GOVERNMENT SUPPORT OF THE EUROPEAN INFORMATION TECHNOLOGY INDUSTRY

by

M. KENDE*

96/28/EPS

* Assistant Professor of Economics at INSEAD, Boulevard de Constance, Fontainebleau 77305 Cedex, France.

Government Support of the European Information Technology Industry

by

Michael Kende*

Prepared for the CEPR/WZB Conference
"Does Europe have an Industrial Policy?,"
Berlin, April 19-20, 1996.

This paper looks first at past and current government policies supporting the European information technology industry, and then, after comparing the performance of the European industry with those of Japan and the U.S., suggests new policies for increasing the competitiveness of the European industry. In the 1960s and 1970s, the policy in Europe consisted of national governments supporting domestic national champion firms. When it became apparent that these policies were unsuccessful, the governments began supporting European-wide cooperative research on basic technology. In the meantime, while U.S. firms have shown continuing competitive strengths in all segments of information technology, and Asian firms have shown increasing strengths in all segments of hardware, European information technology firms have developed few competitive strengths. The greatest weakness of European firms is the inability to market technology; in order to reach the goal of a competitive European information technology industry, policy should focus on creating an environment in which firms, particularly start-up firms, can successfully commercialize existing and new technology.

---

* Assistant Professor of Economics at INSEAD, Boulevard de Constance, 77305 Fontainebleau Cedex, France. Email: kende@insead.fr. I would like to thank H. Landis Gabel for many informative discussions and comments on previous drafts. In addition, I would like to thank Lars-Hendrik Röller, with whom I worked on a related project. Thanks are also owed to Charles Wessner for comments on the latest draft. Fergal Byrne and Paola Patrone provided invaluable research assistance. Thanks to Tamara Lansky for editorial comments. I am grateful to INSEAD for financial assistance.

I. Introduction

European governments have had active industrial policies for supporting their information technology industries since the mid-1960s. Although the policies underwent a major shift in emphasis in the early 1980s, the basic goal of helping European firms become competitive with foreign rivals, first American and later Japanese, has not changed. It is becoming evident that current policies are still not adequate for developing a European industry competitive in the global information technology industry.

In the mid 1960s each of the major European computer-producing countries introduced policies for closing the technology gap separating their firms from U.S. rivals, particularly IBM. Each country focused on the creation of a domestic national champion firm based on the premise that scale would lead to effective competition with IBM. The governments helped create their chosen champion through mergers, subsidized the resulting firm, and purchased a large share of the firm's output. By the end of the 1970s it was becoming increasingly apparent that these policies were inadequate, since these firms continued to lag behind not only U.S. firms, but Japanese rivals as well. At this time support for the national champion policies began to wane and the focus of government policies turned to supporting European-wide research programs.

A series of European-wide research and technological development programs were established in the early 1980s. These programs focused on supporting precompetitive collaborative research efforts undertaken by European firms and universities. While these programs were effective in stimulating cooperation, particularly in standard-setting, they were not effective in advancing the competitiveness of European firms.

A comparison of the European industry with those of the United States and Asia shows that the European research programs are not adequate for helping European firms become competitive. The results of basic research projects are neither necessary nor sufficient for success in the industry. This is demonstrated by the accomplishments of Japanese firms in mainframes and even more so by the example of many U.S. and Asian firms in personal computers. If the goal of European policy is still to create a competitive European information technology industry, greater effort should be channeled into creating an environment in which firms, particularly start-up firms, can achieve commercial success with existing and new technologies.

The paper first examines two phases of European industrial policy supporting the information technology industry; section two covers the 1960s and 1970s, when individual governments were supporting domestic national champions, and section three covers the 1980s to the present, when the focus shifted to supporting collaborative research efforts at the European level. Section four compares the European information technology industry performance of the past decade with the performance of global rivals, and discusses what steps could be taken to improve the competitiveness of the European information technology industry.

II. 1960s and 1970s: National Champion Policies:

The first attempts at an industrial policy targeted at the European computer industry resulted in the creation and support of a number of national champion firms in the larger European countries. The goal was to create firms with the scale to compete with IBM. The means used to create and support these firms, namely mergers, subsidies, and procurement biases, succeeded in creating weak firms facing little competitive pressure. As a result, by the late 1970s, the European competitive position had not improved, and fears of falling further behind in technological advances led to the introduction of European-wide cooperative research programs.

Background: Early U.S. government support of computer industry.

Starting in the mid-40s, the U.S. government played an active role in the computer industry, financing R&D mainly for defense purposes, and by the mid '60s the U.S. computer industry had met overwhelming success. This had two effects on European governments' policies towards their computer industries: first, it motivated European governments to support their own domestic computer industries; and second, it provided an example of the potential effectiveness of government support for a nascent industry.

The beginnings of the U.S. computer industry may be traced back to World War II, before the commercial potential of computers was realized. At this time, the U.S. government, mainly for defense purposes, played a leading role in driving computer innovations by supporting and financing most research and development, both through companies and universities; it also purchased most of the computers that resulted from these R&D efforts. [1] It is also at this time that IBM began to benefit from U.S. government aid, albeit to the same extent as most other U.S. firms.[2] In the mid-

50s, as the commercial applications of computers began to grow, the government's role in stimulating innovations in computer technology remained strong, even though the government's relative share of R&D expenditures and purchases declined.

By the mid 1950s, U.S. companies, notably IBM, began to create a commercial market for computers by targeting business users. IBM not only led the way in product innovations, it was also one of the first computer companies to become international, ushering the way into the European market. Other companies, notably General Electric, National Cash Register, Sperry Rand, and RCA, followed with exports to Europe and licensing agreements with European companies. By 1966 American firms accounted for more than 90 percent of the sales in the European computer market. IBM alone accounted for more than 50% of the European market, with 73% in West Germany, 50% in Britain, and 74% in France.[3] At this point, Europe was already importing almost three times as much from the U.S. as it was exporting.

National Champion Policies:

The U.S. government's defense-driven support of the computer industry in the '40s and '50s was not replicated in Europe in that period. In the mid to late '60s however, the governments of Germany, France, and Great Britain began to worry about the growing gap between their domestic computer industries and the U.S. industry, and decided to implement industrial policies aimed at aiding their domestic computer industries. Each of these governments felt that it was important to have a strong domestic computer industry, and to this end wanted to help its domestic computer industry close a perceived technology gap with foreign, and above all American, competitors.[4] Each government felt that the solution was to have one large "national champion" capable of competing with IBM, and to reach this goal each encouraged the creation of a large firm through mergers and consolidations, subsidized the resulting firm's operations, and used preferential procurement policies to purchase the output of the national champions.

While many of the actions taken by the European governments in support of their computer industry were similar to those taken by the U.S. government, the goals were different, as were the results. In Europe and the U.S., domestic firms were supported with R&D subsidies and government purchases of computer equipment. However, in the U.S., the policy goal was to create cutting-edge technology for government use, mainly in defense. Commercial products, and indeed the U.S. commercial computer industry itself, were merely a by-product of this policy. In contrast, the

European policies were largely defensive; the goal was to create an industry *per se*, one composed of large firms capable of competing with the U.S. firms epitomized by IBM. Unfortunately, the European national champions, lacking competitive pressures, made poor business decisions, including sourcing technology from weak U.S. firms, and the result was that the European industry never closed the commercial gap with U.S. firms. By the end of the '70s these flaws were partly recognized, and new policies, aimed at creating new technologies in Europe, were implemented.

To better understand the issues, a closer look at the computer industry policies in France, Germany, and Great Britain is helpful. After studying these policies, the effects of the policies on the computer industries of the three countries are examined in order to understand the next phase of government support, which began in the early 1980s.

In France, the main motivation behind the government's decision to support the computer industry was the desire to achieve technological independence from foreign producers, partly due to national security concerns. Two events precipitated the government's actions. In 1964, after a financially draining attempt to independently create a supercomputer, Machines Bull sold a controlling interest to General Electric.[5] Although this raised French concerns, no action was taken by the state until two years later when the U.S. government blocked the export of a Control Data supercomputer to be used in developing France's nuclear weapons. While many authors have debated the extent to which these events affected France's decisions, the result was that in 1967 the first of a series of *Plan Calcul* was implemented to develop an independent computer industry capable of competing with IBM.[6]

Financial details of the *Plan Calcul* are given in Table 1. Within the framework of the these plans, which lasted from 1967 to 1980, the French government directed many resources towards creating and sustaining a national champion computer manufacturer. Under the first *Plan Calcul* the government merged the main French computer makers other than Bull into the Compagnie Internationale pour l'Informatique (CII). The government also undertook to subsidize CII while the company developed a line of computers; in the meantime CII distributed the computers of a U.S. company, Scientific Data Systems. The government established the Institut de Recherche d'Informatique et d'Automatisme (IRIA) to undertake basic research. Finally, Jequier claims that there was a *de facto* policy to promote sales of domestic computers.[7] In 1971, the second *Plan Calcul* was initiated, with greater aid for CII. In addition, in an attempt to enjoy even greater economies of scale, CII entered a venture known as Unidata with Philips and Siemens to market a line of IBM-compatible computers. CII withdrew when it merged with Honeywell-Bull in 1976. In the third *Plan Calcul*, the resulting firm, CII-Honeywell-Bull, received even greater subsidies from the government, and a guarantee for orders worth over 4 billion French francs.[8]

The German policy for aiding its domestic computer industry grew out of concern about the technology gap with the United States, and as a means of ensuring an indigenous industry capable of meeting the demands of German companies, hiring German engineers, and exporting to the rest of the world.[9] The technology gap was attributed to the major computer R&D commitments undertaken by the U.S. government as part of its military and space budgets. In order to address these concerns, the government implemented a series of Electronic Data Processing (EDP) plans beginning in 1967. Financial details of these plans are given in Table 1. Much of the focus of these plans was on R&D. This was meant to offset the military aid to computer R&D being given in other countries, notably the U.S.

