governments allow it. Moreover, if the Japanese effort to conquer a major market share abroad induces a Japanese-American war in semiconductors, this will probably put a lot of strain on the much weaker European industry.

The average European technological lag vis-à-vis the US and Japan has already been mentioned. One of the consequences is the relative weakness of the European semiconductor industry. Moreover, significant divergences exist inside Europe, between Germany and Philips on the one hand an the rest of Europe on the other. In the latter, a domestic semiconductor capability is provided by (weaker) national companies (Italy and France), joint-ventures (France) or foreign subsidiaries (UK and France). (Note that Philips has implicitly been considered here as a "country". Actually it behaves to some extent as a national company in four countrie the Netherlands, Germany, the UK and France.)

The more active attitude of European companies in semiconductors in the late '70s (e.g. take-overs of American companies, joint ventures, technological agreements), togethe with the effects of existing national policies, is likely to improve their relative position, somewhat increasing (or at least stabilizing) Europe's share of world markets and slightly decreasing the average initial lag.[36]

The impact of the semiconductor industry as such on employment is negligible and that on trade balances relativel limited. However, the indirect effect of technical progress in semiconductors on employment and competitive capabilities in the related sectors appears to be quite substantial.

Policy Trends

In the discussion on the objectives and impact of industrial policies in Western Europe (Part III), the existence of a similarity among national policies was argued. Policies have often showed a rather low degree of autonomy vis-à-vis the interests and strategies of the private sector and have essentially had a reinforcing effect on already existing trends in the industry. France has been for some time a partial exception and the stalemate which emerged between the national interest and companies' strategies illustrates the difficulty of implementing strategies which represent, so to speak, the long-run interests of the gesamtkapital of a country as opposed to the more particular interests of each company. Given the institutional framework of each European country, one has to rule out as extremely unlikely some of the possible future scenarios. The most obviously excluded scenario would be a Japanese-style industrial policy, characterized by a very wide and consisten set of policy instruments, a rigorous definition of objectives and a powerful commitment of companies and states to the same targets. Moreover, since this kind of MITI-like policy would have much greater likelihood of success on a

European level, as opposed to a purely national one, it belongs more to science fiction than to practical realities.

Even after allowing for a broad similarity, significant differences in the scope and effectiveness of public intervention can be observed. Germany is placed at one end of the spectrum, with rather well-timed and broad-front policies affecting the entire filière micro-electronique (semiconductors, computers, software, applications etc.) and Britain was, until recently, at the other end, with rather specific and narrow policies (military applications, computers, the attempt to leap-frog in semiconductors with INMOS). France is attempting to develop an across-the-board policy, focussing on the subsectors where public leverage is more direct (telecommunications, military electronics) and trying to strengthen the domestic semiconductor industry through joint-ventures with American companies. Italy until recently did not have any significant intervention. The electronics plan, which is only now beginning to be implemented, looks somewhat like the German one, although there must be strong doubts about its practical outcome.

POSSIBLE SCENARIOS FOR THE FUTURE

One way to devise likely European scenarios is to vary the behaviour of two of the main actors involved, companies and governments, and to describe different combinations, together with the possible outcomes. These scenarios will have different levels of generality and will overlap to some extent. In Part II the range of possibilities open to European countries was defined. In particular, given the relative weakness and technological lag of European industry, we tried to show that options open to big integrated companies were relatively greater than for smaller ones: the former have greater research capacities and resources to finance the expensive effort of catching-up, and might be motivated by the synergetic effects between semiconductors and other in-house activities. In the European context two companies, Philips and Siemens, appear to have the financial and technological strength to be, at least to some extent, masters of their own future, while the possibility of choice appears more limited for the other European companies involved in the sector. To Siemens and Philips one could add, with much smaller degrees of freedom, Thomson and recently St. Gobain in France, GEC in the UK and perhaps the STET group in Italy (in the unlikely event that it starts performing as an integrated company and not as a holding company for a series of dispersed firms).

For the European industry as a whole we suggested that the set of options is significantly limited, the only reasonable target being survival. However, the greater the limitations on the scope of strategies that companies can pursue, the greater also is the role of government policies, which can relax the structural constraints individual companies face and/or set targets and instruments. Not surprisingly in the semiconductor industry, several of the differential features among possible scenarios relate to different policy choices. The general set of possible European policy options was briefly outlined in Part II. It must be re-emphasized that the definition of future scenarios in semiconductors has to be considered along with some electronics industry scenarios because of linkages involved.

Scenario A: A European Offensive

Suppose that we start from the actual European situation and that the following developments take place:

a) the major European companies (above all Philips and Siemens) keep increasing their commitments to semiconductors;
b) a series of European collaborations is started in the areas of major R & D projects, technological exchange, reciprocal second-sourcing, etc. (an example, still fairly limited in scope, is the Philips-Siemens collaboration); European collaborations would also mean development of significant technological, research and manufacturing agreements between major European users and producers (for instance Olivetti, St. Gobain, CII-Honeywell); one might conceive some Airbus-style agreement amongst some of the above producers on major research and manufacturing projects;
c) the present national policies continue, although more focussed on the supply-side (structure of the industry, strategic research projects) and on the relation between semiconductor and downstream sectors;
d) at the European level an effort is made to: (i) increase the degree of consistency amongst national policies (aiming at only limited duplication of research effort, some partial specialization etc.); (ii) achieve some European sharing of the R & D results obtained under national public funding;[37] (iii) use the effort towards the creation of a European telecommunications network also as a procurement tool in favour of European semiconductors; (iv) establish a European basic research fund, like Euratom; (v) intervene in electronics sectors which are under strong restructuring pressures (consumer electronics, computers). This latter is not conceived in purely defensive terms (such as protectionist barriers against Japanese TVs, etc.) but as one of the instruments to allow the European electronics industry to grow and to improve its technological level;
e) the policy of internationalization (not only inside Europe, but also overseas) by European companies gains momentum.

These developments could be roughly defined to constitute an offensive European scenario. Given the relevant set of practical and institutional constraints, this kind of strategy would be heading towards a stronger European participation in the new international electronics oligopoly based on microelectronics technology. In particular, in relation to semiconductors, it would allow not only the survival but some growth of the European-controlled industry, although certainly not world leadership.

Note that the occurrence of this scenario would be permitted by the coincidence of two factors. First, it would involve a strong commitment on the part of the companies to expansion in semiconductors and semiconductor-related sectors, together with a strong European preference in their choice of technological and manufacturing partners, commercial agreements, etc. Second, it would involve a determined volonté politique on the part of each European government to define their industrial policies inside a common philosophical framework. It is likely that, in the medium future, under any kind of reasonable scenario, most of the public funds to the electronics industry will continue to be provided by national governments to their own national companies. There is room, however, for important harmonization policies at the European level. To give an example, it appears doubtful that a policy of incentives to American and Japanese investment, like that implemented by Ireland and the UK, would be consistent with a European offensive strategy. On the other hand, it would appear necessary to introduce some monitoring of the allocation of European investments, to prevent major imbalances among countries.

The kind of scenario described above would proceed on a narrow political path, along with decision-making would continue to be mainly in national hands, but with two significant features: first, a capability of action by national governments at least partly independent of the immediate interests of national companies, and second, a commitment to some kind of concerted action with the other European governments and/or the recognition of an autonomous role of some EEC technical body.

One result of this scenario would be the disappearance of national champions in the strict sense and the tendency towards more international conglomerates, somewhat on the pattern of Olivetti-St. Gobain. Again, in terms of industrial policies, it would be a narrow path, since autonomous decisions of the private sector would have to be weighed against the need to maintain a rather balanced distribution of power and control among countries.

Scenario B: An Optimistic View of the Continuation of Present Trends

Suppose that:

a) no international co-ordination of national industrial policies becomes possible;
b) national policies continue on the present trends, mainly focussed on R & D funding, reproducing the differences in terms of targets, instruments, etc., outlined in Part III;
c) industrial strategies are primarily company-led, especially in the UK, Germany and Italy, while in France an effort is made to increase the consistency between company strategies and national goals;
d) the commitment to a gap-closing strategy by the existing European companies varies significantly; apart from Philips, which already belongs to the world's biggest producers, Siemens pursues with determination its attempt at joining the league of the world's biggest producers; SGS, too, tries hard to catch up, but from a much weaker financial position, much lower co-ordination with downstream activities and facing great uncertainties in government strategies and even in the strategies of the holding company to which it belongs; Thomson in France and GEC in the UK maintain their half-hearted attitude, on the one hand willing to increase their role in semiconductors, but, on the other, eager to minimize their risk;[38]
e) some more joint-ventures with American and Japanese companies emerge; some of these might be spontaneous and some other might be blessed by national governments, as has already happened in France for National Semiconductors - St. Gobain, Matra-Harris and Motorola-Efcis.

In this scenario, the existing companies are the main driving force, while national governments maintain a reinforcing role.

Let us have an optimistic view of the final outcome. In this case we may suppose that all the national champions survive: Siemens in Germany, INMOS in the UK, SGS in Italy and a collective championship in France, shared between Thomson (SESCOSEM and EFCIS) and the joint-venture of National Semiconductors with St. Gobain, plus the supranational champion Philips. In more detail: Siemens joins the group of major world producers; SGS survives as a rather important European company, although without any prominent international role; Thomson and, even more, GEC remain rather specialized producers in addition to sharing some manufacturing facilities with foreign companies. In the optimistic view, only some tails would be cut off (AEG-Telefunken?) and this would be more than compensated by new joint ventures and the growth of the existing companies. A European semiconductor industry would survive and even somewhat improve its performance on world markets, without however becoming a major competitor vis-à-vis American and Japanese industries. The imbalances among European countries would tend to be reproduced. Moreover, the European role in what was defined above as the international electronics oligopoly (including not only semiconductors but also the linked downstream sectors) would follow much more the pattern of already existing strengths and weaknesses amongst companies and countries.

