Version donnée par UM le 10/12/97
+ partie 5 de JR
traduit en anglais par BS

Executive summary and highlights of the second European report on S&T indicators

Part I : European science and technology in the world

1. Access to scientific and technological knowledge and the ability to exploit it are becoming increasingly strategic and decisive for the economic performance of countries and regions in the competitive globalized economy.

- The 50 leading S&T countries have enjoyed a long-term economic growth much higher than that of the other 130 countries of the rest of the world. Between 1986 and 1994 the average growth rate of this heterogeneous group of countries was around three times greater than that of the rest of the world. The average economic wealth per capita of these 50 countries has grown by 1.1% per year in constant ECU. On the other hand, the per capita income of the group of 130 countries - which perform less well in education, science and technology - has fallen over the same period by 1.5% per year. These trends prefigure a new division of the global economy, based on access to knowledge and the ability to exploit it.

- Within the group of 50 countries two major trends in terms of economic convergence can be observed over the last fifteen years. The first concerns the most industrialized nations of this group, whose long-term economic performances have tended to converge. The second major trend is the economic catching-up process of about 16 emerging countries, most of them from Asia, which are among the less developed of the group of 50.

- A comparison of the growth of the 50 countries reveals three main differences: the 16 high-growth countries stand out from the others, and notably from the most industrialized countries of the group, in terms of their weak emphasis on monetary stability (except for three or four countries), their simultaneously strong domestic and external demand, and their technological positioning which is based more on the dissemination and rapid economic exploitation of new knowledge than on their national production.

- The long-term growth of the European economy is quite comparable to that of the US and Japan, ignoring short-term divergences which are often due to differing economic cycles. However, certain contrasting trends emerge when one compares the principal factors relating to competitiveness. While the EU’s performance in terms of trade, foreign direct investment, monetary and budgetary stability, labour costs and income distribution would seem to be comparable, even perhaps superior overall to those of the US and Japan, the same cannot be said for savings and investment, the cost of capital, industrial production and economic redeployment in advanced technology industries with high R&D intensity.

- The performance of the EU is weakest in relation to employment creation. In contrast to growth of 27% in the US and 14% in Japan between 1980 and 1995, employment stagnated in Europe during the same period. The manufacturing sector in Europe has lost many more jobs than in the US and Japan, while employment creation in the service sector, which between 1985 and 1990 was greater than in the US and Japan, has fallen sharply during the first half of the 1990s.

- The relationship between technology and employment is both close and complex. Hi-tech industries lost far fewer jobs than other sectors during the period 1980-95, in Europe and in the US and Japan. Taking the OECD countries together, the pharmaceuticals, chemicals, electronics and computer sectors have created employment, whereas industries with a low R&D intensity have shed jobs massively. Contrary to widely held belief, job creation is stronger in those countries that devote a greater proportion of their investment to new information and communication technologies.

2. Compared with the US and Japan, the EU devotes a lower proportion of its resources to S&T, both as a percentage of GDP and per capita.

- Having increased rapidly during the 1980s, global expenditure on R&D stagnated during the first half of the 1990s. The level of intensity of R&D expenditure (R&D expenditure / GDP) of the leading 50 countries fell to 1.6% of global GDP, compared with 1.9% in 1990 and 1.5% in 1980. Although the outlook for growth of the world economy is good for the second half of the 1990s, it is not expected that there will be a rapid increase in the average intensity of R&D expenditure for the 50 countries.

- The share of Asian countries in global R&D spending rose to 27.6% in 1995 compared with 17.1% in 1980. The share of the 27 European countries that feature in the list of 50 leading S&T nations has declined from 38.5% in 1980 to 30.4% in 1995, and that for the countries of the American continent has fallen from 43.3% to 40.5% over the same period.

- In 1996 the intensity of R&D expenditure of EU15 in relation to its GDP was 1.8%, compared with 2.7% for the Developed Asian Economies (DAE), 2.2% for NAFTA and 2.1% for EFTA. The EU also devotes a much lower proportion of its GDP to R&D than the US (2.4%), Japan (2.8%), and the average for South Korea, Singapore and Taiwan (2.3%). Between 1990 and 1996, the US spent 277 billion ecus (PPS 1990) more than the fifteen member states of the EU. The inadequacy of the R&D expenditure of the EU can be seen clearly in per capita terms, with the EU spending 271 ecus (PPS) per head in 1995, while NAFTA spent 396 ecus (PPS) and the DAE 406 ecus (PPS).

