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Scientific and Technological Research in Europe, Japan and the United States (**)

We are living through one of the most far-reaching transformations in the history of mankind, which is powered by extraordinary advances in scientific knowledge and continuous technological innovations.

The economy is faced with a cluster of emerging technologies which bring about continuous innovation and are carrying us towards the post-industrial society, also referred to as the information society because of the prominent role of information, communication and related technologies (ICT).

The emerging technologies are capable of blending with each other and with traditional technologies, giving rise to completely new "hybrids": a classic example of this is the digital watch, which grafts an emerging technology, microelectronics, in a conventional product. Similarly, the blending of electronics with the mechanical industry has given rise to mechatronics.

The globalization of markets and the pervasive nature of technology are leading to a new international division of labour which has little to do with the one we were used to. On the one hand, mature sectors are being rejuvenated by the injection of new technologies accompanied by changes in the organisation, enabling them to remain competitive in the advanced industrialised countries, in spite of the high cost of labour. On the other hand, the new sectors often move towards newly industrialising or developing countries, (just think of microelectronics in South Korea, or of software in India). The rules of the past no longer apply and the world economy is becoming more dynamic and flexible.

An aspect peculiar to our time is represented by the invention of new resources in terms of materials, energy sources, and also agricultural varieties, which are beginning to replace traditional, scarce or vulnerable resources. This, together with the growing importance of the services sector of the economy, the rationalisation of production and the miniaturisation of machines and products,

(*) Uno dei XL.

(**) «Marconi Lecture 1997» tenuta presso la Royal Swedish Academy of Sciences, 11 novembre 1997, Stockholm.

contributes to what is often referred to as the "de-materialisation" of society. The importance of hardware declines steadily, while that of software steadily increases. In addition, hardware itself incorporates ever more knowledge for a given quantity of matter. Industry is thus becoming a supplier of knowledge contained in goods and services, and no longer a purveyor of purely material products.

In the post-industrial society the manufacturing industries, even though providing a decreasing share of direct employment, are still of central importance. We can even say that we are entering into a new era of world-wide industrialisation (or re-industrialisation), given that industry is still at the centre of innovation, which, in turn, induces spectacular changes in the rest of the economy and in everyday life. In the space of a few decades production of a standard and repetitive kind has been automated and taken over by machines and robots. The "factory without workers", tempting as it may be, is perhaps not ideal as an objective. The best solution for the purpose of optimising well-being and added value lies in a skilful mix of machines and organised, intelligent human labour.

Enterprises are no longer constrained to work in a local or regional market, but have to face global competition and make immediate use of innovation, by searching for new operational frontiers, even by way of alliances and joint ventures on a world-wide basis. With respect to the past, we are now living in a world where time is dramatically accelerating and space is shrinking. Firms must, therefore, be flexible and ready for changes in which they must participate actively, lest being left behind and soon becoming obsolete.

This does not mean that short term considerations and competitiveness in the market should monopolise the attention of those working in scientific and technological research. Fundamental research, carried out without specific practical benefits in mind, with a passion for discovery and a sense of adventure, is and will continue to be, of utmost importance to mankind. Furthermore, it is incumbent on our generations that global instances and problems be faced with a far-sighted approach. For example, we need to improve our understanding of the environment's ability to absorb the impact of human activity, and must adopt policies to reduce such impact before irreversibly damaging our ecosystem. The issue of sustainable development is gaining the attention of policy-makers all over the world. It is also a moral imperative to try to reverse the trend to a widening gap in income and standard of living between the rich and poor sectors of the population, on a world scale and in individual countries. This gap has increased over the last decades, as can be seen from the graphs in Fig. 1, reporting the evolution of the ratio between incomes of the richest 20% and the poorest 20% of the population of the world since 1970.

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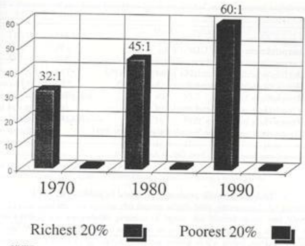
The European Union, the United States and Japan (the so-called "Triad"), are the major protagonists in the field of scientific and technological research and in generating innovation. As far as fundamental research goes, one of the most



Source: UNDP.