Note that one of the possible variants in both the above scenarios is represented by the entry into electronics (and particularly into semiconductors) of big European companies trying to expand into a fast growing sector. It is difficult to assess a priori whether this kind of conglomerate entry will represent just a portfolio investment or whether it will modify the structure of supply in semiconductors and electronics in one country. It is possible, furthermore, to imagine circumstances in which money-against-technology deals (like St. Gobain - National Semiconductors) provide a country with the chance of strengthening its position despite a relative weakness of the existing companies.

Scenario C: A Pessimistic View of the Continuation of Present Trends

Most of the assumptions may remain the same as in the previous case. It is easy, however, to imagine an opposite outcome. Suppose:

a) that national policies fail to affect technological levels and manufacturing strengths of national champions;
b) that in Europe just two companies survive in the semiconductor mass-market - Philips and Siemens;
c) that all other European companies, (SGS, Thomson, INMOS, etc.) either retire into small specialized niches of the market or disappear as autonomous firms.

Such a scenario would imply some kind of polarization in Europe between a "Germany + Philips" area and the rest of Europe, where the main semiconductor manufacturing facilities would belong to joint ventures or to foreign subsidiaries.

Under this scenario, Philips and Simens would somehow represent the European champions, although with a big difference: a proper champion is generally linked, for its strategic decisions, to some political commitment with the institutions of the country of which it is a champion. In our case, these two companies would not necessarily have a European commitment in terms of allocative decisions, strategies, etc., but simply happen to be the two major European participants in an international electronics oligopoly.

The European failure supposed in this scenario would probably also have significant negative downstream effects on user-sectors, in the same way as the European offensive scenario would increase, other things being equal, European strength in related electronics sectors.

How relevant is the Semiconductor Industry?

These three hypothetical scenarios have been defined in a somewhat extreme form to highlight the different possible policies and the different likely outcomes. Actually, all three scenarios must be conceived on a continuum. All three share most of the behavioural assumptions about companies' strategies and about government policies. A difference between the first one and the other two lies in the attempt in the former to affect, through policies, the environmental conditions in which European companies operate.

Note also that each shares the assumption of a trend towards pan-electronics companies, in which semiconductor manufacturing capabilities would represent an important and technologically strategic part. Scenario A implies a greater degree of internationalization than Scenario B. In both, however, each country would participate in the big league of

major electronics producers, despite obvious differences in relative strength and despite sectoral weaknesses in each country. In both scenarios, Germany and France are likely to emerge as better off than the UK and Italy. The underlying hypothesis, then, is of a tendency towards a new micro-electronics-based international oligopoly, led by the technological convergence of different electronics subsectors and the synergetic effects provided by in-house manufacturing of components and final goods. Some arguments in support of this view were put forward in Part II. These arguments relate mainly to the untraded aspects of the mechanisms of transmission of technical change.

This trend towards a new international oligopoly will not prevent intra-electronics specialization amongst countries and regions: certainly the US and Japan will remain stronger than Europe in semiconductors as well as in computers, while Europe will maintain a relative strength (vis-à-vis the US) in consumer electronics, etc. One could on the contrary argue that: (a) a strong pattern of inter-country intra-electronics specialization will prevail, so that someone will produce the components (e.g. the Americans and the Japanese), someone else will produce the final goods, while trade and international investment will take care of the reciprocal interdependence; and that (b) the traded aspects of the transmission of technological advances (those embodied in physical products or sold through licences, patents etc.) are overwhelmingly important. This view could be described as the 'international general equilibrium' scenario. Even without discussing the theoretical foundation of this view, it is useful to recall that in the past an early lead in, and a significant vertical integration around, the elctro-mechanical technology yielded a rather stable German-American dominated oligopoly which lasted around 80 years. One can now observe the emergence of a different international structure of supply based on a new technology. In this process, the capability of successfully mastering the core of the process of technical change (i.e. semiconductors) will give a significant long-run advantage that will be only partly compensated by international specialization.

On the Likelihood of Different Scenarios

The occurrence of one scenario or the other will depend on the nature and the effectiveness of the policies discussed above. Trying to guess which scenario is most likely implies a guess as to which policy is most likely. Our views on this issue are rather pessimistic. The evidence on which this relative pessimism is based is set out below.

First, a fairly consistent European policy is unlikely. Philips and Siemens believe they are able to go it alone. Thus the German and Dutch governments have always been very sceptical about any kind of European policy. Germany has always preferred, moreover, to deal with support programmes on national levels, without any international monitoring or bargaining. This attitude was reinforced after the failure of UNIDATA. The French government has always had a somewhat schizophrenic attitude, reflecting the conflict of interests and strategies between the public planning bodies and private companies. So, for example, it always favoured some kind of European microelectronics plan (at least until it defined its own plan around 1977), but at the same time the coup d'état against UNIDATA sabotaged the only European venture. The coup d'état was carried out by pro-American interests in the French industry, supported by those French companies unwillingly involved in the venture, and by the sectors of the government nearest to the big financial-industrial groups (see Jublin and Quatrepoint, 1976). The British appear to have nothing to lose and nothing to gain, so they are much more interested in a European computer plan (for ICL) than in any comprehensive electronics intervention. The Italians are still in favour of European action but their bargaining power is very low.

Second, the effectiveness of national policies shows the limitations discussed in Part III. Probably they will succeed in allowing the survival of a nationally-controlled industry and some expansion of a domestically-based industry. The main problem is how this survival is achieved: by remaining in specialized markets or joining the big league, or by maximizing the fall-out effects of semiconductors on downstream sectors?

To summarize: the view taken here is that the most likely outcome will be somewhere between scenarios B and C. Note that the pessimism is justified in relation to what could be achieved, given the environmental constraints. An optimist could find, however, some satisfaction:

a) Philips and Siemens will participate in the international oligopoly;
b) each major European country will retain a semiconductor industry, through joint-ventures and foreign subsidiaries;
c) the increasing discussion about the need for European and/or national intervention will have some deterring effects on American companies, which may give rise to a more integrated approach in host countries - i.e. more local production, more R & D and stronger links with local industry;

d) some performance indicators for the European semiconductor industry will probably improve; the European share in world semiconductor production should improve moderately; trade balances will also probably stabilize; the achievements of slightly increasing market shares and stable trade balances is not contradictory, since European markets are forecast to grow faster than world markets.

Is all this enough? The semiconductor experience can be generalized to other high technology sectors. First, patterns of technical change appear to derive from a complex interplay between institutions and reactive market mechanisms; second there is a general correlation between technological capabilities and economic performance; third, technological progress, associated with leads and lags in the various countries, tends to yield international oligpolistic structures with uneven participation from the various countries. Market mechanisms do not seem to operate toward a convergence of technological capabilities and industrial strength as long as the rate of technical change remains very high and its nature somewhat cumulative. This should not be understood as a static vision of the world: economic structures, markets and institutional conditions keep changing and with them also the relative position of the various countries. Among the various possible set-ups, laissez faire is just one of the possible economic environments, and at least in high technologies, it appears to suit much more the winners than the late comers: it is easy to forecast that in the next few years the Japanese will tend toward a liberal ideology.

Conversely, it is symbolic that some representatives of the American semiconductor industry started advocating MITI-style collaboration between companies and government. The role of government in this picture can certainly have opposite signs: it can be, so to speak, part of the problem (the Italian experience probably belongs to this category) or it can be a strong factor affecting the structural conditions in which private industry operates (as it has been - in our view - in Japan). Policies, however, have a crucial role to play in two main areas: first, in the establishment of new technological trajectories and even major advances on the established ones (i.e. what has been called above the burden of the first comer); second, in the process of technological catching-up. In these respects the semiconductor experience finds many similarities in other existing high-technology sectors (e.g. computers) and its relevance might be tested in newly emerging technologies such as various fields of opto-electronics, super-conductors, optical fibres and bio-engineering.

LIST OF TABLES AND FIGURES

KEY TO TABLES

- : nil

.. : negligible

( ) : estimated

: a space signifies information not available

'World' in Tables 1 to 5 excludes the centrally planned economies.

N.B.: Official statistical data for semiconductors are seldom available. Many figures are therefore based on company and consulting organizations' estimates. An effort has been made whenever possible to keep the data from the various sources consistent with each other. Many discrepancies still exist, however, and one should be extremely cautious in interpreting the data as anything more than a simple indicator of the orders of magnitude. In particular:

a) estimates of markets and market shares are often downward biased by the underestimate of in-house consumption;

b) different countries give slightly different definitions of semiconductors, with respect to border-line products such as opto-electronic devices, magnetic bubble memories, and semi-finished parts;

c) Japanese figures on employment and productivity are - in my view - somewhat underestimating the former and overestimating the latter, since in multi-divisional firms activities indirectly related to semiconductor production may not be accounted for (some research and marketing activity, etc.);

d) semiconductor smuggling is a rather wide-spread phenomenon, at least in Europe (our estimates in the Italian case suggest it represents around one quarter of the Italian market). This reduces the size of recorded trade flows and of internal apparent consumption.

TABLE 1

ESTIMATES OF MAJOR WORLD SEMICONDUCTOR MARKETS 1974-80[a]

(US $ m. in current prices)

	1974	1975	1976	1977	1978	1979[b]	1980[c]
US							
Total semiconductors	2,345	1,801	2,904	3,253	3,937	5,061	6,360
of which ICs	1,236	938	1,909	2,223	2,694	3,684	4,876
Western Europe							
Total semiconductors	1,333	1,139	1,564	1,826	2,527	2,820	3,105
of which ICs	520	471	720	885	1,336	1,566	1,788
Japan							
Total semiconductors	1,171	1,126	1,866	2,008	2,331	2,714	3,044
of which ICs	593	625	862	927	1,289	1,590	1,838

Notes:

a. Figures include estimated in-house market of firms which also produce for the open market but exclude consumption of firms exclusively producing for in-house use (e.g. IBM, Western Electric).

b. Estimated.

c. Forecast.