- In 1995 R&D expenditure by EU firms amounted to 103 billion ecus (constant PPS) against 151 and 60 respectively for US and Japanese companies. In terms of R&D intensity, EU enterprises are behind their US and Japanese competitors (who invest 1.6% and 1.9% of GDP respectively) recording only 1.1% in 1995, down from 1.3% in 1990.

- Over the period 1985-1995, the strongest growth in R&D intensity was observed in Sweden (from 2% to 2.7%), in South Korea (from 0.9% to 2%) and in Finland (from 0.9% to 1.5%). The largest decline in technology intensity occurred for German firms (from 2% to 1.5%), followed by US enterprises (from 2.1% to 1.8%). In the other large European countries the intensity of firms' R&D spending has remained relatively stable, for example in France (1.4%) and in UK (1.3%).

- In almost all the large industrialized countries, around 65% of R&D expenditure is generally concentrated in five or six medium- or high-technology industries, such as aerospace, computers, electrical/electronics, chemicals, pharmaceuticals and motor vehicles. Those sectors that are the greatest users of information technologies are different and can be found mainly in the service industries (finance, transport, construction, market services, etc.).

- Government R&D expenditure has fallen sharply over the last fifteen years in response to the combined influences of economic liberalization, privatization, the progressive impoverishment of states, and the end of the cold war, which was the major driving force behind public R&D spending during the post-war era. Government expenditure accounted for nearly 53% of total R&D spending in 1980, but has continually dropped, reaching 45% in 1990 and 38.8% in 1995. The decline in government spending has intensified during the first half of the 1990s; indeed expenditure has begun to fall in absolute value as well, passing from 174 billion ecus (constant PPS) in 1990 to 148 billion in 1995.

- Taking the 50 countries together, their total intensity of goverment R&D expenditure has fallen from 0.84% to 0.63% of GDP between 1990 and 1995. The same figure for the EU dropped from 0.95% to 0.84% over the same period, compared with a decline from 1.15% to 0.95% in the US, and a rise from 0.45% to 0.52% in Japan.The US federal government spent 206 ecus (constant PPS) per capita on R&D in 1995 as against 236 in 1990. Public R&D spending per capita in the EU, while relatively stable at 127 ecus (constant PPS) in 1995, versus 133 in 1990, is still considerably below that of the US federal government. Between 1990 and 1995, public R&D expenditure per capita rose rapidly in Japan, reaching 90 ecus (constant PPS) in 1995. If this trend continues during the second half of the 1990s, public per capita spending in Japan could overtake that of the EU around 2005.

- The aim of government expenditure on R&D is to finance the activities of the public research sector and to complement the efforts of firms. As the public research sector is well developed in both the EU and Japan, it receives a relatively significant share of public R&D resources in these two economies. The situation in the US is different. A larger proportion of government spending in the US finances the R&D activities of the enterprise sector. About 18.4% of the R&D expenditure of US firms is financed by the US government, compared with 9.5% in the European Union and 1.6% in Japan.

- Expenditure on military R&D has continued to decline since 1988 in all the industrialized countries. Nevertheless, its share remains significant in the US, with around 55% of US government spending allocated to defence in 1995, against 18% in the EU and 6% in Japan. The UK and France also invest a high percentage of their public spending in defence: respectively 41% and 30%.

3. Between 1980 and 1994, public investment in education and human capital in the EU rose slightly, but is still below that of the US.

- Public spending on education for the fifteen member states of the EU rose from 204 billion ecus (1990 PPS) in 1980 to 286 billion in 1994. Despite this increase, the EU's share in the total expenditure of the 50 countries most active in S&T has remained stable at around 27%. The sharpest growth in education expenditure occurred in the Asian countries. While the share of the developed Asian economies (Japan, South Korea, Taiwan and Singapore) grew slightly from 12% to 13%, that of the other Asian countries (China, Thailand, Indonesia, India, Pakistan, etc.) more than doubled over the same period from 6% to 13%. The share of the American countries, in particular the US, and of the European countries not members of the EU fell between 1980 and 1994.

- Public expenditure on education per capita in the EU was 774 ecus (constant PPS) in 1994, compared with 1356 for the EFTA countries, 939 for NAFTA, 898 for Australia and New Zealand, and 685 for the DAE. The position of the EU is hardly any better if one considers expenditure as a percentage of GDP (5.4% in 1994), being marginally higher than the developed Asian economies (4.6%) but lower than NAFTA (5.7%), EFTA (6.9%) and countries such as Australia, New Zealand and Israel.

- The five countries that spend the most on education per head of population are Norway (1733 PPS), Canada (1402 PPS), Denmark (1328 PPS), Sweden (1274 PPS) and Switzerland (1139 PPS). These countries are followed by the US (1124 PPS), France (945 PPS) and Finland (941 PPS). With 881 ecus (PPS) education expenditure per capita, Japan sits at fifteenth place among the 50 countries most active in S&T.