The first EDP program lasted from 1967 to 1970. The bulk of the money was directed at industry rather than universities; mainly Siemens but also AEG-Telefunken. In an effort to create a single national champion, the government unsuccessfully encouraged a merger between AEG-Telefunken and Siemens. In the early 1970s two events took place which affected German computer policy and in particular the second EDP program, which lasted from 1971-1975: the first was the emergence of Nixdorf as a successful minicomputer producer; the second was the exit of RCA from the computer market. The emergence of Nixdorf led to a "dual champion" model, with government money being shared between Nixdorf and Siemens. RCA was an important source of mainframe technology for Siemens; RCA's exit had two effects on government policy and firm strategies. The government drastically increased spending on research in the second EDP program, particularly at the university level, in order to help German companies fill the gap left by RCA's exit. Another, somewhat contradictory effect of RCA's departure from the computer industry was that Siemens entered into the Unidata alliance with CII and Philips in order to share the cost of developing a line of computers to replace the RCA line. When Unidata collapsed Siemens turned to Fujitsu and began marketing its mainframes. The third EDP program, which lasted from 1976-1979, kept the industry subsidies at the same level as before, but reduced university support. In terms of the other main element of European national champion policies of the time, namely procurement guarantees, there is some dispute whether there was in fact procurement bias in Germany.[10]

In Britain, due to intensive wartime computer efforts, at the beginning of the '50s native computer technology was perceived to be at least equivalent to that of the United States. However, by the 1960s the decisions of British firms to largely ignore the growing business market left the industry weak. The U.S. share of the British computer market grew from zero in 1959 to 51% in 1965.[11] This drastic change in the fortunes of the British computer industry led the Minister of the newly formed Ministry of Technology to announce in 1965 that, "there should be a rapid increase in the use of computers and computer techniques in industry and commerce and there should be a flourishing computer industry [in Britain]."[12] Although there were no formal plans dedicated to the industry as in Germany and France, similar actions were taken to support the industry. Financial details are provided in Table 1.

The British government helped to create a national champion by 1968, and then favored this firm with subsidies and preferential procurement policies throughout the 1970s. The British national champion, International Computers Limited (ICL), was formed through two principal mergers; in 1967 Elliott Automation merged with the English Electric group to create English Electric Computers, and in 1968 this firm merged with part of Plessey and International Computers and Tabulators (ICT) to form ICL. The government not only helped to create ICL with financial inducements, but gave the firm a continual and increasing diet of subsidies. In addition to financial subsidies there was also a formal policy favoring government procurement of ICL computers.[13]

During the period of European national champion policies, the U.S. government's role changed, mainly due to developments in the commercial computer market. The share of government spending on R&D and computer products declined as the commercial market grew in importance; however, the role of the U.S. government in funding high-end innovations did not change. As the commercial market grew, the share of R&D spending paid for by the government fell from 75% in 1950 to 15% in the late '70s.[14] The government's share declined as companies began investing heavily in R&D; IBM alone accounted for over 40% of the total computer-related R&D expenditures in the U.S. in the 1970s. While the government's share of total R&D fell, the government share of basic research remained high, at around 60 to 75 percent in the late '70s. This implies a continued role of the government in funding innovations which advance the state of the technology. Similarly, while the government's share of computer purchases fell to around 5% in the 1970s, the share of the government in purchasing leading-edge technology in the form of supercomputers was still around 50% in the late '70s. This legacy of U.S. promotion of cutting-edge research influenced the next phase of European computer industry policy, discussed later in this paper.

Analysis:

By the end of the 1970s, the situation was not much changed from the mid 1960s; U.S. firms still had 86% of the European market and the trade deficit with the U.S. was increasing, as Figure 1 shows.

The goal of closing the technology gap with the United States, which led European countries to attempt to create domestic firms capable of competing with the likes of IBM, was not achieved The national champion policies of Europe, based on and aimed at creating scale economies, appear to have been flawed in several respects. Not only did they stem from an inaccurate evaluation of the IBM success story, but they disregarded the fundamentals of building healthy competitive strengths.

There are at least two ways of viewing the success of IBM. One way is to take a static view, that IBM's large size ensures its success, and the other, a more dynamic view, is that its success led to its large size. The European governments seem to have believed the former view. In the belief that size is a necessary, if not sufficient, condition for success, the governments focused on creating large national champion firms; in doing so they removed many competitive pressures and the resulting firms remained relatively weak. Indeed, one result was that the national champions relied on U.S. firms for technology rather than developing their own. Adherence to the latter dynamic view of IBM may have led to greater focus on developing new products rather than creating large firms. The 1980s showed conclusively that new products would provide the most successful challenge to IBM and the other traditional hardware firms.

The national champion policies did not achieve the goal of closing the technology gap as they disregarded the fundamentals of competition, resulting in firms shielded from competitive pressures: the subsidies assured the firms of a source of income; the procurement policies assured the firms of a market for their products; and finally, creating the national champions via mergers of existing domestic firms eliminated many potential competitors. Given the national government procurement bias, the natural advantages domestic firms have in their home markets, and the lack of domestic competitors, the national champions were inward-focused. Not only did these firms have relatively little incentive to increase sales outside their domestic market, but they would have been ill-prepared to compete.

In addition to eliminating potential competitors, the creation of the national champions via mergers of smaller domestic firms contributed to the firms' uncompetitiveness in two ways. The first problem was that many of these smaller firms which were merged together would probably have failed otherwise, and therefore did not make strong partners. As Jequier points out, the U.S. and European industries were similar in one respect; many early computer companies ran into difficulty. The main difference between the U.S. and European industries was that troubled firms in the U.S., including GE and RCA, left the industry, while those in Europe were merged together and subsidized, leaving the resulting firm weak.[15] The second problem with the mergers which created the national champions is that the national champion was left with incompatible product lines. This reduced the potential for enjoying economies of scale, seemingly the motivation behind the mergers, because resources could not be fully shared across the product lines.

In addition to having created firms with few competitive pressures, the European governments did not promote cutting-edge research or innovation, which were the bases upon which the U.S. industry opened the technology gap in the first basis. The U.S. government helped build the foundation for the technology gap by investing in basic research in new computer technologies and commissioning the implementation of new technologies with procurement contracts. Table 1 shows that with the exception of Germany's second EDP plan, basic research, especially at the university level, was downplayed in Europe. While the European governments did provide research subsidies to firms, and used procurement contracts to support the industry, there is little evidence that these elements of the national champion policies were meant to create new products.

In lieu of creating their own products, European firms took much of their mainframe technology from U.S. and eventually Japanese firms, in the form of licensing and resale agreements. Siemens began a licensing arrangement with RCA in 1964 to distribute RCA's computers. After RCA withdrew from the computer industry, Siemens eventually turned to Fujitsu and Hitachi for mainframe technology. In France, CII based its early computers on technology from SDS, and Bull had a series of links with RCA, then GE, and finally Honeywell. Finally, in Britain, EEC licensed technology from RCA in 1967 which ICL inherited a year later along with ICT's line of computers based on the designs of Ferranti Packard. Eventually ICL itself began reselling Fujitsu computers.

The reliance on U.S. technology led to several problems. First, there was an adverse selection problem, pointed out by Gomes-Casseres,[16] in many of these early technical alliances: the U.S. firms willing to transfer their technology in this fashion tended to be weak, and eventually they left the industry. The result of their leaving the industry pointed out the other problem of relying on other firms for vital technology; one does not develop the skills necessary for innovation and commercialization. This meant in the first place that the European firms had to turn to Japanese firms to replace the lost technology. However, perhaps more significantly, the European firms were not in a strong position to be competitive in the new products which arose in the 1980s.

The European computer industry policies of the 1960s and 1970s led to the formation and support of national champion firms: in France CII-Honeywell-Bull, in the U.K. ICL, and in Germany Siemens-Nixdorf. The ultimate goal was to close the technology gap with U.S. firms, but the inverse result was achieved - the national champion firms were weak, uncompetitive, and highly dependent on U.S. and later Japanese technology. These firms were badly positioned to successfully compete in the 1980s.

III. 1980s and 1990s: European Research Policies:

Beginning in the early 1980s, European government support for the computer industry shifted in two important ways: from support at the national level to support at the European level, and from support of specific firms to support of basic research in information technology. Despite this shift, the goals of government policy remained the same: to close the technology gap and create economies of scale in order to enable European firms to be competitive with international rivals. Though early attempts at European-wide cooperation began in the 1960s and 1970s, they failed due to the inherent conflicts with the national champion policies of the member states. In the beginning of the 1980s, as it was becoming apparent that the national champion policies were ineffective, new research initiatives in Japan and the U.S. spurred the movement towards European-level research programs, epitomized by ESPRIT.

Background: Early attempts at European-wide research programs.

The first attempts at creating European-wide science and technology programs occurred while the national champion policies were in full swing in Germany, France and the UK, a fact which did little to facilitate the success of the programs. The first Common Market initiative in science and technology was set up in 1965: PREST (*Politique de Recherche Scientifique et Technologique*) as a subcommittee of the CPEMT (*Comite de Politique Economique a Moyen Terme*), a committee of the EC. Due to EC politics, it was not until the end of the decade however that the first projects, costing about $30 million, were started.[17] PREST was followed, in 1970, by the COST committee (European Cooperation in the field of Scientific and Technical Research) which comprised nineteen Western European countries. As with PREST before it, one of the areas of focus of this research initiative was data processing. However, according to Sandholtz, "what began as an effort to devise EC science and technology policies ended up as a small, minimally funded collection of intergovernmental research agreements."[18]

The 1970s were to see several repeats of this pattern of fairly comprehensive European-wide research proposals being whittled down to more modest projects. The first of these, CREST (*Comite de la Recherche Scientifique et Technique*) was created in 1974 by the Council to be mainly responsible for coordinating national R&D policies; it had relatively little effect. In the mid to late 1970s two more projects, specifically aimed at the computer industry, were proposed and again reduced in size due to conflicts with national governments' domestic programs. The final attempt of the 1970s, the Multiannual Data-Processing Program, was approved in July 1979, with a research agenda including standardization, hardware issues, and a common programming language. However, funding for this initiative was not forthcoming, and European firms objected to their lack of input in the creation of the program.