Source:

Electronics

TABLE 2

WORLD PRODUCTION OF SEMICONDUCTORS BY REGION AND BY OWNERSHIP, 1973, 1976 AND 1978[a]

	All Semiconductors			of which ICs		
	1973	1976	1978	1973	1976	1978
Production in $m						
World total	(6,000)	(7,450)	(10,4000)	(2,700)	(3,900)	(6,000)
By region:						
(2) US	3,640	4,470	(5,800)	2,000	2,740	(3,950)
(2a) of which estimated in-house consumption	1,200	1,400				
(3) Western Europe	1,100	1,250	1,700	280	415	(660)
(4) Japan	1,280	1,500	2,500	400	660	1,330
Shares in Production (%)						
(5) World	100	100	100	100	100	100
By region:						
(6) US	61	60	56	74	70	66
(6a) of which estimated in-house consumption	20	19				
(7) Western Europe	18	17	16	10	11	11
(8) Japan	19	20	24	14	16	22
By ownership:						
(9) US-owned	71	69		79	76	
(10) W. European-owned	11	12		6	9	
(11) Japanese-owned	18	19		13	15	

Note:

a. This table excludes centrally-planned economies, includes estimated US production for in-house consumption, and includes semi-finished parts. It excludes assembly in developing countries in rows (1) to (4), but includes the latter in (9) to (11). World production (row (1)) is thus underestimated to the extent that items assembled in developing countries are not returned to the original country. The underestimate is about 10% for all semiconductors and 15% for integrated circuits. Control of developing country assembly of semiconductors is estimated to be 78% in the hands of US firms, 15% Japanese, and 5% European.

Sources:

Rows (1), (2) and (2a): Dataquest (1978), corrected for US in-house production using data from US Census and Annual Survey of Manufactures and interviews.

Row (3): Mackintosh Consultants (various years), Dataquest (1978), interviews;

Row (4): Nomura Research Institute (1980), Dataquest (1978);

Row (9) to (11): Dataquest (1978), Nomura Research Institute (1980), interviews.

Due to different estimates of in-house production and to the underestimate of LDCs assembly, production (Table 2) and markets (Table 1) do not necessarily match.

TABLE 3

EMPLOYMENT IN WORLD SEMICONDUCTOR INDUSTRY BY REGION AND OWNSERHIP, 1958-78

('000)

	1958	1963	1966	1969	1972	1973	1974	1975	1976	1977	1978
(1) World Total											(263.0)
By Region:											
(2a) US (Department of Commerce)	23.4	56.3	82.2	98.8	97.6	120.0	133.1	96.7	102.5		
(2b) US (International Trade Commission)							106.0	84.7	102.2	112.4	131.6
(3) Western Europe						69,3					(56.7)
(4) of which UK						15.2					(12.2)
(5) Germany						21.2					(16.6)
(6) France						15.2					(13.0)
(7) Italy						8.1					5.8
(8) Japan						(33.0)	33.9	31.9	33.1	32.9	33.3
By Ownership:											
(9) US-owned		58.4	90.8	165.5	173.7		202.9	150.4	175.8	185.5	(210.9)
(10) of which outside US		2.1	8.6	66.7	89.1		69.8	58.7	78.3	81.1	89.3
(11) Western European-owned											(54.8)
(12) of which outside Europe											(18.0)

Notes and Sources

Row (1) World estimates are obtained by the sum of rows (2b), (3) and (10) less the share of row (3) included in row (10) (estimated from Mackintosh (various years)) plus Far Eastern employment in European facilities (estimated at 10,000) and Japanese facilities (estimated at 15,000);

Row (2a) US Department of Commerce, Bureau of the Census, Census of Manufactures and Survey of Manufactures, various years;

Row (2b) United States International Trade Commission (1979) (data are obtained through a survey covering practically the entire statistical universe in 1978, but not in 1974 and 1975; hence discrepancy in these years between rows (2a) and (2b);

Rows (3) to (7): for 1973: unpublished data from Italian consultants; for 1978 own estimates.

Row (8): United States International Trade Commission (1979);

Row (9): 1963-72: Finan (1975); 1974-78: United States International Trade Commission (1979);

Row (11): Own estimates.

TABLE 4

VALUE OF SEMICONDUCTOR SHIPMENTS PER EMPLOYEE
FOR VARIOUS COUNTRIES, 1973 AND 1978[a]

(US $ '000 in current prices)

	1973	1978
(1) US	30	40
(2) Europe	17	30
(2a) European-owned companies	15	
(3) UK[b]	12	23
(4) Germany[b]	16	34
(5) France[b]	14	29
(6) Italy[b]	11	24
(7) Japan[c]	39	75

Notes:

a. Figures in this table represent rough orders of magnitude only. Apart from the problem of reliability of the original data, different degrees of vertical integration and product mix, together with exchange rate fluctuations, affect comparability.

b. European figures tend to be overstated due to American assembly in Europe (the added value of which is rather low while the final output is high). Estimates on some European companies suggest that output per employee (including overseas employees in LDCs) ranged in 1978 between US $ 12 and 20,000.

c. Figures are likely to be substantially overstated because of the restrictive way that semiconductor employment in conglomerate companies is estimated. Nonetheless, for 1978 at least, this does not change Japan's ranking.

Source:

Calculated from Tables 2 and 3.

TABLE 5

WORLD MARKET SHARE AND GEOGRAPHICAL DISTRIBUTION OF MARKETS
OF MAJOR WORLD SEMICONDUCTOR PRODUCERS, 1978[a]

(%)

	World Market Share	Geographical Breakdown of Sales			
		USA	Japan	Europe	Other
Texas Instruments	11	55	10	31	4
Motorola	8	62	5	25	8
Philips	7	24	4	63	9
Nippon Electric	7	8	77	4	11
Hitachi	5	6	80	2	12
National Semiconductors	5	65	5	19	11
Toshiba	5	6	70	4	20
Fairchild	5	63	3	18	15
Intel	4	59	3	27	11
Siemens	3	12	0	78	10
Others	40				
Total	100				

Note:

a. Excludes in-house production.

Source: Nomura (1980)

TABLE 6

INDICATORS OF CONCENTRATION IN THE WORLD SEMICONDUCTOR INDUSTRY, 1970-78

(% of total shipments)

	1970	1972	1974	1976	1977	1978
Semiconductors (excluding in-house production):						
largest company (Texas Instruments)	13	13	12	11	11	
4 largest companies			33	33	33	
8 largest companies			47	51	49	
Integrated Circuits (excluding in-house production):						
largest company (Texas Instruments)	17	19	15	20	19	
4 largest companies		38	37	36	36	
8 largest companies			55	57	57	
Microprocessors:						
4 largest companies						
4 [illegible]						75-80
8 [illegible]						45-50
16 [illegible]						80

Source:

Estimates based on Dataquest data published in Business Week, 19 March, 1979, plus interviews.

TABLE 7

US: INDICES OF SHIPMENTS, PRODUCTIVITY AND PRICES IN THE SEMICONDUCTOR INDUSTRY, 1958-78[a]

(1972 = 100)

	S_p	S_c	VA_{m-h}	P_{m-h}	I
1958	.5	9.3	36.8	1.8	2114.0
1963	4.6	25.4	41.5	8.1	555.6
1964	6.7	26.5	45.5	12.5	392.8
1965	11.3	33.7	47.0	17.6	298.4
1966	19.6	41.5	48.4	24.5	215.4
1967	21.9	42.2	47.5	26.1	192.7
1968	31.8	48.7	51.9	35.4	152.9
1969	49.5	58.2	52.3	43.8	117.5
1970	45.1	55.5	59.2	46.6	123.0
1971	50.0	59.1	81.2	71.8	118.2
1972	100.0	100.0	100.0	100.0	100.0
1973	158.5	134.9	107.3	120.4	85.1
1974	189.9	159.2	115.3	123.0	83.8
1975	172.3	121.2	140.8	203.3	70.3
1976	249.5	165.4	161.1	235.9	66.2
1977		(196.0)			
		(236.0)			

S_p = Shipments at constant prices

S_c = Shipments at current prices

VA_{m-h} = Value Added per man-hour of production worker (at current prices)

P_{m-h} = Productivity per man-hour of production worker (estimates)

I = Price index of semiconductor output.

Note:

a. The price and productivity indexes do not take into account the rapidly increasing complexity of the devices produced. Had this been possible, productivity would have shown a greater increase and prices a manifold greater decrease.

Sources:

Calculated on the basis of data in US Department of Commerce, Census of Manufactures, and Annual Survey of Manufactures, various years. Own elaboration for the price index and value added deflation. For the procedures, Dosi (1980).

TABLE 8

US: ESTIMATES OF MILITARY AND DIRECT GOVERNMENT DEMAND FOR SEMICONDUCTORS AND INTEGRATED CIRCUITS, 1965-1978, AND 1979 VHSI PLAN

Year	Military semiconductor: % of total production by value 1	Federal government circuits $m. 2	Federal government circuits (% of total industry shipments) 3	American Military demand (direct & indirect) as % of shipment 4	Military demand for ICs as % of total shipments 5
1955	38				
1956	36				
1957	36				
1958	39				
1959	45				
1960	48			50	
1961	39				
1962	39				100
1963	35	213.1	35.5		94
1964	28				85
1965	28	193.6	22.0		72
1966	27	254.4	24.1	30	53
1967	27	296.8	27.6		43
1968	25	273.9	23.0		37
1969		246.5	16.9		
1970		274.9	20.6		
1971		192.9	12.7		
1972		228.1	11.9	24	
1973		201.4	5.8		
1974		217.0			13.7
1975					15.0
1976					11.7
1977					12.3
1978		437.0	(11)		9.0
1979-84	VHSI Plan and related military projects: estimated £150-200m subsidies and contracts.				

Notes and Sources:

Column 1: Tilton (1971), estimated on the basis of US Department of Commerce, BDSA, Electronic Components and Related Data, and Shipments of Selected Electronic Components, various years; Electronic Industry Association, Electronic Industry Yearbook, 1969 (military uses include Department of Defence, Atomic Energy Commission, CIA, Federal Aviation Agency, National Aeronautical and Space Administration).