4. The number of university graduates per year is lower in the European Union than in the US, while the EU's university graduation rate in the natural sciences and in engineering is well below that of NAFTA and the DAE.

- In terms of the annual flow of university graduates, all disciplines taken together, the three NAFTA countries, with 3.7 million university graduates in 1994, outstrip the fifteen EU member states (2 million graduates) and the four developed Asian economies (1.6 million graduates). The US holds first place with 2.4 million university graduates, well ahead of Japan, Russia, China and India where the number of university graduates is around one million per year. Even in the larger countries of the EU, the annual flow of graduates is comparatively modest: 471,000 in the UK, 390,000 in France and 314,000 in Germany.

- The university graduation rate in the natural sciences and in engineering per 1000 population of 20-24 year-olds is 17 for western Europe (EU plus EFTA), 22 for North America (US plus Canada) and 26 for the three developed Asian countries (Japan, South

Korea and Taiwan). In the natural sciences the first position is taken by North America, while in engineering and technology the Asian countries occupy the top place, however, western Europe comes third in both cases.

5. The EU has a relatively small number of researchers compared with its competitor countries and regions, and European enterprises employ far fewer researchers than their US and Japanese counterparts.

- In 1995 there were 826,000 research scientists and engineers in the European Union and 36,300 in EFTA, compared with 1,064,000 in NAFTA (of which more than 962,000 in the US) and 746,460 in the DAE (of which 552,000 in Japan). When these figures are related to the active population of each region, western Europe, with 5 research scientists per 1000 active, comes behind NAFTA and the DAE with respectively 7.1 and 7.4. Germany is the leading member state in terms of numbers of research scientists and engineers with 230,000, followed by France and UK with 149,000 and 146,000 respectively.

- A major weakness for the EU emerges if one examines the numbers of researchers and engineers in the enterprise sector. European firms employ only around 397,000 researchers to carry out their R&D activities, compared with 758,000 employed in US companies, and 384,000 in Japanese firms. The extent to which Europe is lagging behind can be seen more clearly when one considers enterprise researchers in relation to the total population of each economy: the EU has 1.1 enterprise researchers per 1000 population, compared with 2.8 in the US and 3.1 in Japan.

6. Overall the EU's scientific performance is excellent, but it needs to specialize more in the fields of engineering and industrial applications.

- During the 1980s, US researchers on average published 25,000 publications per year more than EU researchers. The EU enjoyed higher growth in scientific publications than the US during the first half of the 1990s, and in 1995 European production overtook that of American researchers, registering almost 208,000 scientific publications compared with 203,000 for the US. With around 53,000 publications, Japan lies well behind the EU and the US. The impact of scientific publications produced by NAFTA, in terms of citations, remains above (around 1.4) that of the EU (1.05) and south-east Asia (0.84).

- At the global level there appear to be four main models of scientific specialization: the "*western model*", prevalent in the countries of western Europe and North America, and characterized by a strong specialization in clinical medicine and biomedical research; the "*former communist model*" based on specialization in chemistry and physics and still predominant in the economies in transition and in China; the "*Japanese model*", with its strong specialization in engineering and chemistry, which also encompasses the other countries of south-east Asia; and finally the "*bio-environmental model*" centred around biology and earth sciences, and dominant in the large majority of developing countries.

7. The technological performance of the EU, measured in terms of patents, has halted its decline, but still remains well below that of the US in many fields and behind Japan in information and communication technologies.

- European countries account for 48% of the patents applied for at the European Patent Office (EPO), 5% of the patents at the Japanese Patent Office (JPO) and 20% of those at the US Patent and Trademark Office (USPTO). The American's share of patents in their own system is 55%, and around 24% in the European system. As for Japan, they are responsible for 87% of JPO patents and 20% of EPO patents.

- An analysis of Triad patents - that is, those patents that originate from one of the three poles (EU, US, Japan) but that are also filed in the other two - reveals that patenting activity per employee in Japan was far behind that of the US and the EU at the beginning of the 1980s, but grew remarkably up to 1989 to overtake the Europeans and the Americans. While Japanese technological performance deteriorated sharply during the first half of the 1990s, it was still above that of their competitors in 1995. The improvement in the US performance (from 1987) preceded the US economic recovery, but has stagnated between 1990 and 1995. As for the European decline, which worsened between 1989 and 1992, it appears to have halted in recent years, but European performance is still behind that of the US and Japan.