Fig. 1 - Per capita income of the richest and poorest 20% of the world population.

significant indicators of excellence is the number of Nobel Prizes awarded for chemistry, physics, physiology or medicine, and, in the case of mathematics, that of the Field Medals. From 1901 to 1945 Europe was by far the dominant region, but after the Second World War the United States have progressively gained the leadership in chemistry, physics and the bio-medical sciences. Up until now Japan has been a second rank country as far as Nobel Prizes and other awards to its scientists go. When we come to an analysis of financial resources devoted to research and development in the various regions of the world, the European Union, the United States and Japan, which together, with a population of 750 million, make up less than 15% of mankind, are responsible for over 80% of the financial effort devoted to R&D on a world scale. The same countries employ in these activities 2.2 million scientists and engineers, that is over half of those active in the whole world (Table 1). It comes as no surprise that 75% of scientific publications reported in the Science Citation Index and in Compumath originate in the European Union, the United States and Japan (Table 2). The supremacy of the Triad Countries is even more impressive when reference is made to the number of patents filed in the United States and Europe which are, respectively, 90.3% and 94.6% of the total filed in the whole world (Table 3).

Table 1 - *Some R&D indicators for the Triad.*

	EU15	USA	JAPAN
Total R&D expenditures (MECUs) 1994	121,882	142,047	104,069
Total R&D expenditures as % of GDP 1995	1.91	2.45	2.95
Total R&D expenditures per inhabitant (ECUS) 1994	329	545	833
% of total R&D expenditures financed by governments 1993	39.6	39.2	19.7
% of total R&D expenditures financed by industry 1993	53.5	58.7	73.4
Number of researchers 1993	774,100	962,700	526,500
Number of researchers per thousand employed 1993	4.7	7.4	8.0
Number of researchers in industry 1993	376,000	765,000	367,000
Number of researchers per thousand employed in industry 1993	2	6	6

Source: European Commission, DG XII from OECD data.

Table 2 - *Scientific production measured by publications, 1993.*

	World share 1993 (%)	1993 index (base 1992 = 100)
European Union - 15	31.5	107
European Free Trade Association *	1.7	100
Central and Eastern European Countries	2.3	87
Israel	1.0	90
Commonwealth of Independent States	4.8	56
USA	35.3	96
Canada	4.5	108
Latin America	1.5	127
North Africa	0.4	111
Middle and Near East	0.6	186
Sub Saharan Africa	0.8	89
Japan	8.1	119
NICS **	1.4	412
China	1.2	347
India	2.1	83
Other countries in Far East	0.1	113
Australia e New Zealand	2.7	94
World total	100.0	

* Iceland, Liechtenstein, Norway and Switzerland.
** Korea, Malaysia, Hong Kong, Singapore and Taiwan.

Source: UNESCO, World Science Report (1996).

Table 3 - *Positions of the Triad Countries by technological area, measured in patents, 1993.*

	Share (%) of European patents in the World			Share (%) of US patents in the World		
	EU	USA	Japan	EU	USA	Japan
Electronics/electricity	34.2	30.0	31.8	11.5	46.7	35.4
Instruments/optics	37.8	32.4	23.4	14.9	50.8	28.0
Chemicals/pharmaceutical prod.	40.3	33.7	20.0	28.2	51.0	19.7
Industrial processes	50.1	25.6	16.6	22.3	50.5	19.3
Mechanical engineering/transports	58.5	19.2	15.5	23.6	45.4	22.5
Consumer goods	64.0	16.9	8.0	19.1	50.1	12.5
All areas above	46.4	27.3	20.9	16.6	48.7	25.0

Source: USPTO.
Data: Treatments STO and CHI-Research, 1995. Unesco report on Science in the World.

Let us now try to examine the factors which have determined the economic evolution and the competitive position of Japan, the United States and Western Europe. A caveat, however, is in order: it is somewhat simplistic to think of a country as if it were a big corporation, competing in the global market. We must be aware of the extreme complexity of the concept. In operational terms, competitiveness involves a wide variety of factors, including technological innovation, productivity, investment in physical and human capital, sectoral specialisation and organisation.

* * *

Japan's emergence as a world power was based on the use of its traditional social model, with a strongly ingrained sense of belonging, to achieve an economic and industrial development that has involved an accelerated passage, in the post-war period, through the phases recorded over a much longer time by the Western industrialised countries. The target was success in world markets, thus overcoming the country's lack of primary resources such as food, energy and minerals, and the consequent structural dependence on imports. The domestic market proved to be a useful trial ground for exports. The winning of substantial shares in the world market was made possible, initially, by literally copying Western technologies, giving rise to products of low to medium technology and middling quality, the competitive factor being low price. In a remarkably short time, however, with the joint guidance by the government (the Ministry of Finance and MITI) and industry (Keidanren), Japan learned how to improve imported technologies and to create new products of ever higher quality in many technologically-advanced sectors.