Columns 2 and 3: US Bureau of the Census, Current Industrial Report: Shipments of Defence-Oriented Industries, various years: except 1974 and 1978 in column 2; Electronic Times, 14 December 1978.

Column 4: 1960: Finan (1975); 1966 OECD (1968); 1972: J.P. Ferguson Associates estimates, quoted in Finan (1975). (Figures for all three years include semiconductor inputs in government purchase of military equipment.)

Column (5): See Notes and Sources for Column 1 except 1974-78: United States International Trade Commission (1979) (this source includes all government purchases).

TABLE 9

END-USERS OF SEMICONDUCTORS ON US AND WESTERN EUROPEAN MARKETS, 1978

(%)

	US	Western Europe
Computers	56	20
Consumer products	9	30 (Consumer products and Automotive combined)
Automotive	2	
Industrial	11	18
Communications	9	14
Government	13	5
Distributor	a	13
Total	100	100

Note:

a. attributed to estimated end-user

Sources:

US: Arthur D. Little, Inc.
Western Europe: SGS-Ates.

TABLE 10

MAJOR US SEMICONDUCTOR PRODUCERS, 1978

	Total Turnover ($m) 1	Semiconductor Turnover ($m) Total 2	In-house Use 3	Major Areas of Firm Specialization 4
Texas Instruments	2,550	1292	112	Semiconductors, consumer electronics, data processing.
IBM	21,076	(750)	(750)	Computers, office equipment, telecommunications.
Motorola	2,220	732	(40)	Semiconductors, consumer electronics military.
Fairchild[a]	534	389	6	Semiconductors, consumer electronics.
National Semiconductors	719	364	337	Semiconductors
Intel	400	298	(30)	Semiconductors, micro-computers.
Western Electric	41,744[c]	(200)	(200)	Telecommunications utility, telecommunications equipment.
Signetics[b]	180	180	n.a.	See Philips (Table 14) of which it is a subsidiary.
ITT	15,261 (Total of the group)	170	n.a.	Telecommunications, military, consumer electronics, diversified activities.
RCA	6,601	(130)	n.a.	Consumer electronics, household appliances, military, data processing.

Notes:

a. Taken over by Schlumberger (France) in 1979.

b. Taken over by Philips (see Table 14) in 1975.

c. Total for ATT.

Sources:

Truel (1980), p.269; Brezzi (1980), p.197; company reports; estimates of US turnover for in-house consumption, based on the report Integrated Circuit Engineering (1979) appears only to refer to in-house production within the US and not to the total for the firm.

TABLE 11

FOREIGN INVESTMENTS IN THE US SEMICONDUCTOR INDUSTRY, SELECTED YEARS 1969-79

Year				Equity Ownership (%)	Investment ($)
1969	Monolithic Memories	Northern Telecom Ltd	Canada	12.4	285,000
1971	Micropower	Daima Seikosha (Seiko)	Japan	77.0	3,385,000
1972	EXAR	Toyo Electronics	Japan	53.0	1,073,000
1975	Maruman	Mansei Kogyo Kabushiki-Kaishi	Japan	60.0	2,700,000
	Signetics	N.V. Philips	Netherlands	100.0	43,850,000
1976	Supertex	Hong Kong Interests	Hong Kong	n.a.	n.a.
	MOS technology	Commodore International-Ltd.	Bahamas	100.0	n.a.
1977	Frontier	Commodore International-Ltd.	Bahamas	100.0	10,000,000
	Intersil	Northern Telecom Ltd	Canada	24.0	10,865,629
	Interdesign	Ferranti Ltd.	United Kingdom	100.0	3,500,000
	American Micro-systems	Robert Bosch, Gmbh.	West Germany	25.0	14,230,000
	Litronix	Siemens, Gmbh.	West Germany	80.0	16,200,000
	Advanced Micro Devices	Siemens, Gmbh.	West Germany	20.0	26,723,087
	Solid State Scientific	VDO	West Germany	25.0	4,500,000
	Siliconix	Lucas	United Kingdom	24.0	6,100,000
1978	Electronic Arrays	Nippon Electric Co.	Japan	100.0	8,905,000
1979	Fairchild Camera and Instrument[a]	Schlumberger Ltd.		100.0	363,000,000

Notes:

a. Reported in Electronics News, May 1979.

Source:

United States International Trade Commission (1979), p.106, based on hearing before the Committee on Commerce, Science and Transportation, United States Senate on Governmental Policy and Innovation in the Semiconductor and Computer Industries, (95th Congress, second session). Serial No. 95-138, 1978, pp.96-97

TABLE 12

WESTERN EUROPE: PRODUCTION OF INTEGRATED CIRCUITS, BY COUNTRY, 1974-78[a]

(US $m)

Country	1974	1975	1976	1977	1978
European Economic Community:[b]					
Belgium	8	6	3	3	3
France	74	65	78	78	84
Italy	29	15	49	55	84
Netherlands	7	16	14	20	23
United Kingdom	100	100	100	118	147
West Germany	112	115	134	191	250
Subtotal	330	317	378	465	591
Other European countries:					
Austria	4	4	-	-	-
Spain	2	2	4	4	4
Sweden	3	4	5	6	7
Switzerland	4	4	25	27	40
Subtotal	13	14	34	37	51
TOTAL	343	331	412	502	642

Notes:

a. A slight divergence between this table and row (3) of Table 2 is due to different accounts for semifinished parts and European assembly of imported parts by American companies.

b. This does not include data for Luxembourg, Ireland or Denmark.

Source:

United States International Trade Commission (1979), p.119.

TABLE 13

EUROPEAN ECONOMIC COMMUNITY:
PRODUCTION, IMPORTS, EXPORTS, AND APPARENT CONSUMPTION OF INTEGRATED CIRCUITS, 1974-78[a]

Year	Production[b]	Imports	Exports	Apparent Consumption	Ratio of Exports to Production	Ratio of Imports to Apparent Consumption
	($m)				(%)	
1974	330.0	226.1	58.6	497.4	17.8	45.4
1975	313.0	183.8	72.8	424.1	23.2	43.3
1976	378.0	380.2	121.5	636.7	32.1	59.7
1977	465.0	328.5	107.5	685.9	23.1	47.9
1978[c]	(591.0)	(630.0)	(216.3)	(1,005.0)	(36.6)	(62.7)

Notes:

a. Excludes intra-Community trade.

b. Does not include data for Luxembourg, Ireland or Denmark.

c. Our elabroations on Eurostat for 1978.

Sources:

United States International Trade Commission (1979), p.123, based on Mackintosh Yearbook of West European Electronics and Eurostat, Analytical Tables of Foreign Trade, and our elbatorations on Eurostat for 1978.

TABLE 14

MAJOR WESTERN EUROPEAN-OWNED SEMICONDUCTOR PRODUCERS, 1978

Firm (country of ownership)	Location of Semiconductor Production; (* including R & D)	Company Turnover ($m) Total	SCs	ICs	Main Area of Firm Specialization: Within SCs	All firm activities
Philips[a] (Netherlands)	Netherlands*, Germany*, France*, UK*, US*, Far East	15,121 (100%)	500[b] (3.3%)	250[b] (1.7%)	ICs (linear & digital bipolar) & discrete SCs (consumer); standard & custom (in-house).	Consumer, telecommunications, professional, military, peripheral/ terminals.
Siemens (Germany)	Germany*, (France) (Italy) Far East	13,860 (100%)	300[b] (2.2%)	120[b] (0.9%)	ICs (bipolar, MOS, MPU) & discrete SCs (industrial); standard & custom (in-house)	Industrial, military, heavy electrical, telecommunications, office equipment, some consumer, data processing.
Thomson[c] (France)	France* N. Africa	5,075 (100%)	160[b] (3.1%)	25-30[b] (0.5%)	ICs (mainly discrete & analog, mainly custom) for consumer & military.	Consumer, military, telecommunications, small data processing equipment.
SGS-Ates[d] (Italy)	Italy* France, UK, Far East	120[e] (100%)	120 (100%)	(65) (54%)	ICs (analog digital bipolar) for consumer & military	Specialization of holding company (STET): telecommunications, military
AEG-Telefunken (Germany)	Germany*	6,000	150[b] (2.5%)	(50)[b] (0.8%)	Discrete SCs (& some ICs) consumer, military, industrial, custom & standard	Consumer, electrical engineering, military
GEC (UK)	UK*	4,214	30 (0.7%)		Custom SCs for military and industrial	Electrical engineering, military, consumer, industrial
Plessey (UK)	UK*	1,100[b]	20 (1.8%)	10-15	Custom SCs for military and telecommunications	Military, telecommunications
Semikron (Germany)	Germany*		40		Discrete SCs for industrial	
Ferranti (UK)	UK*		25	12	Custom ICs for military & telecommunications	Military, data processing, telecommunications

Notes:
a. Includes Signetics (US) and all European subsidiaries
b. Including in-house consumption
c. Includes SESCOSEM, SILEC (70% Thomson-owned) and EFCIS (owned 50% by Thomson, 50% by Agence Atomique)
d. Part of STET holding company
e. For STET: $3,495m

Sources:
Brezzi (1980), Truel (1980), company reports.