Problems were not restricted to common market initiatives. Individual firms also had difficulty collaborating on research and development, again due to conflicts with the national champion policies which supported the firms. For example, in 1969 a European-wide consortium, Eurodata, consisting of ICL, CII, Philips, AEG-Telefunken, Saab and Olivetti, was created to bid for the ESRO (European Space Research Organization) computing requirements. This consortium fell apart due to pressure from Germany resulting from Siemens' absence from the group.[19] In 1973, the Unidata grouping of Siemens, CII, and Philips was meant to collaborate in the creation of a complete line of IBM-compatible mainframes. This group fell apart as well; France caused the rupture when it decided to pursue ties with Honeywell. In 1978 a further initiative for cooperation was undertaken by Bull, ICL, and Siemens. While this too led nowhere, it seems to have left the companies ready to collaborate under the aegis of the EC in the talks that led to the establishment of ESPRIT.[20]

EU Research and Technological Development Programs:

By the 1980s European computer companies were lagging, not only behind their American competitors but increasingly behind their Japanese competitors as well. The growing trade deficits with the U.S. and Japan are given in Figures 1 and 2, respectively. The response was a series of European-wide research and technological development (RTD) programs which supported collaboration between firms, universities, and research institutes from European countries.

The movement towards cooperative research owes itself to many factors. Shortcomings in Europe's IT industry were pointed out by the Commission's Forecasting and Assessment in the Field of Science and Technology (FAST) group, which recommended "a coordinated approach in order to derive maximum value from the scientific, technological and industrial potential of the Community countries."[21] Furthermore, there was a fear that foreign competitors were bound to be strengthened by research programs being undertaken by their respective governments; in Japan the Fifth Generation Computer program launched in 1981, and later in the U.S. the Strategic Defense Initiative (Star Wars), begun in the early 1980s.

Finally, while the first successful European-wide research program was being implemented in the early 1980s, the major impediment to previous European-wide research programs, namely the conflict with national champion policies, was disappearing. In the early 1980s, in response to the weakness of their domestic industries, the national policies of France, Germany, and Great Britain evolved from supporting national champion policies to promoting collaborative research at the national and European level. In France, the main initiative of the early '80s was the *Programme d'Action Filière Electronique*, launched by Mitterand in 1982. This ambitious plan was abandoned the next year in favor of European cooperative research programs due to financial pressures in France. In Germany, the *Informationstechnik* program was launched in 1984 to undertake R&D, with an emphasis on small firms in general and cooperation between universities and firms. Finally, in Britain, the Alvey program began in 1982 in response to Japan's Fifth Generation project; like Esprit, it sponsored cooperative R&D projects.

The first successful European-wide research program of the 1980s grew out of a series of so-called Roundtable discussions with the directors of the largest electronic companies in the EC.[22] These discussions were organized by the newly appointed Commissioner for Industry, Etienne Davignon, and they culminated in a proposal to create the European Strategic Programme for Research and

Development in Information Technology (ESPRIT). This program allowed companies, research institutes, and universities to engage in joint pre-competitive[23] research projects with funding from the Commission. The rationale for ESPRIT was given to be the following:[24]

> The glaring and inescapable fact that Western Europe has fallen behind its competitors, the USA and Japan, in the IT industry has persuaded governments and major IT companies in the Community to embark on a new, and hitherto unprecedented, venture in co-operation....
>
> The aim of the programme is to concentrate on long-term research for IT product leadership rather than catching up with foreign innovators, and so lay the basis for Community industry to be in the forefront of innovation in the 1990s rather than lagging behind. It is now slowly being recognized that the cost of such research is beyond the resources of one Community country, but that by acting together much could be achieved.
>
> Annual world sales of IT products are reckoned to be in the region of £55,000 million, with the European market accounting for one third of the £17,000 million telecommunications market, a quarter of the £35,000 million market for data processing systems and a fifth of the £3,000 million world integrated circuit market. But the European IT industry has failed to match the opportunity; only 40% of the European domestic market and 10% of the world market is held by the Community industry itself....
>
> Part of the problem is the enormous scale of U.S. and Japanese research and development investment. Backed by U.S. Government procurement and close links between the Department of Defense, industry, and the universities, America's R&D expenditure outstrips the whole of the Community's put together. The Japanese, employing effective, coordinated industrial strategies based on government-initiated industrial research, probably devote 50% more to R&D than the largest European spender. The result is that 80% of European R&D is spent in trying to catch up the US/Japanese lead.

The pilot phase of ESPRIT ran from 1983-1984, with ECU 11.5 million in EC funding granted to 38 projects. The perceived success of the pilot phase led to the launch of the first phase of ESPRIT, which ran from 1984-1988 and received a contribution of ECU 750 million from the Commission. Table 2 contains details on the focus of ESPRIT I.

In 1985 another important European research initiative, Eureka, was created. Eureka was proposed by the French in response to fears that the U.S. Strategic Defense Initiative would attract the best European scientists.[25] Eureka is similar to ESPRIT in that it acts as an umbrella for cooperative research projects between companies and research institutes from at least two participating countries. However, Eureka differs from ESPRIT in several important ways: first, companies and researchers from European countries that are not in the EC can participate; second, the research is more market-oriented than the research carried out under ESPRIT; and finally, it has no research budget of its own.[26] By March 1993, 623 projects were approved by Eureka, with budget commitments totaling 8.8 billion ECU; these projects include Prometheus, the European HDTV initiative, and JESSI (Joint European Structure on Silicon Initiative). Information technology projects make up about 25% of the money committed to Eureka.[27]

In 1987, the Single European Act (SEA) articulated several goals of the Community regarding science and technology research. One of the articles of the SEA stated that:

> The Community's aim shall be to strengthen the scientific and technological base of Europe's industry and to encourage it to become more competitive at an international level. In order to achieve this it shall encourage undertakings, including small and medium-sized undertakings, research centres and universities in their research and technological development activities; it shall support their efforts to cooperation with one another, aiming, in particular, at enabling undertakings to exploit the Community's internal market to the full, in particular through the opening-up of national public contracts, the definition of common standards and the removal of legal and fiscal barriers to that cooperation.

Other sections of the SEA laid the groundwork for the Framework Programmes, which set objectives and coordinate science and technology research in five-year plans. The Framework Programmes encompass ESPRIT and a host of other technology programs. Currently, the EU is running the Fourth Framework Programme.

Over time the stated goals of the European RTD programs began to tout collaboration as a goal itself, rather than simply as a means of increasing competitiveness.[28] The reason for this change is twofold: in several areas the success of information technology research projects depend on collaboration, and in these areas contacts made within the programs have catalyzed successful independent European collaboration.

One area where collaboration can be crucial to ensuring success is the development of standards; an area of importance for European policy. There have been several successful standards developed in ESPRIT projects.[29] In addition, several important open systems initiatives have continued outside the European RTD programs. The twelve companies comprising the Roundtable that led to ESPRIT created SPAG, the Standards Promotion and Application Group, to support the adoption of the OSI (Open Systems Interconnection) standards which enable computers from different manufacturers to communicate with one another.[30] Another group known as X-Open formed in 1985 to push the adoption of Unix as an alternative to proprietary operating systems.[31] In an effort to aid this movements, there was a commitment by the Commission and European national governments to purchase equipment conforming to open standards.

Another area where collaboration can be crucial to success is research projects which require large scale. This characterizes much research in basic components such as integrated circuits. In 1985, Siemens and Philips began a $2 billion research program called the Megaproject, to develop very large integrated circuits. This project was outside the European research projects, but co-sponsored by the German and Dutch governments. In 1989, the Megaproject gave way to JESSI, a project within Eureka. This project now includes the major European IT companies as well as the European subsidiaries of many foreign companies.

There is a growing emphasis in European programs towards helping small and medium-sized enterprises (SMEs) in high-technology fields. Title XV of the Maastricht treaty stresses that small and medium-sized undertakings should be encouraged in their RTD activities. The Fourth Framework program includes technology stimulation measures for SMEs which assist them in preparing proposals and in undertaking cooperative research. As a result, SMEs participate in a relatively high share of Esprit projects. In addition, one of the goals of the Fourth Framework program is to ensure the dissemination of RTD results to SMEs in particular; towards this end, ECU 330 million are allocated in the Fourth Framework budget for the dissemination and exploitation of results. Finally, Eureka projects also involve a relatively high percentage of SMEs.

The Fourth Framework Programme has a total budget of ECU 12.3 billion, of which almost ECU 2 billion is earmarked for information technology projects. The Fourth Framework Programme was influenced by the Maastricht Treaty, which sets out four priority areas for RTD activities: 1) RTD programs promoting cooperation between firms, research centers, and universities, 2) RTD programs promoting cooperation with third countries and international organizations, 3) Dissemination and optimization of Community-funded RTD programs, and 4) Stimulation of the training and mobility of researchers in the Community.[32]

The main European RTD program aiding the Information Technology industry is still ESPRIT; other relevant programs are dedicated to research in communications technologies.[33] Over time the focus of ESPRIT became more demand-driven; the objectives of the four phases of ESPRIT are given in Table 2. The overall objective of the latest phase is "to contribute to the healthy growth of the information infrastructure so as to improve the competitiveness of **all** industry in Europe, not just the IT industry..."[34] Towards this end there is a greater emphasis "on spreading 'best practice', fostering user-supplier collaborations, helping enterprises gain access to new technologies, making these technologies user-friendly, and training people in their use."[35] In terms of the research agenda, part of the program addresses basic technologies for the information infrastructure, including software and multimedia technologies, and the other part consists of "focused clusters," consisting of various activities with a single goal. Examples of focused clusters include one researching technologies for business processes and another working on high performance computing and networking technologies.