It is possible to detect, through the analysis of the evolution of the structure of Japanese exports, a clear strategy of progressive shift towards increasingly

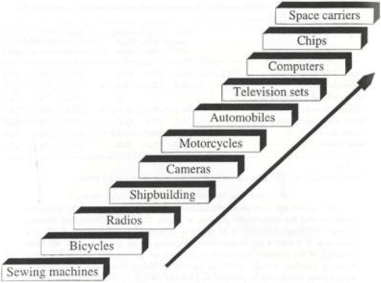


Fig. 2 - Industrial sectors in which Japan has applied its "Laser Beam" approach. Some examples in chronological order.

sophisticated industries and technologies up to the point where Japan emerged as a champion in many high-tech sectors (Fig. 2). One of the decisive factors in this success was the commitment to education, training and research: more than 95% of Japan's children of both sexes, gain a high school diploma of some kind, with very demanding and competitive courses, whilst R&D, mostly applied research and technological development, accounts for about 2.9% of the GNP.

The Japanese Government, which in the 1960s and 1970s had created instruments for the support of industrial research (tax credits, loans and incentives of various kinds), has recently set up the "R&D project on Basic Technologies for Future Industries", which includes 14 specific programmes covering new materials, biotechnologies and new electronic devices and systems. For over a decade it has supported the programme for the development of fifth generation computers based on artificial intelligence and other forms of advanced treatment of information, including intelligent manufacturing systems. It has founded the "Japan Key

Technology Centre" which reports to MITI and the Ministry of Posts and Telecommunications, and created, together with the Science and Technology Agency, the international scientific project "Human Frontier" in bio-sciences and related technologies. The Government now supports basic research in the universities and in science and technology parks. To this end, a law was promulgated in 1996 to strengthen basic scientific research. Last year, the Government decided to spend over 30 billion dollars per annum in a five-year period, on scientific and technological research, mostly targeted to civilian technologies.

One should add, however, that although the Japanese real economy is now improving after four years of distress — by and large the result of malfunctioning of the banking system — the financial mess in which the system is still embroiled could have negative repercussions, national and unfortunately global. Massively bureaucratic government intervention in industrial policy is now being attacked for its rigidity and dirigism, at a time when flexibility and rapid diffusion of technology and knowledge are the decisive factors of success. The over disciplined educational system stifles initiative and individual creativity. Alliances of the big corporations and the banks starves SMEs of capital and generates dependent relationships which hamper their growth. The patent disequilibrium between inflated return on capital and the poor return on labour is finally threatening to demotivate the labour force, already disenchanted with the stress and the poor quality of life Japan offers. The disadvantages suffered by those not covered by the "cradle to grave" corporate system are all too visible. They are an uncomfortable reminder to the more fortunate that the cost of their privileges may soon become too high even for paternalistic Japanese corporations to bear.

The country is now going through a set of structural reforms in government, finance, education, with the fading away of gerontocracy and the emergence of a younger generation of leaders, bringing about a dramatic upheaval in the traditional scale of values. How the Japanese research and production system will adjust to these changes is difficult to predict.

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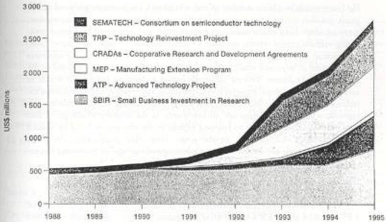
In contrast with Japan, the huge domestic market has always dominated in the United States and the demands of this market have been the driving force behind technological development. In addition, there was the Government's high level of commitment to technical and production efforts during the war and its subsequent contribution to the development of advanced technologies within the framework of military and space projects during the period of "cold war" with the USSR. The development of information technologies and computers is a case in point. However, increasing competition from Japan gradually revealed the limits of a technological strategy that relied on "spin-off" from the results of military research to stimulate innovation in the civilian economy. The involvement in objectives unrelated to the logic of the market, such as military and, for a long time, space research, reduced the country's ability to transform knowledge into commercial products. It is sufficient to cite the case of compact disc readers where the United States, despite their lead in the development of lasers, the key technology, is almost completely absent. We now see attention growing in the United States, and in some European countries as well, towards the promotion of dual-use technologies and the fostering of "spin in" from civilian to military innovative products, a process quite common in Japan.