TABLE 15

WESTERN EUROPE: SHARES OF MAJOR FIRMS IN MAJOR NATIONAL SEMICONDUCTOR MARKETS, SELECTED YEARS

(%)

	All W. Europe	Germany			France			Italy		UK			
	1978	1968	1972	1978	1968	1972	1978	1973	1978	1962	1968	1973	1977
Philips[a]	19	25	18	15	22	16	14	7	10	49[c]	22[c]	17	18
Texas Instruments	14	16	12	13	20	12	13	15	14	13	23	18	22
Siemens	11	22	26	21				6	5				
ITT	8	10	8	7		3		7	9	2	7	13	8
Motorola	7	6	7	6	5	10	12	10	8		6	14	11
AEG-Telefunken	6	9	12	9					3				
SGS-Ates[b]	5	6	3	3	7	6	6	20	19		14	2	3
SESCOSEM	4				20	15	16	6	5				
Fairchild	3						3	13	10	e	e	4	
Intel	3						3		2				8
RCA	3						2		3			e	
National Semiconductors	2	6	14	26	26	38	4	16					5
Ferranti									12	10	5	4	1
GEC	18						28			7[d]	4		6
Other										19	19	28	18
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100
Of which US-owned firms:		36	51	43	33	55	60	n.a.	61	n.a.	53	59	64

Notes:
a. Valvo in Germany, RTC in France and, from 1968 Mullard in the UK.
b. SGS was originally established as a joint venture between Fairchild, Olivetti and Telettra.
c. Production in ASM, a joint venture of Mullard (Philips) and GEC, entirely taken over by Mullard in 1968.
d. Production in AEI, purchased by GEC in 1967.
e. Included under "other".

Sources:
For UK: Golding (1971), Sciberras (1977) and (1980); for shares of US-owned firms in other countries: 1968, Finan (1975), 1978, interviews; for other figures: Tilton (1971) and interviews.

TABLE 16

AVERAGE NATIONAL LAGS IN
FIRST COMMERCIAL PRODUCTION OF COMPONENTS,
1951-63

Country	Average lag (in years)	
	13 Innovations 1951-60 1	13 Innovations 1951-63 2
UK	1.9	2.2
Germany	2.7	2.7
France		2.8
Italy	3.8	
Japan		2.5

N.B. The sets of innovations covered in each column do not coincide, but are similar. In column 1, one innovation was first introduced in the UK (germanium rectifier), the Italian lag refers to only 9 innovations, and the German lag to only 10. In column 2, one innovation was first introduced in Japan (tunnel diode) and the American lag was one year.

Notes and Sources:

Column 1: Freeman, Harlow and Fuller (1965), p.64 (innovations previous to transistor are excluded).

Column 2: Tilton (1971), pp.25-27.

Original sources for both columns are: US Department of Commerce, Patterns and Problems of Technical Innovation in American Industry, Report to National Science Foundation, 1963; interviews by C. Freeman, T. Golding and J. Tilton.

TABLE 17

LAGS IN FIRST COMMERCIAL PRODUCTION IN WESTERN EUROPEAN[a] COMPONENT INDUSTRY BY TYPE OF PRODUCT, 1970-78

Class of products and technologies	Estimated minimum and maximum lags in years
Analog ICs	0/2[b]
Digital ICs (other than MOS)	0/3[c]
MOS ICs (incl. MPU) and memories	2/4[d]

Notes:

a. Located in Europe and European-owned.

b. Average is nearer to 0 than 2.

c. Average is nearer to 3 than 0.

d. Average is nearer to 4 than 2.

Source:

Interviews.

TABLE 18

WESTERN EUROPE: RANKING INDICATORS OF CURRENT TECHNOLOGICAL LEVELS AND COMPETITIVENESS OF NATIONALLY-OWNED ELECTRONICS INDUSTRIES[a]

	UK	Germany	France	Italy	Netherlands[d]	Sweden
Semiconductors	C/D[c]	B/C	C	B/C	A/B[e]	
Telecommunications[b]	B/C	B	A/B	C	A/B[e]	A/B
Big computers	B					
Small computers, peripherals, terminals etc.	C-	B	C+	B		
Software	A/B	B	B	C		
Office equipment	C/D	B	C	B		
Professional/medical electronics	B/C	B	B/C	D	A/B	
Industrial controls, (NCs automation, etc.)	D	B	C	B		A/B
Consumer electronics	C/D	B/C	C	D	B	
Military electronics[b]	A/B	B	A/B	B/C		

Key:

A = on the technological frontier, i.e. in a strong competitive position.
B = above the European technological average and/or in a good competitive position.
C = imitative technological capability, substantial adjustment problems, but still competitive.
D = increasing technological lag, declining competitiveness and shrinking markets.

Notes:

a. National industries are ranked from A-D in descending order of technological levels and competitiveness. The ranking is broadly impressionistic.
b. Implies a good competitive position, rather than above average technological levels.
c. Refers mainly to markets for standard components, considers Philips and ITT as foreign companies, and excludes consideration of INMOS.
d. Philips' subsidiaries in other Western European countries are considered to be Dutch.
e. To the extent that Philips is invlved in this field.

Source: own estimates.

TABLE 19

GOVERNMENT SUPPORT TO THE SEMICONDUCTOR INDUSTRY IN UK, GERMANY, FRANCE AND ITALY, 1964-82[a]

	1967 '68 '69 '70 '71 '72 '73 '74 '75 '76 '77 '78 '79 '80 '81 '82
UK	
(1) Microelectronics support scheme	£10m ($21m)
(2) Component industry scheme[b]	£5m ($10m)
(3) Microelectronics support programme[c]	est. £55m ($111m)
(4) Establishment of INMOS	£50m ($101m)
(5) Microprocessors Application Programme[d]	est. £55m ($111m)
(6) Support to microelectronics under Product and Process Development Scheme	£2.8 (1979) ($0.6m)
(7) Other[e]	annual average: £1-2m ($2-3m)
(8) Military	annual average for '70s (est.) £2-3m ($4-6m)
(9) Non-business institutions and universities	annual average for late '60s & for '70s (est.): £2-3m ($4-6m)
GERMANY[f]	
(10) BMFT (Research & Technology Ministry) support	DM84m ($23m)
(11) BMFT Electronic Component Programme[g]	DM287 ($118m); DM135m $74m
(12) 2nd & 3rd Data Processing Programmes	DM99m ($32m); n.a.
(13) Synchrotron Radiation Project	DM48m ($26m)
(14) Military and space[h]	DM100m ($33m); n.a.
(15) German Research Association[h]	DM84m ($22m) (1964-77); n.a.
FRANCE	
(16) First Plan Calcul[ij]	FF92m ($18m) (1964-70)
(17) Second Plan Calcul[ij]	FF155m ($33m)
(18) Plan Development Circuits Intégrés	FF600m ($132m)
(19) Non-business institutions & government laboratories	annual average (est.): FF155m ($10m) (1965-76); n.a.
(20) Military	n.a.
ITALY	
(21) Technological Evolution Funds a) grants b) loans	grants L600m ($1m) loans L3,00m ($m)
(22) Electronics Plan (Law 675)[km]	grants L80,000m ($96m) loans L50,000m ($60m)
(23) Military	n.a. (but limited)
(24) National Research Council project on solid state physics	n.a.

Notes:

a. Values are in national currencies, rounded with approximate equivalents in US dollars. Unless otherwise specified, figures cover grants, subsidies and transfers on capital account and mostly refer to R & D support. Regional incentives are excluded, as also (except in Italy) are low interest loans. Note that support measures to other parts of the electronics industry, which are not listed here, can represent implicit support to the semiconductor industry itself. Since only in the UK case such measures are grouped in a specific programme, the above figures tend to over-state government intervention in the UK relative to other countries. The figures in this table differ somewhat from figures to be given for the UK and Germany (Tables 20-21) as a result of different definitions of the industry and classifications of R & D projects.

b. The total Component Industry Scheme involved £20 million of which the amount shown in the table went, until mid-1978, to semiconductors.

c. Our estimate of the amount that the Conservative government is likely to retain from schemes introduced by the previous governments. The degree of overlap with row (6) is not clear.

d. There might be some overlapping between (3), (5) and (6).

e. Included under this item are funds from the Advanced Computer Technology Project of 1964.

f. The figures for Germany include R & D performed by industry and by other institutions.

g. Subsidies after 1979 are sometimes referred to as "VLSI Plans".

h. Includes expenditure on other electronic components.

i. Figures refer to total component, most of which is believed to have been attributed to semiconductors.

j. Covers grants, subsidies, and other transfers to the business sector only.

k. Proposed amounts going to total components, mostly in semiconductors (actual amounts available are believed to be somewhat lower).

Sources:

OECD (1968); Golding (1971); Treille (1973); General Technology Systems (1979); Maclean (1979); Ministero dell'Industria (1978); data from German Ministry of Research and Technology (BMFT), French and Italian Ministries of Industry; various issues of the Financial Times and Mondo Economico.

TABLE 20

UK: ELECTRONICS SUPPORT PROGRAMMES, 1969/70 to 1974/75[a]

(£m)

	1969/70	1970/1	1971/2	1972/3	1973/4	1974/5
International Computers (Holdings) Ltd. (ICL)	4.00	3.25	2.25	11.95[b]	9.45	10.20
Advanced Computer Technology Project	0.43	0.63	0.45	0.67	0.61	0.40
Software Products Scheme	-	-	-	0.03	0.06	0.15
Systems and Software Development	-	-	-	1.45	0.78	0.45
Central Computer Agency Expenditure on Development Studies	-	0.09	0.11	0.20	0.20	0.53
Other extra-mural contracts	0.44	0.36	0.23	0.17	0.14	0.17
Computer Aided Design Centre	0.45	0.49	0.42	0.67	0.97	1.32
National Computing Centre	0.60	0.64	0.60	0.77	1.06	1.15
Science Research Council	-	0.70	0.86	0.91	n.a.	n.a.
TOTAL	5.92	6.16	4.92	16.82	13.27	14.37

Notes:

a. Figures exclude regional industrial development aid and computer-related R & D expenditure in government research establishments (which is not separately identifiable).

b. Including purchase of shares: under the Industrial Expansion Act, 1968, the government paid £350,000 in 1968/69 and £3,130,000 in 1972/73 for the purchase of 3.5m £1 shares in ICL.

Source:

Grant and Shaw (1979)

TABLE 21

GERMANY: ELECTRONICS SUPPORT PROGRAMMES,

1967 - 1979

(DM m.)