In spite of the expenditures and successful collaborative efforts, the European RTD programs of the past decade have not helped Europe reach the goal of "IT product leadership" which was put forth in early ESPRIT documents. During the past decade the European information technology industry performed poorly relative to the industries of the U.S. and Asia. These trends show that the European RTD programs are insufficient to increase the competitiveness of the European industry; what is needed is a greater focus on commercializing technology, both existing and new, from European sources or elsewhere.

IV. Industry trends

In spite of healthy government support, the European information technology industry has declined relative to the industries of the U.S. and Japan. The European industry is currently composed mainly of firms which provide software and services.[36] The source of most hardware is now U.S. and Asian companies. While the U.S. industry retains strengths in mainframes, many of its firms now specialize in supplying the components of distributed systems.[37] Japanese companies are strong in hardware, and firms in other Asian countries specialize in the components of distributed systems. Because Europe's software and services firms are not very competitive at the global level, and Europe purchases most of its hardware abroad, Europe has a large trade deficit with its foreign rivals. The European research policies of the last decade are not adequate to enable European firms to meet all the challenges and opportunities of the information technology industry. The greatest weakness in Europe is the inability of firms to successfully commercialize technology.

The majority of European firms currently specialize in providing software and/or services. Table 3 at the end shows the top twenty European IT suppliers in 1984 and 1994, as listed in the *Datamation* 100 worldwide rankings. Only three European-owned traditional hardware manufacturers are left on the list in 1994; the other hardware firms declined or were acquired.[38] The majority of the entrants to the list provide software and/or services. In addition, the top four traditional hardware firms increasingly specialize in software and services. Table 4 gives a comparison of the 1984 and 1994 revenue breakdowns of the top four European IT suppliers; this table shows a shift away from hardware towards software and services. The result of these changes is that Europeans purchase most hardware from American and Asian firms.[39]

The U.S. industry has strengths in the full range of hardware as well as software and services. The top twenty U.S. firms in 1984 and 1994 according to the *Datamation* 100 rankings are given in the Table 5. The majority of the entrants to the 1994 list sell components of distributed systems, the rest provide software and services. As in Europe, many traditional hardware firms declined; the remainder changed focus. Table 6 gives the revenue breakdowns of the top four U.S. hardware firms in 1994 compared with 1984. This table shows a movement away from mainframes and minis towards personal computers, and a movement away from hardware in general towards services.

Finally, Asian companies have become major suppliers of a range of hardware products. Table 7 shows the Asian firms in the top 100 worldwide firms in 1984 and 1994. In 1984 there were only six Asian firms in the top 100, all Japanese. In 1994, there were 19 Asian firms, consisting of 14 Japanese firms, three Taiwanese firms, and two South Korean firms. The Japanese companies currently focus on mainframes, personal computers and peripherals. At the same time, firms from Taiwan and South Korea are strong in parts, notably for personal computer systems, and some have recently made inroads selling their own brands of personal computers.

Europe now depends on the U.S. for almost all types of information technology products, and Asia for much hardware, leaving software and services almost as a default for European firms. The main reason for the European success lies in geographic advantages which are particularly easy to exploit in software and services. However, it should be noted that while software and services firms are successful at the European level, on a global level the firms are much less successful, relatively, and there are signs of concern for the future of the European software and service industry.

European firms have a native advantage in software and services because these areas are to a large degree language, and to some degree culture, specific. Software companies have an advantage in writing programs, custom and packaged, in their native language. The programs themselves can be targeted to local practices. Service companies also have a language advantage as well as a greater familiarity with domestic clients and their practices. It should be noted, however, that these very strengths leave the European software and services firms vulnerable.

The geographic factors which give these European software and services providers an advantage also act to limit the firms growth. There is a natural limit to the size of a company whose main strength is in serving its home market. Many of these European software and services companies derive most of their revenues from their home markets, and almost all earn almost all of their revenue from Europe. For example, Finsiel earns almost 100% of its revenues from Italy, Sligos 68% from France, and Getronics 76% from the Netherlands. Only Software AG and SAP derive less than 90% of their revenues from Europe. The result is that these companies are not very large compared with the American firms which lead the industry: Siemens Nixdorf, the largest European software provider, earns 1.7% of world software revenues, and Cap Gemini, the largest European service company, only earns 2.7% of world services revenues, ranking them tenth and eight worldwide in their respective categories.[40]

The regional focus of most of these European firms leaves them vulnerable to larger U.S. firms who can enter the European market with acquisitions and on the strength of their large scale and ability to service the global needs of multinationals. Indeed, EDS has been particularly active in Europe, purchasing SD-Scicon in 1991, and lately winning some large contracts. EDS signed billion dollar contracts with the UK Inland Revenue in 1993, the UK Department of Social Security in 1995, and the Dutch National Railway in 1995. These deals are specially noteworthy because they are with government agencies, formerly the first to favor domestic firms in Europe. In sum, the number of software and service companies in the top 20 European firms should be considered further evidence of the European weakness in hardware, which has left room on the list for relatively small, regional software and services companies.[41]

Given its reliance on foreign information technologies, Europe remains a relatively minor player in the global information technology industry. In 1984, according to McKinsey, 11% of the world market was supplied by firms from the Asia/Pacific region, 12% from Europe, and 77% from North America. In 1994 the Asia/Pacific region's share had more than doubled to 24%, mostly at the expense of North American vendors, whose share fell to 65%, while Europe's share fell slightly to 11%. The table below shows the breakdown of supply to each market:

Table 8: IT Supply Sources to Major IT Markets in 1994

	Market:		
Source:	North America	Europe	Asia/Pacific
North America	88%	64%	40%
Europe	4%	28%	2%
Asia Pacific	8%	8%	58%

Source: McKinsey, *The 1995 Report on the Computer Industry*, p. 2-13.

The table shows that of the three markets, Europe is the only one that does not even control a majority of its own market; North American vendors supply 88% of the North American market, Asian/Pacific vendors control 58% of their market, while European vendors only control 28% of their own market. This number has been steadily falling; in 1987 European firms controlled 41% of their market. Given that European firms only account for 4% of the North American market, and 2% of the Asia/Pacific market, Europe is running a large trade deficit with both areas. Indeed, in 1994, while Europe supplied 11% of world output for information technology products and services in 1994, it accounted for 29% of the worldwide demand.

European Commercialization Gap

Much of the problem in Europe is the focus on creating technology rather than commercializing it. The European RTD programs have focused predominantly on inventing new technology. This focus has ignored the potential gains that can be had from successfully commercializing existing technology. The majority of the successful hardware firms which have emerged in the past ten years have simply commercialized pre-existing technology. These firms are almost all from Asia and the United States. Even when some degree of innovation is required, a successful commercialization strategy is necessary in order to be successful.

Japanese firms have become very successful in commercializing mainframe technology. In the '60s many Japanese companies relied on the same U.S. suppliers of mainframe technology as the European firms relied on: GE, RCA, and Honeywell.[42] It follows that European and Japanese hardware producers faced a similar crisis when these U.S. sources of technology began to leave the computer industry in the 1970s. The Japanese industrial policy response to this crisis was to help these firms produce commercial products. This policy was largely successful, and firms such as Hitachi and Fujitsu became world-class suppliers of mainframes.[43] Hitachi and Fujitsu developed IBM-compatible mainframes; in this sense, the technology they commercialized was existing rather than new technology.

In the meantime, just as there had been relatively little concern about European firms relying on U.S. firms for mainframe technology in the 1960s and 1970s, there was little European effort to replace U.S. sources by commercializing mainframe technology domestically. Instead, every major European firm simply began distributing Japanese computers: Siemens sells Fujitsu mainframes, Comparex sells Hitachi mainframes, Olivetti sells both Toshiba and Hitachi computers, and Bull sells NEC computers. Before being acquired, ICL sold Fujitsu mainframes, and both Nixdorf and Nokia sold Hitachi computers. This pattern is repeated in most types of hardware.

Europe currently has few successful personal computer producers. Success in personal computers requires a winning commercialization strategy rather than intensive R&D. Even the first U.S. companies to sell personal computers were able to draw from existing technology sources. Currently, IBM-compatible personal computers can be assembled from readily available parts. Nevertheless, no European firm has matched the success of American firms or Asian firms at entering this business.

Many U.S. firms have moved into the list of the top 20 U.S. firms by successfully commercializing existing personal computer technology. Perhaps most famously, Apple Computer began producing personal computers in a garage, and soon became very successful with its Macintosh, which was largely a commercialization of Xerox' personal computer innovations. IBM's first personal computer, which became the standard with the largest share of the PC business, was designed relatively quickly using many existing components from other companies.[44] Compaq was the first to sell an IBM-compatible computer; the U.S. industry is now populated with such firms. Demonstrating the potential of these markets, both Compaq and Apple now each earn more revenues from selling personal computers than the total IT revenues of any European firm, and there are four IBM-compatible PC manufacturers among the top 20 U.S. companies.

Asian firms have also been successful in the personal computer market. Japanese firms, notably NEC and Toshiba, are major personal computer vendors, and Taiwanese firms are major PC components vendors. Taiwanese firms also supply finished computers to firms such as Apple, IBM, Hitachi, Siemens, and ICL. Almost inevitably, these firms are beginning to sell their own computers, led by Acer. The success of these companies demonstrates that competing in the personal computer business does not require creating new technology: "The Americans bring Taiwanese suppliers into their inner sanctum, brief them on plans for the next generation of products, and give them the necessary specifications. As a result, Taiwanese companies obtain technology with very limited investment in R&D. They just improve existing designs and make them commercially viable."[45]

In contrast, many European firms have tried and failed to become strong in the competitive personal computer business. There is no single reason explaining the pattern of failures. Many firms have simply not succeeded in expanding beyond their domestic market, but even those that have did not succeed for long. The immediate problem seems to be the lack of a successful commercialization strategy.[46] The more fundamental problem is that start-up companies seem to be particularly well suited to succeed in this fast-paced segment of the industry, as demonstrated by U.S. PC companies; in Europe there is a lack of both a strong entrepreneurial culture as well as the infrastructure for supporting start-up companies. The result is that only three European firms are among the top ten PC suppliers to the European market, and the largest, Olivetti, only supplies five percent of the market.[47]

European RTD programs such as ESPRIT which support precompetitive research in information technology can do little to help European firms become successful in personal computers because the technology already exists, and is embodied in established standards. These policies could help firms develop the technologies that underlie the standards of the future. However, turning a promising technology into a new standard also requires a successful commercialization strategy. The history of RISC technology illustrates the lesson that technology is only a necessary condition for success in the IT industry.[48] While several small U.S. firms successfully commercialized their RISC technologies, two European companies failed with their own technologically advanced versions.