Shortcomings in education and training in the United States, only partly offset by the "brain drain" from other countries, gave rise to a cultural level considerably lower than that of other developed countries. This, in turn, led to a reduced ability to innovate on a wide front and to an inadequate attention to quality. These phenomena, accompanied by a slower gain in productivity, attracted the attention of American decision makers when international markets began to be of increasing importance to the United States. The response came rapidly, and has been quite effective. In 1991 the U.S. Council on Competitiveness carried out an exercise which produced interesting results. Research involving hundreds of industrial experts led to the identification of 22 critical technologies where the United States were in a weak competitive position. Public and private research was then focused on these technologies, giving rise to forms of co-operation between enterprises and the public sphere, which previously had been most unusual in America. The major collaborative programmes of research and development between the U.S. Federal Government and industry for the period 1988 to 1995 are listed in Fig. 3, along with data on investment. In 1994 the Council on Competitiveness produced another report, which showed a pronounced improvement in all the critical technologies previously identified. In this effort, the method used is that of benchmarking, i.e. comparing the American position for each technology with that of the leading countries at the world level. Europe is seen as the strongest competitor only in chemicals, pharmaceuticals and biotechnology, while Japan remains strongest in electronics, new materials and many manufacturing technologies. India has emerged as a front-runner in software, and some of presently industrialising countries in the Far East, including China, are emerging in a whole series of manufacturing sectors and technologies of importance for the future. The White House Office of Science and Technology and the National Critical Technologies Review Group collaborate in the production of biannual reports on critical technologies. The Federal Government has become the dominant sponsor of the nation's long term, basic research portfolio.

American universities are in the process of re-defining their mission in training and research. On the one hand, they are developing mechanisms for the transfer of knowledge to industry, on the other hand, encouraged also by the Administration, they are trying to reinforce their position in basic research. The best American universities are the main beneficiaries of public funding of scientific research, through the programmes of the National Institute of Health, the National Science



Source: Department of Commerce data, 1995.

Fig. 3 - Selected Federal partnership with industry. Years shown are fiscal years (e.g. FY 1995 = 1 October 1994 to 30 September 1995).

Foundation and various other government Departments and Agencies. The Federal Government's mission is to sustain U.S. leadership across the frontier of scientific knowledge, to enhance connections between fundamental research and broad national socio-economic goals, and to foster R&D partnerships between universities, industry and government laboratories. The results are spectacular, and indirect evidence of this is the fact that all Nobel Prizes in the scientific and economic disciplines over the last five years (1993 to 1997) were awarded to scientists working in the United States and funded by the U.S. Government, even if 50% of the prizes were jointly awarded to European and other non-American scientists.

One should not ignore the commitment to competitiveness of the individual States. Many of them have launched programmes to foster co-operation between universities, industry and government, with the aim of increasing research efforts and directing them towards targeted industrial sectors, including traditional ones for their importance as purveyor of jobs, so as to create centres of excellence in the chosen industries and to orient university research and teaching towards exploiting synergies with industry.

This overview of the position of the United States in research and innovation cannot end without acknowledging that industry is the backbone of innovation in the country, where a large number of major high tech corporations are in an avant-garde position world-wide, and a multiplicity of small-sized scientific enterprises, many of which born in the university environment, and supported by a brave, risk-taking venture capital system, generate a continuous flow of important innovations. The present undisputed American superiority is due above all to this extraordinary combination of large and small entrepreneurial activities paving new ground in the economy of the future. Federal and State action to remove regulations acting as constraints to innovation, especially in the fields of information and communication technologies and in the biotechnologies, has had crucial impact. Deregulation, re-regulation and self-regulation are all key words in the ongoing challenge to free American society enabling it to respond rapidly to the changes induced by science and technology. Competition is the crux: from this perspective, America's unplanned, chaotic economy has major advantages in an age of increasing importance of information and communications

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Europe invests less than its competitors in research and development: a total R&D effort of about 1.9% of the GNP, as against 2.5% for the United States and 2.9% for Japan. Furthermore, the European Union is anything but homogeneous: Sweden invests 3%, Germany and France 2.3%, Italy 1.1%, Spain about 0.8%. Even the number of European researchers is relatively low: about 4.7 per 1000 employed, against 7.4 per 1000 in the United States, and 8.0 per 1000 in Japan. There is general agreement on the fact that Europe couples a position of excellence in fundamental scientific research with an inferior capacity, with respect to the United States and Japan, to translate results into industrial innovations and a solid competitive position in the high technology sectors. This fracture between research

Table 4 - *Indices of scientific and technological production relatd to GDP, 1993.*

	Scientific publication	European patents	US patents
European Union	126	181	73
USA	144	112	200
Japan	81	208	251
World Total	100	100	100

The shares of world scientific publications, and of the European and US patents, have been divided by the GDP of the regions in question; the world value for each index (the average value) has been set at 100 for easier reading.