1st programme 1967-70	2nd programme 1970-75	3rd programme 1976-79	
R & D Support to Hardware Manufacturers		Manufacturers	DM554.0
Min. of Economics & Finance DM112.4	Min. of Economics & Finance DM188.0	System architecture & programme languages	DM 73.0 DM 73.0
Min. of Education & Science DM128.2	Min. of Education & Science DM157.4	Data processing technology	DM 76.3
		Remote peripherals	DM 62.0
Data Processing Applications		Small systems	DM149.0
DM57	Min. of Economics & Finance DM79 for software packages	Medium & large systems	DM194.0
		Applications	DM561.6
	Min. of Education & Science DM479 for systems & development	Information systems	DM165.0
		Medical information	DM141.3
		Teaching	DM 15.5
		Computer aided design	DM 66.0
Basic Research & Special Programmes		Process control	DM 94.8
DM42	DM226.6	Tele-processing	DM 31.5
Data Processing Education		Aid to users	DM 42.0
Higher education DM43	Higher education DM757.9	Shape recognition	DM 5.5
Professional training centres DM4	Professional training centres DM162	Training	DM264.2
		Supra regional research programmes	DM 86.5
		Scientific data exchange	DM 6.0
		Regional computing centres	DM168.0
		Professional training centres	DM 3.7
		Gesellschaft für Mathematik und Datenverarbeitung	DM194.8
TOTAL DM386.6	TOTAL DM2,409.9	TOTAL	DM1,574.9

Source:

Grant and Shaw (1979)

TABLE 22

FRANCE: DATA PROCESSING SUPPORT PROGRAMMES

1966 - 1975

(frs. m)

	'66 '67 '68 '69 '70	'71 '72 '73 '74 '75 '76
	First Plan Calcul	Second Plan Calcul
Computers	411.5	910 (Computers and Peripheral Equipment)
Peripheral Equipment	90.0	
Components	91.6	155
Software	15.9	165
Specific - action	22.0	95 (Specific action, C.R.I. and IRIA Budget)
C.R.I.	9.0	
IRIA Budget	86.1	
TOTAL	726.1	1,315

Source:

J.M. Treille (1973)

TABLE 23

ITALY: PROPOSALS FOR CURRENT ELECTRONICS SUPPORT PROGRAMMES

(thousand million Lire)

Support to be provided under Law 675 for the period 1978 - 82 (provisional figures)[a]									
	R & D	First production	Research contracts	Total	R & D	First production	Total	Subsidies to rationalization and restructuring	Grand Total Law 675
Computers and Office Equipment	115	14	20	149	55	28	83	-	232
Telecommunications	100	-	-	100	100	-	100	-	200
Electronic Components	80	-	-	80	50	-	50	100-125	230-255
Consumer Electronics	b	-	b	b	b	-	b	-	-
Automation and Instruments	b	-	b	b	b	-	b	-	-
TOTAL	295	14	20	329	205	28	233	100-125	662-687
National Research Council									
Projects on informatics									25
Projects on solid-state physics									n.a.

Notes:

a. These figures were proposed by a group of independent experts and approved by the government. However, the total financial outlay under Law 675 is inconsistent with its component parts (whose sum exceeds the total). Therefore the figures can only be taken to be broad indicators of industrial requirements that will be fulfilled sooner or later by the government. Actual amounts under the finally allocated present law to computers and office equipment are not far from the figures in the above table.

b. Not quantified.

Source:

Ministero dell'Industria (1978).

TABLE 24

MAJOR JAPANESE SEMICONDUCTOR PRODUCERS, 1978

	Turnover ($m)			Major Areas of Firm Specialization	
	Total Group[a] 1	Total Parent Company 2	Semi-conductor 3	Within SCs 4	All Firm Activities 5
Nippon Electric	3,765	2,932	581	MOS, linear.	Telecommunications, computers, semiconductors.
Hitachi	12,260	7,187	450	MOS-ICs, bipolar digital memories.	Consumer electronics, industrial, computers, telecommunications.
Toshiba	9,110	5,905	386	Very diversified. Linear for consumer application, MOS, automotive applications, discretes.	Consumer electronics, industrial, data processing, telecommunications.
Matsushita Electric	10,218	7,614	232	Discretes, linear for consumer products.	Consumer electronics.
Mitsubishi Electric	4,851	4,451	197	Very diversified. MOS, memories, discrete.	Industrial electronics, consumer, data processing, telecommunications.
Tokyo Sanyo		2,520	23	Linear bipolar.	Consumer electronics.
Fujitsu	2,634	2,100	106	MOS (especially memories), digital bipolar.	Computers, telecommunications, industrial electronics, semiconductors.
Sony		1,977	11	Discretes, ICs for consumer electronics.	Consumer electronics.
Sharp		1,311	37	MOS (especially for calculators, etc.)	Consumer electronics, calculators.

Notes:

a. Consolidated.

Sources:

Nomura (1980); except column 2 figures for Tokyo Sanyo, Sony and Sharp from Brezzi (1980); columns 3 and 4 also supplemented by information from interviews.

TABLE 25

JAPAN: MITI'S PLANS FOR THE
PROMOTION OF THE DATA-PROCESSING INDUSTRY, 1972-82

(Million Yen)

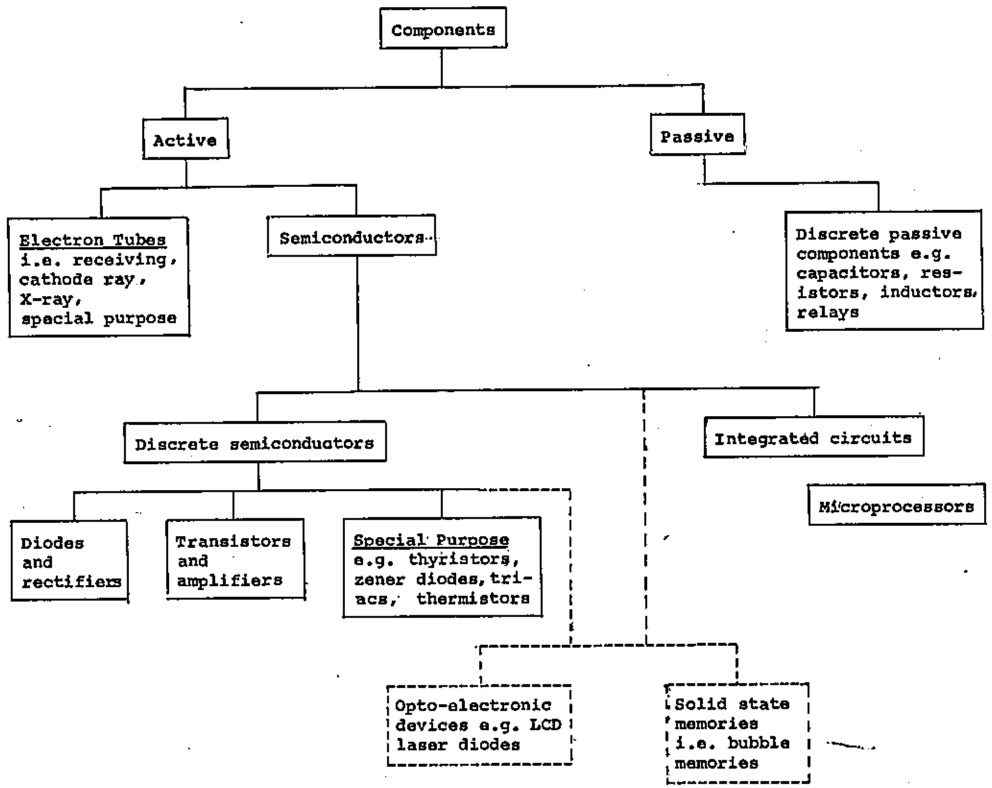
A. Programme for 1972-76					
	1972	1973	1974	1975	1976
General promotion of computer development: new machines	4,510	14,026	15,250	12,475	10,825
Peripherals	700	936	1,400	900	600
Integrated circuits	-	1,700	1,800	0	0
Measures for the industry generally	-	600	1,200	1,200	0
New generation of LSI	-	-	-	-	3,500
Loans to the NECC	2,000	1,150	3,250	4,600	4,700
Japan Development Bank grants	1,100	850	850	850	850
Information Technology Promotion Agency	37	79	100	132	123
Government guarantees to lending institutions	1,450	1,750	900	1,200	1,500
Systems development	110	205	378	1,109	1,086
B. VLSI Plan for 1976-79: estimated ¥ 30 bn.					

Sources:

A. OECD (1977); B. Nomura (1980)

FIGURE 1

A CLASSIFICATION OF ELECTRONIC COMPONENTS

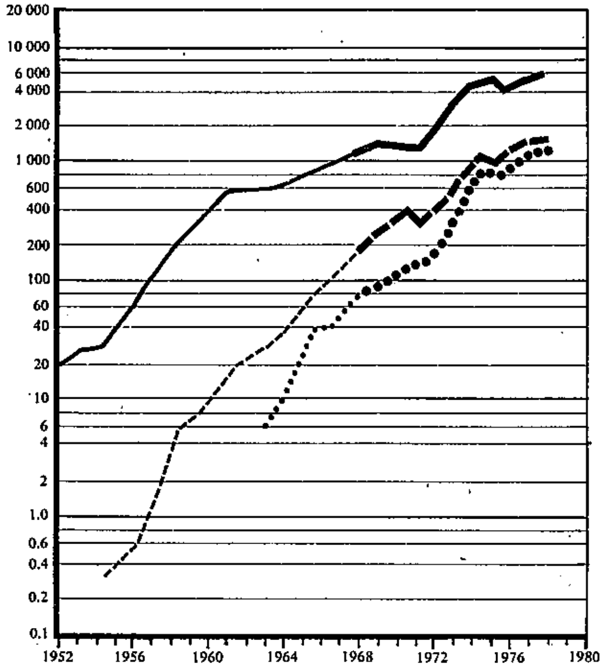


Source:
elaboration on Tilton (1971), p.8.