The U.S. industry history with RISC technology shows that commercialization is as important as technology innovation. RISC technology was invented at IBM in the late 1960s, but IBM did not introduce a computer using this technology until 1986.[49] In the meantime, researchers at Berkeley and Stanford began working on RISC technology in the early 1980s and eventually left to help Sun and Mips create the first successful RISC workstations. Mips and Sun battled for years to establish their respective RISC technology as the industry standard, using a variety of strategies including liberal licensing arrangements. Both companies were successful; while Mips was eventually purchased by Silicon Graphics, Sun holds the 17th position on the 1994 Datamation 100 list, making it almost as large as the largest European IT companies.

In the meantime, the RISC technologies of two small European firms, Inmos and Acorn, languished because neither had a successful commercialization strategy.[50] Inmos was born in 1978 with monetary support from Britain's National Enterprise Board, and was later sold to Thorn EMI in 1984 as part of the Conservative government's privatization drive. In 1985 Inmos introduced the Transputer, which embodied a RISC processor, memory, and communications in a single chip. This processor is ideal for parallel computing, and an early use of the Transputer was in a supercomputer developed in the ESPRIT Supernode project.[51] While several companies used the Transputer in products offering quantum price/performance improvements,[52] it never developed the software support critical for mass acceptance. One factor hindering its success was the lack of a second source of the chips, which would have reassured computer manufacturers of both the longevity of the chip supply as well as inducing competition. Thorn EMI, better known in entertainment and consumer electronics, may not have been the ideal corporate parent, and in 1989 Inmos was sold to SGS-Thomson, the French-Italian chipmaker. At this point it may already have been too late for Inmos, as processors from several U.S. firms including Intel had caught up with the Transputer in power, and surpassed the Transputer in sales.

Recently a small European firm, Advanced RISC Machines, Ltd. (ARM), has had some commercial success with its RISC processor. However, the history of ARM is as much a confirmation of the typical European pattern as it is a contradiction. The ARM chip was developed by Acorn Computers, which has been 80% owned by Olivetti since 1985. This chip was smaller and more efficient than the other chips in the market, and therefore ideal for many portable computer applications. The chip had little commercial success until 1990, when Apple became interested in using the chip for its Newton Personal Digital Assistant.[53] As a result, ARM was spun out of Acorn, and Apple purchased 43% of the new company. It was only at this point that ARM implemented its successful commercialization strategy, which includes allying itself with leading firms worldwide, a strategy more commonly used by U.S. firms. Until Apple intervened, Acorn and Olivetti were following the typical European pattern of allowing innovative technology to languish, while Olivetti at least was turning to the U.S. for RISC technology.[54]

The European policy focus on technology research is insufficient to help the European industry increase competitiveness, especially in hardware. The examples of the Japanese mainframe producers, and U.S. personal computer producers, show how firms can be built by successfully commercializing existing technology. While new technologies are always needed to become the backbone of future standards, a successful commercialization strategy is still needed to translate the technology into revenues.

Information Technology Industry Policies for the Future

In this section I examine the role that governments could play in aiding the European information technology industry. Before addressing this question one needs to be clear about the goal of the policies. One goal could be to simply increase the competitiveness of all European industries. In this case the RTD programs may be appropriate, combined with any liberalization needed to increase competition. Another goal could be to increase the competitiveness of the European information technology industry, if only for the accompanying jobs and revenues. In this case, the current European RTD policy is insufficient. What is needed are policies for helping firms commercialize technology regardless of the source or vintage.

If the current ESPRIT objective of helping to improve the competitiveness of all industry in Europe is the only broader European objective concerning the IT industry, policy should focus on the usage of information technology, rather than the source of the technology. In this case, the current ESPRIT emphasis on the information infrastructure is appropriate. Measures outside of the European RTD programs should focus on liberalizing markets where needed so that European end-users have early access to the latest technology at competitive prices from any source.

If on the other hand, the broader European objective is to increase the competitiveness of the European IT industry, the European RTD programs alone are unlikely to meet this goal. New technology is neither necessary nor sufficient for success in the industry. When new technology is necessary, the RTD programs could provide useful results. However, European firms are no longer sure to be the only ones to benefit from the results of the RTD programs, given the globalization of the industry.

The increasing globalization of the information technology industry has affected both the feasibility and rationale of the European RTD programs. While U.S. companies have had a local presence in many foreign markets since the 1950s, recently the industry has become much more international due to a wave of mergers, acquisitions, and strategic alliances between companies from all major production areas. This has two profound effects on the European RTD policies. First, the feasibility of aiding the European IT industry is in question as European firms are bought by or ally themselves with foreign firms. Second, this internationalization of the industry somewhat undermines the rationale of programs such as ESPRIT because these links enable European firms to utilize technologies from their foreign partners.

A two-way flow of technology between European firms and foreign ones has emerged through a series of acquisitions and alliances. Many European firms have been purchased in part or whole by foreign companies, which led to relatively heated debates about who should be allowed to participate in the European RTD programs; currently, foreign-owned companies carrying out research in Europe are eligible to participate in these programs.[55] The above pattern of global purchasing is not a one-way street, however; European firms are also active in purchasing abroad.[56] This shows that European firms have access to foreign sources of technology, making programs such as ESPRIT less important as a means of keeping the European industry competitive.[57] Finally, there has been a wave of strategic alliances involving the global industry, many of which are in the same spirit as the collaborative research efforts pioneered in ESPRIT. Similar to the mergers and acquisitions discussed above, these alliances further increase the two-way flow of ideas on a global basis.

The increasing globalization of the computer industry ultimately undermines both the feasibility and necessity of European RTD programs. While the globalization makes it harder to help European firms without helping their foreign partners, it also strengthens the research base of the European firms so that programs such as ESPRIT may be less necessary.

In order to increase the competitiveness of the European IT industry, attention should be paid to helping start-up firms commercialize existing and new technology. Experience has shown that many large established firms are not as well suited to commercializing information technology as start-up firms.[58] Experience has also shown that small start-up firms in the U.S. are very good at commercializing information technology, while the environment in Europe is not well suited to breed these firms. The difference between the United States and Europe which explains the greater success that U.S. start-up firms have experienced in commercializing technology is the greater entrepreneurial spirit in the U.S., backed by the infrastructure needed to nurture start-up firms. It is difficult to quantify the difference in entrepreneurial spirit, but many commentators have noted that few Europeans are willing to take the risk to start new ventures, partly due to the stigma attached to failure.[59] What is easier to show is that Europe is lacking the infrastructure available in the U.S. to support computer start-up firms.

Many start-up firms depend on venture capital for initial funding. While Europe has a sizable pool of venture capital, less of it is available as seed capital for new ventures. According to *Business Week*, in the last five years 7% of European venture capital was invested as seed money versus 24% in the U.S.[60] Several government programs are available to help offset this, including the European Commission's "European Seed Capital Fund Scheme," and in the U.K. the Small Firms Merit Awards for Research and Technology (SMART), but they offer relatively limited funds.[61]

Another advantage available to U.S. startup firms is mature stock markets, notably NASDAQ, which help young firms raise additional money through initial public offerings (IPOs). Aiding firms with their IPOs is a large group of technically sophisticated analysts and investors who are experienced at valuing high-tech companies and interested in investing in them. European stock markets are less enticing to European high-tech startup firms, forcing many of them to list their shares in the U.S., and even move to the U.S. One reason is that investors and analysts are less familiar with high-technology stocks. One problem is that European investors prefer dividends to capital gains, while startup firms prefer to reinvest earnings to fuel future growth.[62]

The final advantage that many U.S. startup firms have over their European counterparts is that they can locate themselves in Silicon Valley or to a lesser degree other regions of the country where there is a high concentration of similar firms. The advantages that an area like Silicon Valley brings are: a highly mobile skilled labor force, proximity to at least one major university, and a network of local specialized suppliers and venture capitalists. There are several areas in Europe which have attempted to duplicate Silicon Valley, notably Sophia Antipolis in France, Silicon Glen in Scotland, Cambridge Science Park in the UK, and the Wissenschaftsstadt Ulm in Germany. While these areas all have succeeded in attracting a concentration of international high-tech firms due to a combination of financial incentives, proximity to a university, and a good technical infrastructure, they have not succeeded in breeding a generation of European high-tech startup firms competitive even in existing computer segments. It is probable that this deficiency will remain until there are more entrepreneurs, and the supply-side problems of seed capital availability and the lack of a capital market for high-tech startups have been solved.

There are several areas which should be addressed to increase European start-up firms ability to commercialize technology. The overriding principle should be to create an environment in which entrepreneurs can flourish. In order to address the problem of insufficient venture capital for start-ups, the effectiveness of existing programs for giving grants to start-up firms should be studied, and perhaps these programs should be enlarged. The upcoming EASDAQ market, modeled on the U.S. NASDAQ market, should increase the number of European high-tech IPOs and increase investors' interest. One step that governments may take to increase investment is lower capital gains taxes to help convince investors to forego dividends. Finally, the European "Silicon Valleys" should be studied in order to determine whether there are actions which can make them more effective in hosting new firms as well as existing firms. Until European firms are better at commercializing technology, the results of the European RTD programs will be insufficient for increasing the competitiveness of the European information technology industry.