Source: UNESCO, World Science Report (1996).

Table 5 - *The position of the Triad by technological area, measured in patents, 1993.*

European	European patents world share (%) UE-15	USA	Japan	1993 (base 1987 = 100) UE-15	USA	Japan
Electronics/electricity	34.2	30.0	31.8	83	101	129
Instruments/optics	37.8	32.4	23.4	84	106	136
Chemistry/pharmaceuticals	40.3	33.7	20.0	95	103	107
Industrial processes	50.1	25.6	16.6	95	100	125
Mechanical engineering/transport	58.5	19.2	15.5	96	100	134
Consumer goods	64.0	16.9	8.0	99	98	142
All area	45.4	27.3	20.9	91	103	129

United States	US patents world share (%) UE	USA	Japan	1993 (base 1987 = 100) UE	USA	Japan
Electronics/electricity	11.5	46.7	35.4	64	98	117
Instruments/optics	14.9	50.8	28.0	74	111	100
Chemistry/pharmaceuticals	28.2	51.0	19.7	90	103	108
Industrial processes	22.3	50.5	19.3	79	106	115
Mechanical engineering/transport	23.6	45.4	22.5	80	110	102
Consumer goods	19.1	50.1	12.5	76	103	106
All area	18.6	48.7	25.0	76	105	111

Source: USPTO, OST e CHI Research, 1995.

and innovation is a paradox of Europe. The low propensity of Europe to apply for U.S. patents is evident from the data in Table 4. It is also interesting to note (Table 5) that the position of Europe in terms of patents filed in Europe and the USA in six diverse high technology areas has been deteriorating steadily from 1987 to 1993, whilst those of Japan and the USA have been generally improving.

Let us now look at research and development activities undertaken or co-ordinated at the European level. The growth of European co-operation in R&D has so far been a slow process, that has nevertheless given rise to a complex of institutions and programmes, altogether accounting for 13% of public R&D expenditures in the 15 E.U. member countries. This may seem a small proportion, but one should also consider the indirect effect that co-operative European R&D has in orienting national programmes. This is evident in such fields as high-energy physics, space, molecular biology, and in a number of advanced technologies.

Some European co-operative research programmes are based on intergovernmental agreements: this is the case of CERN, ESA, ESO, EMBL, COST, EUREKA. The RTD Framework Programme and the Joint Research Center are managed directly by the European Commission, with a co-decision process involving the European Council of Ministers and the European Parliament. For the selection of projects, in most cases the criterion of excellence prevails. In the case of ESA, however, for a large part of the budget, member countries are expected to have a just-return of their financial contribution.

Large European laboratories (JRC, CERN, EMBL, ESA), common infrastructures (such as the synchrotron radiation facility in Grenoble, or the Jet fusion research reactor in Culham), co-operative networks (such as the European Science Foundation in various areas of fundamental research), constitute together the core of what has been christened a true "European scientific area", that co-exists with the national research activities to which as much as 87% of public R&D funds are dedicated.

The Framework Programmes for research and technological development of the European Community were designed since their beginning in the early 1980s with a strong supply-side component, so that proposals for research mostly reflected ideas generated by researchers themselves, rather than by the potential users of the results ("demand side"). It is easy, then, to understand why the overall conception of the Framework Programmes has been very fragmentary, as Table 6, (which refers to FP IV, currently being executed) confirms. Results have been good, sometimes even excellent, from the scientific point of view, but generally disappointing when it comes to their applications and impact on the economy.

Hitherto, the European Framework Programmes have been confined to the areas of basic and "pre-competitive" research, in the sense that co-operation between European enterprises must cease when competition in the market begins. There is now a growing awareness of the fact that research should be viewed having in mind that competition has an increasingly global character and that inter-European industrial alliances in research are becoming a necessity. Furthermore, it has become increasingly difficult to distinguish between basic research, pre-competitive and competitive research, since there are examples of fundamental scientific discoveries being at the same time a matter of competitive nature on which to pump fresh capital and human resources. European scientists, for example, discovered in the second half of the 1980s high temperature superconductors and novel magnetic materials (giant magneto-resistance materials), but the U.S. and Japanese industries were readier to focus on them intense development efforts. European research must now aim at success in achieving the delicate balance between competition and co-operation.