FIGURE 2

SEMICONDUCTOR PRODUCTION, EXPORTS AND IMPORTS

US



Note on Figure 2: The difference between 'production plus imports' and 'imports' represents domestic production and the difference between 'production plus imports' and 'exports' shows domestic apparent consumption.

Key to Figure 2:

——————— production + imports

- - - - - - - - - exports

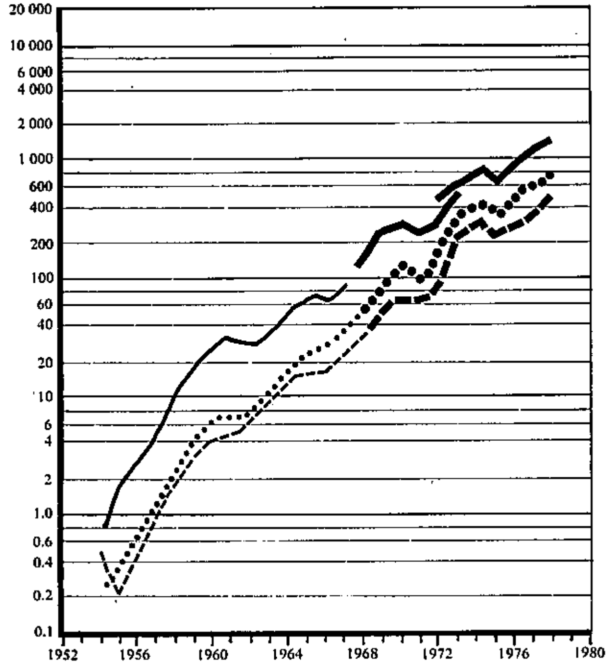
• • • • • • • • • imports

Source: Up to 1968: Tilton (1971).
From 1969: own estimates based on US Department of Commerce, US General Imports and US Exports, plus sources listed in Table 2.

FIGURE 3

SEMICONDUCTOR PRODUCTION, EXPORTS AND IMPORTS

GERMANY



Note on Figure 3: The difference between 'production plus imports' and 'imports' represents domestic production and the difference between 'production plus imports' and 'exports' shows domestic apparent consumption.

Key to Figure 3:

——————— production + imports

- - - - - - - - - exports

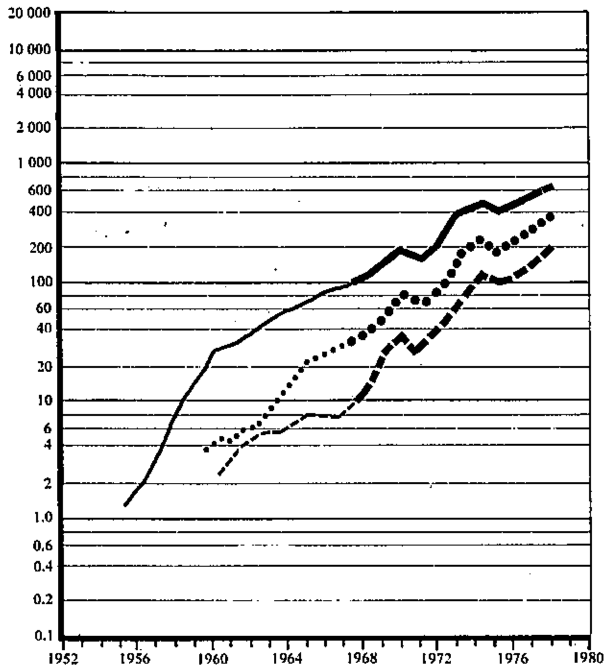
• • • • • • • • • imports

Source: Up to 1968: Tilton (1971).
From 1968 own estimates based as follows: for trade data: Eurostat Analytical Tables of Foreign Trade; for production data from 1968 to 1973: data from Bundesministerium für Forschung und Technologie; for production data from 1972 to 1978: Mackintosh Consultants.

FIGURE 4

SEMICONDUCTOR PRODUCTION, EXPORTS AND IMPORTS

UK



Note on Figure 4: The difference between 'production plus imports' and 'imports' represents domestic production and the difference between 'production plus imports' and 'exports' shows domestic apparent consumption.

Key to Figure 4:

——————— production + imports

- - - - - - - - - - exports

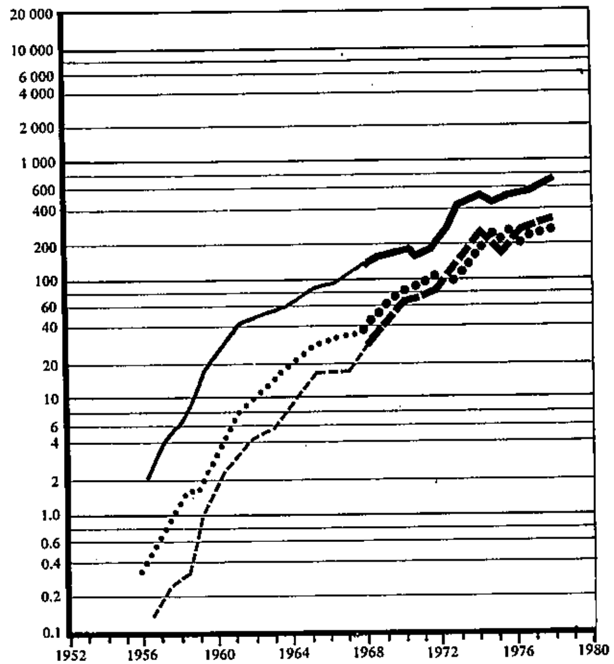
• • • • • • • • • • imports

Source: Up to 1968: Tilton (1971).
From 1968: own estimates for trade based on UK national trade statistics, company estimates, and Eurostat Analytical Tables of Foreign Trade; own estimates for production based on company data and Mackintosh Consultants.

FIGURE 5

SEMICONDUCTOR PRODUCTION, EXPORTS AND IMPORTS

FRANCE



Note on Figure 5: The difference between 'production plus imports' and 'imports' represents domestic production and the difference between 'production plus imports' and 'exports' shows domestic apparent consumption.

Key to Figure 5:

——————— production + imports

- - - - - - - - - - exports

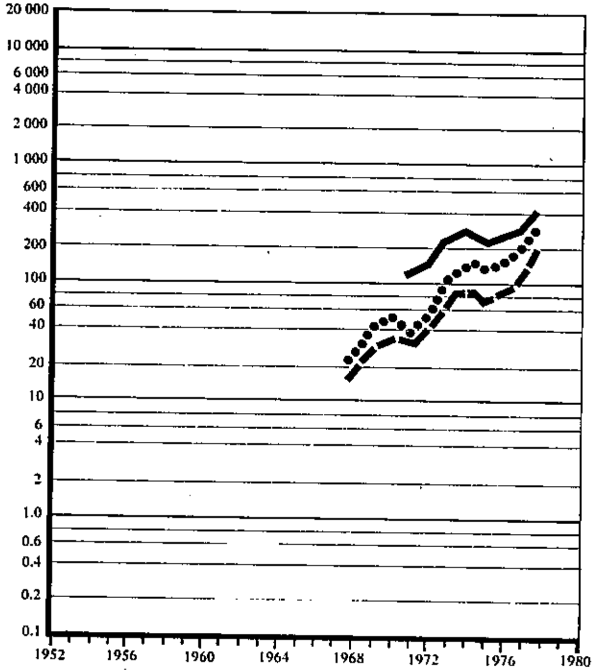
• • • • • • • • • • imports

Source: Up to 1968: Tilton (1971).
From 1968: own estimates for trade based on Eurostat Analytical Tables of Foreign Trade; for production, own estimates based on data from Ministère de l'Industrie and Mackintosh Consultants.

FIGURE 6

SEMICONDUCTOR PRODUCTION, EXPORTS AND IMPORTS

ITALY



Note on Figure 6: The difference between 'production plus imports' and 'imports' represents domestic production and the difference between 'production plus imports' and 'exports' shows domestic apparent consumption.

Key to Figure 6:

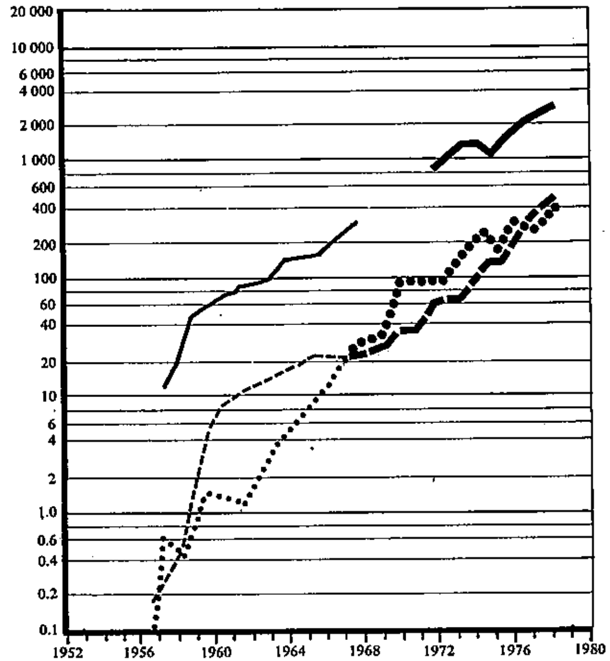
——— production + imports
- - - - exports
• • • • imports

Source: Own estimates for trade based on Eurostat Analytical Tables of Foreign Trade; for production data from Ministero dell 'Industria and Mackintosh Consultants.

FIGURE 7

SEMICONDUCTOR PRODUCTION, EXPORTS AND IMPORTS

JAPAN



Note on Figure 7: The difference between 'production plus imports' and 'imports' represents domestic production and the difference between 'production plus imports' and 'exports' shows domestic apparent consumption.

Key to Figure 7:

——— production + imports
- - - - exports
• • • • imports

Source: Up to 1968: Tilton (1971).
From 1968: own estimates based on data from MITI and Nomura Research Institute.