V. Conclusion:

Since the mid-1960s European governments have aimed a series of largely unsuccessful industrial policies at helping the European IT industry become competitive with the industries of the U.S. and Japan. In the 1960s and 1970s, the policy in Europe consisted of national governments supporting domestic national champion firms. When it became apparent that these policies were unsuccessful, the focus of government policy switched to supporting European-wide cooperative research on basic technology. Recent changes in the information technology industry have shown that these new policies are also insufficient for creating a European IT industry capable of competing at a global level.

In the past decade, U.S. firms have shown competitive strengths in all segments of information technology, and Asian firms have increased strength in all segments of hardware, while European firms are left specializing in software and services. What is notable in the industry is that many if not most firms in the industry become successful by commercializing existing technology, as has been shown for hardware ranging from mainframes to personal computers. Firms wishing to commercialize existing technology do not need the European RTD programs to become successful. Even when new technology with great potential is invented, there is still no guarantee of success. In order to reach the goal of a competitive European information technology industry, policy must focus on helping firms commercialize technology.

Table 1: Subsidy Breakdown of European National Champion Policies

Country	Program	Industry	Education and Research	Total
France[1]	1st Plan Calcul (1967-1970)	640	876	2546
	2nd Plan Calcul (1971-1975)	1030		
	3rd Plan Calcul (1976-1980)	1438	0	1438
Germany[2]	1st EDP Program (1967-1970)	298	89	387
	2nd EDP program (1971-1975)	1263	1147	2410
	3rd EDP program (1976-1979)	1116	459	1575
Great Britain[3]	1969-1973	33.8	13.31	47.1
	1974-1979	175-180	55-65	230-245

Source: Kenneth Flamm, *Targeting the Computer*, p. 153.
[1]Millions of francs
[2]Millions of German marks
[3]Millions of pounds

Table 2: Description of ESPRIT I-IV.

Program	Years	EU Budget	Program Areas
ESPRIT I	1984-1988	750 MECU	•Microelectronics •Software Technologies •Advanced Information Projects •Office Systems •Computer Integrated Manufacture (CIM)
ESPRIT II	1988-1992	1,600 MECU	•Microelectronics •IT Processing Systems •Applications Technologies
ESPRIT III	1990-1994	1,350 MECU	•Microelectronics •Advanced Business and Home Systems Peripherals •High-Performance Computing and Networking •Technology for Software Intensive Systems •CIM and Engineering (CIME) •Open Microprocessor Systems •Basic Research
ESPRIT IV	1994-1998	1,932 MECU	•Software Technologies •Technologies for Components & Subsystems •Multimedia Technologies •Technologies for Business Practices •Integration in Manufacturing •High Performance Computing and Networking •Open Microprocessor Initiative •Long Term Research

Source: ESPRIT I-III, Stubbs and Saviotti, "Science and Technology Policy."
ESPRIT IV, About the ESPRIT Programme, World Wide Web site:
http://www2.cordis.lu/esprit/src/about.htm.

Figure 1: European Computer Equipment Trade with U.S.

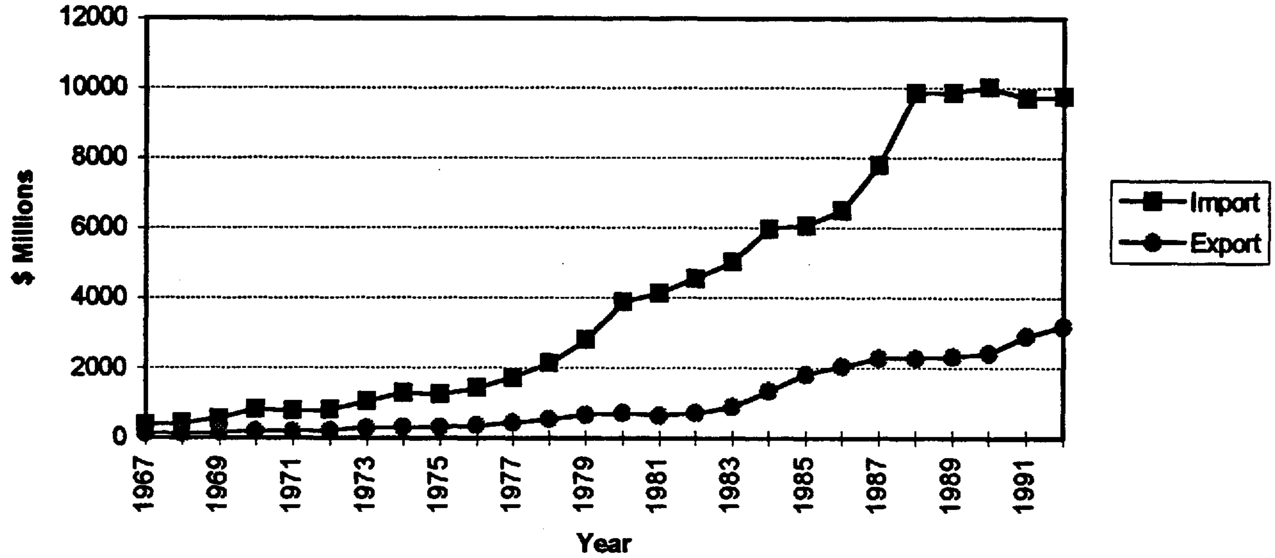
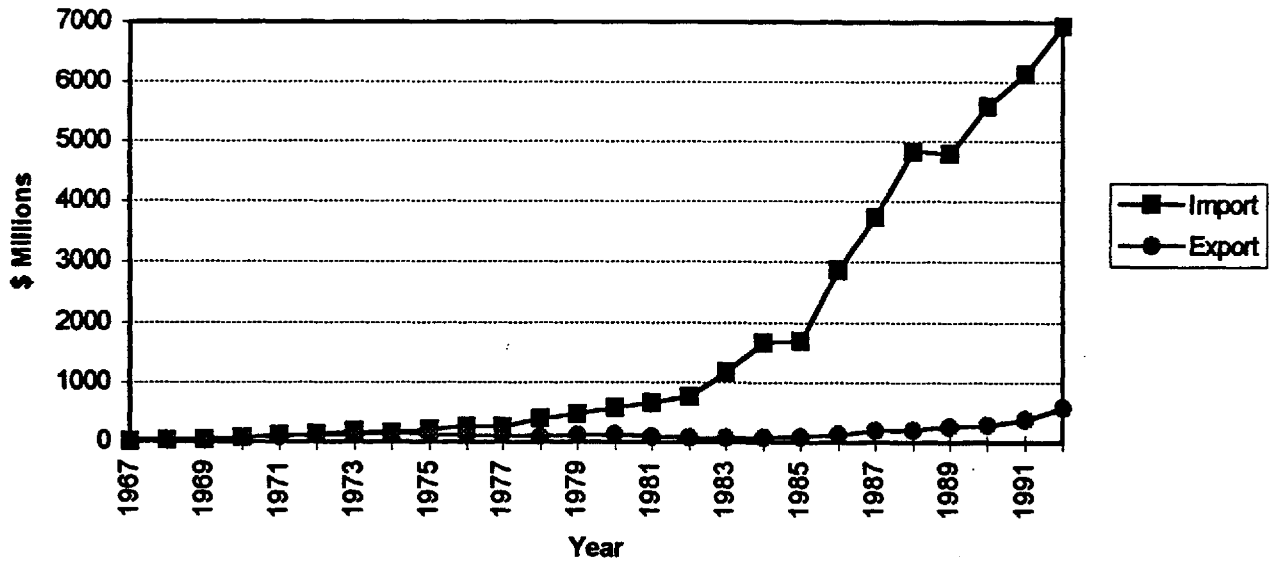


Figure 2: European Computer Equipment Trade with Japan



Source: CHELEM, Bureau van Dijk, 1994.

Table 3: Top 20 European IT Firms in 1984 and 1994.

Top European Firms - 1984			Top European Firms - 1994		
World Rank	Company	Major Product[63]	World Rank	Company	Major Product
10	Siemens AG	H/W (Mainframe)	12	Siemens Nixdorf	H/W (PC)
13	Ing. C. Olivetti	H/W (Mini)	16	Groupe Bull	H/W (PC)
16	Groupe Bull	H/W (Mainframe)	18	Olivetti	H/W (PC)
20	ICL	H/W (Mainframe)	**	ICL	Services
21	Nixdorf	H/W (Mini)	28	Cap Gemini Sogeti	Services
24	LM Ericsson	Datacom	56	Alcatel Alsthom	Datacom
26	N.V. Philips	H/W (Mini)	58	SAP	Software
42	Triumph Adler AG	Peripherals	65	Finsiel	Services
51	Racal Electronics	Datacom	68	Sema Group	Services
59	Thorn EMI PLC	Software	72	LM Ericsson	Datacom
60	Mannesmann Kienzle	H/W (Mini)	78	British Telecom	Datacom
63	BASF	H/W (Mainframe)	***	Sligos	Services
64	Plessey Co. PLC	Telecom	81	Comparex	H/W (Mainframe)
69	Ferranti PLC	Hardware	84	Racal	Datacom
*	Rank Xerox	Peripherals	90	Software AG	Software
82	Cap Gemini Sogeti	Services	98	France Telecom	Services
87	Nokia Electronics	Hardware	99	Getronics (GSI)	Services
90	Scicon International	Services	>100	BSO/Origin	Services
91	CISI	Services	> 100	Cray Electronics	Datacom
92	Norsk Data	H/W (Mini)	> 100	Ascom	Telecom
Firm in 1984 and 1994 lists					

* Rank Xerox is considered part of Xerox for worldwide rankings.
** ICL is considered part of Fujitsu for worldwide rankings.
*** Sligos is a subsidiary of Credit Lyonnais and thus does not appear in worldwide rankings.
Source: 1984, *Datamation*, August 1, 1985, p. 56-5. 1994, *Datamation*, June 15, 1995, p. 60-2.

Table 4: Comparison of revenue breakdowns of top four European IT firms in 1984 and 1994.