Framework Programme V, (1998-2002), which aims at correcting the defects met with so far, is still being defined, but its purpose is to pursue a higher level of strategic concentration. In its present formulation, it is divided into 6 specific

Table 6 - *Specific Programmes under the Fourth Framework Programme (1994-98).*

Specific Programme	Acronym	MECU
A. Research, technological development and demostration programmes		
1. Information technologies	ESPRIT	2,035
2. Telematic applications	TELEMATICS	898
3. Advanced communication technologies and service	ACTS	671
4. Industrial and materials technologies	IMT	1,722
5. Standards, measurements and testing	SMT	184
6. Environment and climate	ENVIRONMENT	566.5
7. Marine science and technology	MAST	243
8. Biotechnology	BIOTECHNOLOGY	588
9. Biomedicine and health	BIOMEDICINE	358
10. Agriculture and fisheries	FAIR	646.5
11. Non-nuclear energy	JOLE/THERMIE	1,030
12. Nuclear fission safety	FISSION	170.5
13. Controlled thermonuclear fusion	FUSION	846
14. Transport	TRASPORT	256
15. Targeted socio-economic research	TSER	112
16. Direct measures (joint Research Centre)	JRC	1,094.5
B. Co-operation with third countries and international organisations	INCO	575
C. Dissemination and optimisation of results	INNOVATION	312
D. Training and mobility of researchers	TMR	792
	Total	13,100

programmes, three of a thematic nature and three of the horizontal type (Fig. 4). The will of Europe to assure a more selective and directed strategy, remains to be confirmed, given that it cannot be excluded that the Programme may be modified during the process of political bargaining, into something as fragmented as the previous Framework Programme.

It is difficult to assess the overall competitive situation of Europe. There are a number of large enterprises from European countries that are competitive in important industrial sectors, such as chemicals and pharmaceuticals, engineering, machinery, automobiles, durable consumer products, energy including the generation of electricity, metallurgy, where there is a long standing tradition of European excellence. In the emerging high-tech sectors, however, the strongest European

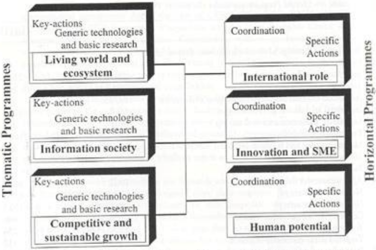


Fig. 4 - Organization and content of RDT Framework Programme V of European Union (1998-2002).

enterprises are to be seen in smaller countries such as Sweden, Finland, the Netherlands, where companies have been forced since the beginning to face global competition: this is the case, for example, of L.M. Ericsson and Nokia in the telecommunication supply industry and mobile telephony. There are data which demonstrate the backwardness of Europe's competitive position in the emerging technologies. For example, attention is drawn to Table 7, from OECD, which shows the values of international specialisation indices with reference to 1970 and 1992. The already unsatisfactory position of Europe in high technology sectors has deteriorated during the period under consideration, whilst Japan has strongly improved, to the extent that it now challenges America's leading position. This assessment is confirmed by the data on average annual values of interchange of high technology products between the countries of the Triad over the five years between 1989 and 1993, from which we see that the European Union's average annual deficit with respect to the USA and Japan amounts to nearly 24 billion ECU (Fig. 5).

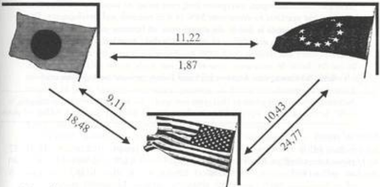
As underlined in the Delors White Paper, Europe must now accelerate the construction of its large-scale modern infrastructures in energy, transport and telecommunications. These ought to be conceived and designed from the start as instruments for development of the whole of Europe, West and East, and take into

Table 7 - *International Specialisation Index for High, Medium and Low Technology Industries.*

OECD = 100	JAPAN 1970	JAPAN 1992	USA 1970	USA 1992	EUROPE - 15 1970	EUROPE - 15 1992
High Technology	124	144	159	151	86	82
Medium Technology	78	114	90	90	103	100
Low Technology	113	46	67	74	103	113

Specialisation index: Country's share on total exports, divided into the same coefficient of the OECD countries. An index higher than 100 in one range of products states that the country is specialised in the export of those products.

Source: OECD.



Source: Eurostat.

Fig. 5 - Trade of high technology products between the three poles of the Triad (average 1989-1993). Volume of trade (expressed in billion ECU).

account the opportunities represented by an increasing interaction with its neighbouring countries of the Mediterranean basin.