FIGURE 8: UK, FRANCE, GERMANY AND ITALY: MAJOR STRUCTURAL CHANGES AND GOVERNMENT INTERVENTIONS IN THE ELECTRONICS INDUSTRY, 1964-79.

Country	Year	Event
UK	1958 - 1968	Series of publicly supported mergers leads to constitution of ICL (computers) in 1968. Initial government ownership of 10.5%.
	1976-78	NEB buys shares in Ferranti (computers, semiconductors, military etc) & in various small & medium firms in software, industrial & consumer electronics.
	1978	Constitution by NEB of INMOS (VLSI memories and MPUs), entirely publicly financed.
	1980	Conservative government sells to private market ICL and Ferranti.
France	1964	Government allows Bull-General Electric merger.
	1966	Government fosters CAE-SEA merger to create CII (computers): heavily supported by public funds.
	1968	Government fosters SESCO (Thomson) COSEM (CSF) merger to create SESCOSEM (Thomson) (semiconductors) heavily supported by public funds.
	1970	EFCIS (semiconductors) created as joint venture between Thomson & Atomic Energy Commission.
	1973	Creation of UNIDATA (computers) as joint venture of CII, Siemens & Philips. Uncertain government attitude.
	1975	Failure of UNIDATA. Government supports merger of CII, Honeywell Bull.
	1978	Thomson takes over semiconductor division of SILEC and LTT
	1978-9	Government supports joint ventures of: Saint Gobain, PM/National Semiconductors, Matra/Harris, Thomson/Motorola, Saint Gobain entry into CII and Olivetti.
Germany	1970	Creation of DATEL, as joint venture of Federal Government, Siemens, AEG-Telefunken, Nixdorf (in computer applications to telecommunications, etc.).
	1973	Creation of UNIDATA (see above). Favourable government attitude.
	1975	Siemens takes over big computer division of AEG-Telefunken (with government approval).
	1978-1979	Rescue of AEG-Telefunken by a consortium of banks. Indirect support by Federal Government.
	1979-80	Plans for the establishment of a joint research laboratory between the three major firms and public agencies (Berlin Synchrotron Project).
Italy	1964	Government refuses support to Olivetti computer division, which is then sold to General Electric.
	1969-79	Expansion of state-owned companies in military and industrial electronics (SELENIA, ELSAG, etc) and industrial semiconductors (ANSALDO).
	1971	Developments in semiconductor field by ATES (state-owned). STET (IRI-owned telecommunications and electronic holding) acquires SELENIA (military & other electronics companies).
	1971	STET (IRI) takes over share in SGS.
	1972-3	Merger of SGS and ATES.
	1978	STET buys Telettra and Olivetti shares in SGS-ATES.

FOOTNOTES

1. This study draws both on primary sources (interviews and company data) and secondary sources (national and business association statistics, and marketing surveys). These sources are generally specified in the tables and footnotes. Those data obtained on a confidential basis have been properly re-arranged and their sources simply defined as "interview".

2. Productivity is defined as value added at constant price per hour of direct labour. The estimates are bound to be imprecise because of the lack of a complete set of relevant data and the unavoidable difficulty of a changing product mix. It must be noticed that the above figure does not take into account the superior performance of new products vis-à-vis old (e.g. the fact that an integrated circuit accounts for several thousands of transistors).

3. Tables 5 and 6 exclude US firms producing exclusively for in-house consumption, an estimated 30-40% of total US output. If the largest such producers (IBM and Western Electric) were ranked by size of semiconductor output (Table 5), they would appear among the world's top five.

4. On the learning curve concept see Boston Consulting Group (1973). For a discussion of learning effects in semiconductors, see Golding (1971) and Sciberras (1977).

5. A critical review of studies on innovation can be found in Rosenberg and Mowery (1979). A more policy-oriented review is found in Pavitt and Walker (1976). For a general analysis of the economics of innovation, see Freeman (1974).

6. See Nelson & Winter (1977) and Nelson (1976).

7. Source: elaborations on Tilton (1971), Golding (1971), Sciberras (1977) and Finan (1975).

8. See Freeman, Harlow and Fuller (1965), Kleiman (1977, and Braun and MacDonald (1978).

9. A notion of Western Europe's average time lags is given for the '50s to early '60s in Table 16 and for the '70s in Table 17. The most innovative and fastest-growing product in the '70s, MOS-ICs, had an average lag approaching four years, compared to average lags of well under three years for major products in the earlier period.

10. Tilton (1971), among others, argues causation in the opposite direction.

11. According to the fragmentary evidence, only Philips seems to have made profits on semiconductor production. All the other large and medium manufacturers accumulated considerable losses in the '70s. Siemens' losses decreased in recent years, till near the break-even point; SGS saw some recent slight improvement but is still in the red; SESCOSEM has had stable losses and AEG-Telefunken is still running a deficit. Some experts suggest that many of the smaller, more specialized companies, among them the IC divisions of Plessey and Ferranti, are not much better off.

12. On the worldwide oligopolistic structure of the electrical industry, see Newfarmer (1979).

13. See Business Week, December 3, 1979.

14. Ibid., p. 66.

15. A detailed discussion of these features of the semiconductor industry can be found in Truel (1980), who suggests the emergence of a cluster (filière) of micro-electronic activities.

16. See Business Week, op. cit., and United States International Trade Commission (1979).

17. See United States International Trade Commission (1979).

18. For a view supporting the efficacy of national and international market mechanisms see, inter alia, Ergas (1978).

19. See Sciberras (1980), Sciberras, Sword-Isherwood and Senker (1978), MacLean and Rush (1978), and MacLean (1979).

20. Second-sourcing is the term for customers who, seeking greater security of supply, require that a given component be manufactured by a second company. In the US this

procedure has tended to speed up the rate of diffusion of innovation. It occurred, however, among companies at similar technological levels which would probably have reproduced the device even without a second-sourcing agreement.

21. Based on interviews and Webbick (1977). The equivalent ratio for US subsidiaries in Europe is generally below 5% and is between 5% and 10% in their US parents.

22. Assembly is now becoming partially automated and being returned to the home country. Among European countries, Siemens appears to have gone furthest in this direction, partly as a result of trade union pressures to bring back some assembly from the Far East.

23. See MacLean and Rush (1978), Freeman (1977), Minc and Nora (1978).

24. See Dosi (1979 b) for a formal treatment of this problem.

25. For a discussion of the evidence see the author's longer study on semiconductors (in preparation).

26. De Gaulle reportedly became very interested in the future of the French electronics industry after the US refusal to sell a big CDC 6600 computer on which the simulations for French H-bomb testing were to be made.

27. See Finan (1975).

28. See Financial Times, 23, 24 July, 1979.

29. General Technology Systems (1979) has made an unpublished survey of these centres.

30. French Ordinateur, by Jublin and Quatrepoint (1976), provides a fascinating description of "planning" in French electronics. Public decision-making was often a compromise between CGE and Thomson, the two major electronics groups. For instance, when the establishment of CII in computers was set as a national target, the new entity was considered by CGE and Thomson (which retained formal ownership in spite of an overwhelming share of funding from the state) as an unwanted child to be sent to the orphanage as soon as possible. The stalemate was not only between the private and public sector, but within the private sector itself. Often the objective of both companies was to prevent the other from expanding in electronics, rather than to pursue its own expansion. The

story is not so different in semiconductors. CGE had already sold its semiconductor division to Philips in 1968 and Thomson was going to sell SESCO to General Electric. SESCOSEM is, at least partly, a child of the Délégation. Thomson's more solid commitment to semiconductors is fairly recent.

31. See, for example, Zysman (1974, 1975).

32. Based on interviews. Preferential loans are excluded from the German figures. It is possible that the French ratio is particularly low because government financed R & D may include low interest loans from Credit National. Even if account is taken of this, the German ratio is likely to remain higher.

33. Quoted from a memorandum of the Délégation, cited in Jublin and Quatrepoint (1976).

34. The Japan Development Bank has not played an important part in financing the semiconductor industry, but it appears to play a critical role in indicating areas of priority to the private sector.

35. Conclusive supporting evidence for our thesis on the sources of Japan's competitive strength is difficult to find. Our argument has been based both on general works on the Japanese economy and on sources that specifically treat semiconductors. On semiconductors, see Altman and Cohen (1977), Tilton (1971), EDP Industry Report (1978), and United States International Trade Commission (1979); on technology transfer, see Goode (1978).

36. In this respect one should bear in mind the remarkable role of Philips in world semiconductor markets and the relatively successful attempts of Siemens to improve its levels of technology and market penetration in semiconductors.

37 This was one of the proposals suggested during the 1976-77 discussion on the possibility of a European microelectronics plan. It had the support of the French and the Italians, but not of the Germans and the Dutch (i.e. Philips).

38. This implies a degree of specialization in custom devices plus joint ventures with American companies in the mass market. Such joint ventures are already taking place; for instance, the Thomson-Motorola and GEC-Fairchild agreements.

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The astounding developments in semiconductors, or microelectronics, an industry barely thirty years old, promise a revolution in the products we consume, in the way we produce them, and even in the way society is organized. So rapid are these developments and so specialized are many new semiconductor products in their end-uses that countries without strong semiconductor industries may increasingly find themselves at a competitive disadvantage in the broad range of industries using these products.

This study analyses the performance of the semiconductor industry in the major countries of Western Europe. It argues that market forces have not been able to close Europe's technological gap and that public policies instituted from the 1960s onwards were too partial and limited to be very effective. Even the more ambitious policies of recent years have tended overly to support "survival" rather than "catching-up" strategies. The study concludes that, if Europe is to catch up, its governments must promote far more comprehensive policies within a European framework.

Giovanni Dosi is currently completing a doctorate at Sussex University and has been a research fellow at the Sussex European Research Centre, working on problems of industrial adjustment. He has produced several studies, both in Italian and English, concerning macroeconomic topics, industrial [illegible] and the theory of technical change.

[illegible] for the Anglo-German and
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