Company	Year	Mainframe (Large-Scale)	Mini (Midrange)	Micro (PC + Wks)	Datacom	Peripherals	Software	Maintenance	Service
								(Services & Support)	
Siemens	1984	28.9%	6.3%	.6%	35.2%	17.6%	1.4%	9.9%	0
	1994	10.3%	12.8%	14.5%	0	17.1%	14.5%	30.8%	
Bull	1984	32.1%	6.4%	6.4%	0	39%	6.4%	9.6%	0
	1994	16%	7%	25%	0	6%	9%	37%	
ICL	1984	29.7%	16.4%	0	3.3%	36.5%	4.9%	9.3%	0
	1994	6.6%	12.4%	21.7%	0	6.2%	15.1%	38%	
Olivetti[1]	1984	1.5%	26.8%	14.4%	4.3%	17.9%	4.7%	21.8%	4.5%
	1994	2.3%	5.4%	26.3%	4%	18.7%	21.3%	22%	

(1994 Category name)
[1]In 1984 Olivetti had 8.6% of revenues from Other.

Source: 1984: *Datamation* European 25, August 1, 1985
1994: *Datamation* International, June 15, 1995

Table 5: Top 20 U.S. IT Firms in 1984 and 1994

Top North American firms - 1984			Top North American firms - 1994		
World Rank	Company	Major Product	World Rank	Company	Major Product
1	IBM	H/W (Mainframe)	1	IBM	H/W (PC)
2	Digital Equipment	H/W (Mini)	3	Hewlett-Packard	H/W (Peripherals)
3	Burroughs	H/W (Mainframe)	6	Digital	Services
4	Control Data	H/W (Mainframe)	7	AT&T	H/W (Midrange)
5	NCR Corp.	H/W (Mainframe)	8	Compaq	PC
7	Sperry	H/W (Mainframe)	9	EDS	Services
8	Hewlett-Packard	H/W (Mini)	11	Apple	PC
11	Wang Laboratories	H/W (Mini)	13	Unisys[1]	Services
14	Apple Computer	Micro	17	Sun Microsystems	Workstations
15	Honeywell	H/W (Mainframe)	19	Microsoft	PC Software
17	Xerox	H/W (Peripherals)	20	Xerox	Peripherals
18	AT&T	Datacom	23	Dell	PC
19	Data General	H/W (Mini)	24	Seagate	PC Peripherals
23	Commodore	Micro	25	Quantum	PC Peripherals
25	TRW	Software	27	Computer Sciences	Services
28	McDonnell Douglas	Services	31	Gateway 2000	PC
29	Automatic Data	Services	32	Packard Bell	PC
31	General Electric	Services	33	Computer Associates	Software
32	Texas Instruments	H/W (Mini)	34	Andersen Consulting	Services
34	Storage Technology	Peripherals	35	Conner Peripherals	Peripherals
Firm in 1984 and 1994 lists					

[1] Unisys was formed by the merger of Sperry and Burroughs in 1986.
Source: 1984: *Datamation* 100, June 1, 1985. 1994: *Datamation* 100, June 15, 1995.

Table 6: Comparison of revenue breakdowns of top four U.S. IT firms in 1984 and 1994.

Company	Year	Mainframe (Large-Scale)	Mini (Midrange)	Micro (PC+Wks)	Datacom	Peripherals	Software	Maintenance (Services & Support)	Service
IBM	1984	29.6%	6.8%	9%	4.1%	30.9%	7.2%	11.9%	.5%
	1994	9.3%	9%	18.7%	5.6%	13.4%	18%	26%	
Hewlett-Packard	1984	0	27.9%	15%	7.4%	26.5%	14.7%	8.5%	0
	1994	0	14%	21%	5%	33%	3%	24%	
DEC	1984	0	24.5%	4	0	40.1%	3.2%	28.1%	0
	1994	.3%	11.7%	18%	2%	12%	9%	47%	
Unisys[1]	1984	36.4%	9.5%	6.3%	2.2%	23.5%	5.1%	13.4%	2.3%
	1994	20%	8%	11%	0	0	11%	50%	

(1994 category name)

Source: 1984: *Datamation* 100, June 1, 1985.
1994: *Datamation* 100, June 1, 1995.

[1]Unisys is the result of the merger of Sperry and Burroughs. In 1984 1.4% of revenues was in "Other".

Table 7: Top Asian IT Firms in 1984 and 1994

Top Asian Firms - 1984			Top Asian Firms - 1994		
World Rank	Company	Major Product	World Rank	Company	Major Product[1]
6	Fujitsu	H/W (Mainframe)	2	Fujitsu	H/W (Mainframe)
9	NEC	H/W (Mainframe)	4	NEC	H/W (PC)
12	Hitachi	H/W (Mainframe)	5	Hitachi	H/W (Mainframe)
22	Toshiba	H/W (Mini)	10	Toshiba	H/W (PC)
30	Oki Electric	Peripherals	14	Matsushita	H/W (Peripherals)
33	Mitsubishi	Hardware	15	Canon	H/W (Peripherals)
			21	Mitsubishi	H/W (Peripherals)
			22	NTT	Datacom
			26	Acer	H/W (PC)
			29	Ricoh	Datacom
			30	Oki	H/W (Peripherals)
			43	Seiko Epson	H/W (Peripherals)
			50	Samsung	H/W (Peripherals)
			61	Tatung	H/W (Peripherals)
			80	Sony	H/W (Peripherals)
			82	Mitac	H/W (PC)
			83	First International	H/W (PC)
			91	Alps Electric	Peripherals
			94	Omron	H/W (PC)

Firm in 1984 and 1994 lists.

[1]The Major Product Classification is based on 1991 revenue breakdowns, *Datamation* Asian 25, Sept. 1., 1992.
Source: 1984: *Datamation* 100, June 1, 1985. 1994: *Datamation* 100, June 15, 1995.

References

Cool, Karel and H. Landis Gabel, "Open Systems and the European Mainframe Computer Industry in 1990," INSEAD Case, 1991

Charles H. Ferguson and Charles R. Morris, *Computer Wars*, (Times Books: 1993)

Flamm, Kenneth, *Targeting the Computer : Government Support and International Competition*, (The Brookings Institute, 1987)

Flamm, Kenneth, *Creating the computer : Government, Industry and High Technology*, (The Brookings Institute, 1988)

Gomes-Casseres, Benjamin, "Computers: Alliances and Industry Evolution," in David B. Yoffie ed., *Beyond Free Trade: Firms, Governments, and Global Competition*, (Harvard University Press, Boston, MA, 1993)

Harmon, Alvin J., *The International Computer Industry: Innovation and Comparative Advantage*, (Harvard University Press, 1971)

Jequier, Nicolas, "Computers", in Raymond Vernon (Ed), *Big Business and the State* (Harvard University Press, 1974)

McKinsey & Co., Inc., *The 1995 Report on the Computer Industry*

Murphy, Brian, *The International Politics of New Information Technology*, (Croom Helm Ltd., Great Britain, 1986)

Murray, Gordon C., and Jonathon Lott, "Have UK Venture Capitalists a bias against investing in new technology-based firms?" *Research Policy*, 1995, v. 24, pp. 283-299

Sandholtz, Wayne, *High-Tech Europe: The Politics of International Cooperation* (University of California Press, 1992)

Sandholtz, Wayne, "European Electronics: From Crisis to Collaboration," in Wellenius, Bjorn , Arnold Miller and Carl J. Dahlman, *Developing the Electronics Industry : A World Bank Symposium* , (The World Bank, Washington, DC, 1993)

Sharp, Margaret, Chapter 11, "The Community and New Technologies," in Juliet Lodge, ed., The European Community and the challenge of the future, (St. Martin's Press, Inc., New York, 1989)

Stubbs, Peter and Paolo Saviotti, Chapter 6, "Science and Technology Policy," in Mike Artis and Norman Lee, eds., *The Economics of the European Union: Policy and Analysis*, (Oxford University Press, 1994)

Webber, Douglas, Jeremy Moon and J.J. Richardson , "State Promotion of Information Technology in France, Britain and West Germany" (Strathclyde Papers on Government and Politics , No. 3 , 1984)

Zysman, John, *Political Strategies for Industrial Order* (University of California Press, 1977)