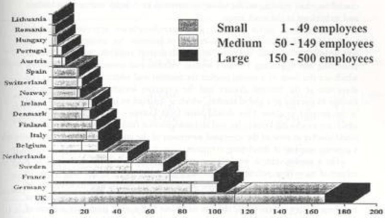
It is particularly important for Europe to identify those "critical technologies" which can provide a driving force for the European economy. The selection of critical technologies for Europe should, I believe, take into account the sectors where Europe itself is already competitive on a world scale; those that are a feature of the continent's high level of social welfare, (health, housing and urban structures, and the environment); those that are based on deep cultural and aesthetic roots (fashion and style, cultural heritage); and, last but not least, those that are the products of the technological revolution. These, of course, are broad indications and not an exhaustive list. Further, each technology must be analysed carefully so as to identify specific tendencies and applications on which to concentrate ideas and resources.

Biotechnology is certainly amongst the most promising, and therefore, critical technologies for Europe. It should be recognized, however, that, in spite of the scientific excellence of Europe in the biosciences, the biotechnology industry is much more developed in the United States. Today, as shown in Table 8, in the U.S. there are almost 1300 active enterprises, about 300 of them being quoted on the stock exchange, which give a job to nearly 120,000 people and have a turnover of 13.2 billion dollars. Given the long time needed to develop and bring to the market a new biotechnological product, for example, in the pharmaceutical sector, American biotechnological enterprises lose, even today, an average of 32% of their turnover, but continue to invest over 50% of it in research and development. This extraordinary position is due to the strong sense of business which dominates the country and to the availability of venture capital, attracted by the enormous

Table 8 - *Comparison between USA and Europe in biotechnology industry.*

	1995		1996		Variation %	
	USA	Europe	USA	Europe	USA	Europe
Financial aspects						
Sales (million ECU)	10,160	1,471	11,680	1,721	15	17
R&D expenditures (million ECU)	6,160	1,252	6,320	1,508	3	20
Net Loss (million ECU)	3,680	1,206	3,750	1,113	2	−8
Industry						
Number of enterprises	1,308	584	1,287	716	−2	23
Number of employees	108,000	17,200	118,000	27,500	9	60

Source: Ernst & Young, BioBusiness.



Sources: Ernst & Young, BioBusiness.

Fig. 6 - European biotechnology industry shared between different countries and between the size of enterprises.

potential for development of the biotechnologies. Some of these enterprises have already begun to make large profits: Amgen, for example, has realised profits of 180 million dollars in the first three months of 1997. Only recently has Europe, thanks mainly to the UK, which alone has 180 biotech companies of which 65 are of medium or large size, begun to gather momentum. Fig. 6, which records data on the number of biotechnology companies operating in the various European countries, indicates, however, that we are a long way from fully realising the available potential. From an American point of view, biotechnological Europe is still a kind of "Wild East", full of rich, by and large unexploited, scientific resources.

It needs, however, to be recognised that the technologies that are critical the United States or by Japan. Each country (or group of countries in the case of Europe) has its own characteristics. Europe must overcome its weaknesses where necessary, but it must also build on its strengths. Europe, in fact, has an extraordinary cultural for Europe may partly differ from those considered to be critical by endowment stemming from the diversity of ethnic groups and national cultures, languages, customs and traditions. This diversity makes the integration of the various components of the Union more difficult. However, it results in an extremely rich social fabric and is especially useful in a world where innovation increasingly requires an approach that extends to the social sciences and humanistic disciplines, thus drawing on the whole spectrum of knowledge and not just science and technology in the strict sense.

To mention a sector where a wide interdisciplinary approach would be particularly useful, just consider the enormous potential for integrating historical and artistic studies with scientific and technological research, with the aim of protecting and upgrading Europe's artistic, cultural and environmental resources, which are the basis of a strong market for tourism and educational activities. The sheer size of the internal market and the expertise accumulated would permit Europe to operate in a global market, which is destined to become very important in the decades to come. One should learn from Europe's environmental policies, which are producing knowledge and technologies that find important outlets in the world market in view of the increased awareness of the environmental problems in a growing number of developing countries.

On a similar vein, it would be a mistake if Europe, rightly committed to a reform of its welfare policies, were to throw the baby out with the bath water. In addition to renouncing, not so much an operational instrument as a system of values which has made a positive contribution to the quality of life on our continent, such a course would deprive us of one of the most promising sources of future technological development and new jobs. In the field of health, for example, the longer life expectancy and lower birth-rate, along with the multi-ethnic transformation of European populations and the spread of old and new diseases, are expected to lead to a growing diversification of the demand for social services, with a potential spin-off in terms of new and improved products and activities.

Overall, a good competitive position has been achieved by Europe in the traditional sectors of medium-low technology, where a myriad of European small and medium-size enterprises (SMEs) have been able to absorb and adapt technological inputs from the outside, either incorporated in modern equipment and machinery, or in new materials as they have become available in the market. This was helped by the strong position in mechatronics of some European countries, including Germany, Italy, Sweden. European SMEs are often highly specialised, flexible and dynamic. On the usual definition of SMEs (fewer than 500 employees), they provide more than 70% of E.U. employment and generate more than two thirds of the total turnover and a proportional fraction of value-added. The role of SMEs should be seen also in the light of their contribution to solving Europe's difficult unemployment problem. The average unemployment rate in Europe is over 10%, involving some 18 million people: it is as if the unemployed in Europe made up the whole population of the 6th largest member of the Union. In comparison, unemployment in the United States is now below 5%, and in Japan is about 3%. This colossal waste of human potential is particularly felt by the young, (the unemployment rate for Europeans under 25 years old is over 20%), even when well qualified. Without a massive injection of technological innovation, the situation is destined, irreversibly, to worsen.

Table 9 - *Venture Capital Investments in Europe and the United States (1995).*

1995	USA (1)			UE (2)		
	KEKU	%	#	KEKU	%	#
Total investments	5,748,000	+ 50	1,100	5,546,000	+ 2	4,955
Investments per stage						
seed & start-up	1,475,000	26	445	320,000	0,2	939
development	3,307,000	58		2,300,000	5.7	
Leveraged buy-out	932,00	16		2,900,000	52	
Investments per sector						
Informat-techno.	2,641,000	46		902,000	16	
life sciences	1,398,000	24		422,000	8	
non-technology	1,709,000	30		4,222,000	76	
average size of seed-capital	932			280		

(1) *Source:* VentureOne (American Company).
(2) EVCA.

Even though European SMEs possess a series of qualities that result in their being superior, on average, to their counterparts in the United States and Japan, (important among which is the widespread culture which is part of the inheritance of a long-standing tradition of highly specialised artisan and craft activities, often associated with a taste for design and creativity), their small size is an objective handicap when it comes to tackling the complex challenges of new technologies and global competition. It is therefore necessary to adopt policies that will encourage European SMEs to grow in size and, even more important, to become linked in networks. The risk facing SMEs is that of remaining "prisoners" of the culture of the sectors in which they operate, without being able fully to appreciate the benefits which new technologies, especially in the fields of ITC, can bring in terms of productivity, quality and flexibility. Governments should therefore implement policies to foster the demand for information, training and advice to the SMEs, leading to a systematic uptake of new technology. The issue of venture capital is of critical importance for the success of high tech SMEs. Table 9 indicates that the riskiest undertakings, i.e. seed & start-ups, are much more financed in the United States than in Europe, where safer, "non-technology" investments, are preferred by venture capital outfits.

The European Union's Research and Development effort should remain catalytic in nature, strategic and based on high-quality programmes and projects. Its value added should reside in promoting European research co-operation and networking; reducing the degree of parochialism of the research milieu and favouring a dialogue between university and industry in basic and strategic research; helping to co-ordinate national RTD programmes; stimulating the mobility of European young scientists and engineers; promoting the dissemination and diffusion of new technologies, wherever generated; involving SMEs; and co-operating with non-European countries. Furthermore, the Union must definitely abandon the pre-competitiveness constraint, and consider the subsidiarity principle in a modern way, that is by promptly recognising and facing boldly those projects that, by their own nature, demand a European, if not global, approach.

The dedication of greater resources to research and to the scientific and technological training of European human capital is certainly necessary. But a change in mentality becomes even more necessary in order to overcome, in European research, the attitude that considers public financing as subsidies to be granted to universities and enterprises, no matter what are going to be the results. Similarly, the European financial system should learn from its American counterpart how to adopt an attitude rewarding new ideas and innovation, even if it means a much higher acceptance of risk than has so far been the practice. We need to define and carry out, with a new entrepreneurial spirit, a strategy for sustainable economic and social development, to be shared by all the members of the European Union.

In closing, let me say that a forward-looking science and technology policy should also be ethically inspired, if Europe wants to play the role it deserves in ensuring that social progress keeps pace with scientific advance, and that the gains of today's technological revolution go to benefit the whole of mankind.