[1] By 1950 only 25% of all computer R&D was undertaken privately. Through the 1950's the average government share of R&D expenditures was 58%. In 1953, up to 70 percent of the computers in use were indirectly or directly paid for by the government. Flamm (1987), p. 96. See Chapter 3 for a detailed discussion of the U.S. government role in developing computer technology.
[2] Flamm (1988), p. 87.
[3] Harmon (1971), p. 20.
[4] The notion of a European technology gap vis-à-vis the U.S. gained currency in the late 1960s following the distribution of the following two publications: the first was a report entitled *Gaps in Technology*, published by the OECD, and the second was a book entitled *Le Defi Americain*, by Jean-Jacques Servan-Schreiber. See Sandholtz (1993), p. 112.
[5] Harmon (1971), pp. 35-36.
[6] See Flamm (1988) p.155, f56. For the decision to compete directly with IBM, see John Zysman, *Political Strategies for Industrial Order* (University of California Press, 1977), p. 76.
[7] Jequier (1974), p. 222.
[8] Webber et al. (1984), p. 11.
[9] Murphy (1986), pp. 65-66.
[10] Webber et al. (1984) state that there was discussion of implementing a pro-German purchasing policy, for various reasons this was not successful. pp. 42-43. Jequier (1974) concurs that there was no formal provision for procurement preferences, at least in the first two EDP programs, but that there was de facto bias towards domestic producers. p.222. Flamm (1988), p. 164 concurs with the views of Jequier.
[11] Flamm (1988) pp. 142-150
[12] Webber et al. (1984), p. 14.
[13] In 1968 the government introduced a principle whereby it would purchase large computers, or computers which were meant to be upgraded at a future date, from ICL. Jequier (1974), p.221. Under this policy, British machines not more than twenty-five percent more expensive than an American one are preferred. Harmon (1971), p. 33.
[14] Statistics from Flamm (1987), p. 103-109.
[15] The other difference was that the U.S. had IBM. Jequier (1974), p. 199.
[16] Gomes-Casseres (1993), p.114
[17] This discussion is based on Sandholtz (1992), pp. 92-99.
[18] Sandholtz (1992), p. 94.
[19] Sharp (1989), p. 205.
[20] Murphy (1986), pp. 67-68.
[21] FAST, "Eurofutures: the Challenges of Innovation," xi., as quoted by Sandholtz (1992), p. 159-160.
[22] Siemens, Nixdorf, AEG, Bull, CGE, Thomson, Olivetti, STET, ICL, Plessey, General Electric and Philips.
[23] Pre-competitive research is defined to be research in "areas where market opportunities can be reached within 5-10 years, and in so doing, ESPRIT stands between basic research and applied research and development work." This quote is from COM (84) 608, dated 8th November, 1984. Cited in Murphy (1986), p. 71.
[24] From Community document ISEC/B1/83, January, 1983, quoted in Murphy (1986), p. 69.
[25] Sandholtz (1986), Chpt. 9.
[26] Eureka projects are self-funded. However, once a project is approved under Eureka it is likely to qualify for financial assistance from national governments or private sources.
[27] Budget information from Stubbs and Saviotti (1994), p. 156.
[28] Sandholtz (1992), pp. 186-192.
[29] Two examples of standards developed in ESPRIT projects are the Office Document Architecture (ODA), a formatting standard allowing files to be passed between computers, which was developed in a collaboration of Olivetti, Siemens, Groupe Bull, and ICL ("European team effort breaks ground in software standards," *Electronic Business*, August 15, 1988, pp. 90-92.), and the Integrated Systems Architecture, facilitating compatibility between computers, which was developed by British Telecom, Hewlett-Packard and others. ("ESPRIT Evades the Soft Option," *International Management*, February 1991, pp. 58-61.)
[30] Sandholtz (1992), p. 202.
[31] X-Open began with Groupe Bull, Nixdorf, Phillips, Olivetti, Siemens, and ICL. Sandholtz (1992), p. 204. It has since grown to include more European firms as well as AT&T, DEC, Hewlett-Packard, IBM, and Fujitsu. The movement to UNIX became complicated when two rival groups, Unix International and the Open Software Foundation attempted to standardize on their incompatible versions of Unix (both of which conformed to X/Open's guidelines). For more detail see Cool and Gabel (1991).
[32] Maastricht Treaty, Title XV, Research and Technological Development, Article 130g, found in CORDIS World Wide Web site (http://www2.cordis.lu/cordis/0001.htm).

[33] The telematics applications program receives ECU 843 million, and the advanced communication technologies and services (ACTS) program receives ECU 630 million.
[34] About the Esprit Programme, Background, http://www2.cordis.lu/esprit/src/about.htm.
[35] Ibid.
[36] Software companies provide either pre-written software or custom-written software. Service companies provide a range of services to companies, from taking over their entire computer operations to providing certain systems or consulting advice. Demand for software and services has increased worldwide as firms attempt to become more competitive: companies outsource computer operations to service companies in order to focus on "core competencies," and companies search for software which will give them a competitive advantage.
[37] Distributed systems are characterized by providing computing power directly to end-users, rather than the traditional system of accessing a centralized mainframe with a dumb terminal. Personal computers and workstations are given to end-users who are usually connected together in a local area network (LAN). A common form of distributed system is the client/server system, in which the "clients," namely personal computers and workstations, can turn to "servers," computers ranging in size from dedicated personal computers to mainframes, for data, programs, and supplementary computing power. Demand for these systems has increased because many firms attempting to become more competitive feel that they help increase the productivity of end-users at a relatively low cost.
[38] The most notable purchase is that of ICL by Fujitsu.
[39] A large portion of hardware sold by European IT firms is indirectly Asian or American as well, as will be shown below.
[40] McKinsey & Co., Inc (1995), pp. 2-24, 2-25.
[41] SAP AG is perhaps the one glaring exception to this rule. Its products are generally recognized to be world-class if not the best in their field.
[42] For a history of the Japanese industry see Flamm (1988), Chapter 6.
[43] It should be noted, however, that Fujitsu and Hitachi were greatly aided by ties with Amdahl, the first IBM-compatible producer. NEC continued to work with its U.S. partner, Honeywell, until Honeywell became dependent on NEC for technology, and eventually, Honeywell also left the industry.
[44] The IBM PC standard is now controlled by two of the original suppliers, Intel, which supplied the microprocessors, and Microsoft, which supplied the operating system.
[45] Peter Kurz, chief representative in Taiwan for Baring Securities, as quoted in, "Your next PC could be Made in Taiwan," *Fortune*, August 8, 1994, p. 91.
[46] Although in one sense IBM-compatible PCs are a commodity product, the successful companies employ any of a variety of commercialization strategies: innovative features, a reputation for quality, or an original marketing idea.
[47] Olivetti had 5.1% of the European market, Vobis had 3.6% and ESCOM had 3.2% in the second quarter of 1994. "Lost on the Infobahn?", *Newsweek*, October 31, 1994, p. 42.
[48] RISC stands for Reduced Instruction Set Computing. These chips are much simpler than conventional chips, providing greater performance at lower cost.
[49] For greater detail on the history of RISC technology, see Ferguson and Morris (1993), pp. 37-50.
[50] The RISC technologies of both Inmos and Acorn were not perfect substitutes for those of the U.S. companies listed above. Nevertheless, both fit a nice niche and could have profited from a successful commercialization strategy.
[51] This supercomputer used an array of Transputers rather than a single large processor. "Europe launches New High-Tech Project," *Europe*, June 1988, pp. 32-33.
[52] "Parallel World of a New Superpower," *International Management*, November 1990, pp. 58-60.
[53] Although arguably the ARM chip found little commercial success inside the Newton, this was the first of many uses since 1990.
[54] None of the European hardware firms developed their own RISC processor. Instead, Ericsson, Nokia, Philips and ICL sold Sun-based systems, and Olivetti, Bull, Mannesmann and Siemens-Nixdorf sold Mips-based systems. Later Bull turned to IBM for RISC technology, and Olivetti turned to DEC for its Alpha RISC technology. Finally, Nixdorf, Olivetti, ICL and Siemens also sold Pyramid RISC systems. Pyramid is a U.S. company which was purchased by Siemens in 1995.
[55] The most notable purchase was that of a majority share in ICL by Fujitsu in 1990, with the remainder owned by Northern Telecom. ICL-Fujitsu then purchased the computer division of Nokia in 1991. The French government began to sell parts of Groupe Bull to foreign companies: IBM, Motorola and NEC all own significant shares. Olivetti was partially owned by AT&T for a period in the 1980s and by Digital Equipment for a period in the early 1990s. Digital Equipment also purchased the computer interests of Mannesmann and Philips in 1991. This trend is not limited to hardware; in services, EDS purchased SD-Scicon in 1991, and recently ADP purchased GSI. The question of participation in European research programs first flared when Fujitsu bought ICL and ICL was subsequently voted out of the European Roundtable group which guides ESPRIT, because, according to the group, "it is important that the roundtable comprises companies that are truly European-owned." ("Japan may find closed doors in Europe,"

Computerworld, March 4, 1991, p. 66.) In addition, ICL was expelled from parts of JESSI because of the access it gave Fujitsu to European innovations. Making the question political, IBM was participating in JESSI at the time

[56] Bull owns a majority share of Honeywell Bull, the remainder of Honeywell Information systems, and bought Zenith Data Systems, a personal computer manufacturer, in 1989. This year Zenith Data Systems was merged into Packard Bell, a U.S. PC company in which Groupe Bull and NEC are minority shareholders. ("Packard Bell and Zenith Data: The Tortoise and the Tortoise?", *Business Week*, February 19, 1996, p. 36.) Siemens recently purchased Pyramid, a prominent supplier of RISC computers.

[57] However, acquiring technology from foreign firms is not always without cost. Many of these European equity sales listed above stemmed from supply relationships with the foreign purchaser, or were parts of attempts by European firms to acquire technology. ICL had been selling Fujitsu mainframes for years before Fujitsu purchased ICL. Bull sold 5% of its equity to IBM in order to access IBM's RISC technology, and Olivetti sold a stake to Digital as part of a deal to access DEC's Alpha technology.

[58] Two U.S. examples mentioned in this paper are IBM, which waited two decades after inventing RISC technology before introducing a commercial product, and Xerox, which saw many of its innovations commercialized in the Apple Macintosh. Xerox, at its Palo Alto Research Center (PARC), had many other innovations which were commercialized by start-up companies, including the first Local Area Network, or LAN, commercialized by Novell among others, the Ethernet standard, commercialized by 3Com, and the laser printer, for which Adobe set the PostScript standard. See Ferguson and Morris (1993), pp. 104-106. Finally, a European example mentioned in this paper is Olivetti's failure to commercialize the ARM RISC technology developed by Acorn, in which it had an 80% stake.

[59] Jean-Louis Gassée, while vice president of product development at Apple headquarters in California, wrote:

> Unfortunately, in France the words "adventure" and "capital" seem to have incompatible meanings. Furthermore, it is the spirit of enterprise itself that is perceived as an unseemly passion, a little bit like the time when an aristocrat could not get his hands dirty doing business. By definition, an entrepreneur is success-oriented, or failure-oriented, just because he does not sit with his arms folded. And if the French have an exaggerated contempt for those who fail, they do not have an equivalent admiration for those who succeed.

"The French Contradiction," *Across the Board*, July/August 1987, pp. 35-37.

[60] "Springtime for Startups," *Business Week*, May 22, 1995, p. 130H.

[61] Murray and Lott (1995).

[62] "More European Firms Shun Local Exchanges to Try U.S. Market," *The Wall Street Journal Europe*, June 26, 1995.

[63] The major product is determined by revenues: if the company receives over 50% of revenues from hardware it is hardware (H/W), with the leading product within hardware in parenthesis. If the company produces only one type of hardware, such as Apple, then its major product is simply PC (1994) or Micro (1984).