- A more detailed analysis of patenting activity at the EPO and USPTO shows that the EU's share of patents remained stable at around 50% at the EPO and 20% at the USPTO between 1980 and 1987. During the last three years of the 1980s, it shares fell sharply in both systems: to 44% at the EPO and to 15% at the USPTO. However, during the first half of the 1990s, this decline has slowed down and its patent share has started to level off.

- The EU's fields of specialization are without doubt aerospace, chemistry, pharmaceuticals and motor vehicles. Its already weak degree of specialization in computers, electronics and instruments dropped further during 1993 to 1995 compared with the mid-1980s. NAFTA does not appear to be strongly specialized in any one field, but its performance has improved in practically all technology areas. The developed Asian economies are strongly specialized in computers and electronics and to a lesser extent in motor vehicles, to the detriment of other sectors of technological activity.

- The patent shares of Germany and France (the two member states that file the most patents) have also fallen in recent years in both the European and US systems. Those of the UK (in 5th place at the EPO and at the USPTO) and Sweden (8th in Europe and 11th in the US system) have increased slightly between 1993 and 1995. However, Italy and the Netherland's patent shares have declined somewhat in the two systems over the same period. The same is also true for Japan, which seems to have entered a phase of technological recession, having been unable to specialize in new areas of technology other than computers and electronics. The Americans, on the other hand, are in a phase of technological "reconquest", with their performances improving in practically all fields.

- In terms of shares at the EPO in the various key technologies, the EU is in a relatively weak position in relation to its competitors in the fields of audiovisual and telecommunications, computers, electronics and instruments. Europe appears in top position in environmental and transport technologies and in materials and industrial processes. Its technological position seems to be improving in telecommunications, computers, materials and industrial processes. On the other hand, its performance is declining in electronics, instruments, pharmaceuticals and transport, and remaining stable in biotechnology and the environment.

8. The EU's trade performance in high-tech products is generally improving, but is still weak compared with the US and Japan.

- The EU's exports of high-tech products amounted to 12% of its total exports of manufactured goods to non-EU countries, compared with 24% for the US and 25% for Japan. As a result of Ireland's strong specialization in new technology during recent years, high-tech products now account for 37.6% of its total exports. In second place among the member states comes the UK, with 22% of its total export trade in high-tech products, followed by France (16.2%), the Netherlands (16%), Sweden (15%), Denmark (12.2%), Finland (11.7%) and Germany (11.4%). The other member states are relatively non-specialized in exports of high-tech products.

- In terms of the technology balance of payments, the US has recorded a significant and growing surplus in recent years. The opposite trend has been observed for the EU, with a deficit position that has tended to worsen during recent years. Only two member states - Sweden and UK - have registered an average surplus over the period 1991-1995. Belgium, Germany and Italy have deficits, although these are comparatively less significant than those of France, the Netherlands, Austria and Spain.

Part II : From R&D to innovation and competitiveness

1. In terms of investment in R&D, the EU is lagging behind its partners in most of the research-intensive sectors. The productivity of these sectors has been growing, but at the cost of jobs.

- Of the eight R&D-intensive industries considered in the report, electronics is the only sector in which the EU displays a higher R&D intensity (*i.e.* R&D expenditure as a percentage of production) than the US and Japan. It is furthest behind in scientific instruments (2.6% versus 8.2% and 8.5% for Japan and the US respectively), computers and office machinery (EU 4.6% against Japan 8.3% and US 13.5%) and chemicals (EU 2.8%, Japan 6% and US 3%).

- Nevertheless, across all eight sectors there has been a sharp increase during the 1990s in EU labour productivity, accompanied in most cases by strong growth in output. However, over the same period it has proven difficult to maintain levels of employment in these same industries.

2. ***In terms of technological specialization, the EU tends to focus its patent activity in the more mature industries, while in many of the key emerging technologies it is lagging behind the US and Japan. Meanwhile new players are rapidly coming onto the world scene.***

- It is in the more traditional industries (chemicals, motor vehicles and aerospace) that Europe performs most solidly in terms of its patenting specialization, while it is seen to be least specialized in computers and office machinery, electronics and instruments. This said, there are some significant exceptions: for example, the UK in pharmaceuticals and the Netherlands in electronics.

- Perhaps more important for the future is the EU's relatively weak inventive performance in the key emerging technologies. The US has the dominant share of patents at the European Patent Office (EPO) in virtually all key technology fields, and in particular enjoys a substantial lead in key technologies relating to pharmaceuticals and drugs (with 60% of EPO patents versus the EU's 27%) and biotechnology (56% EPO share against 31% for the EU). Japan remains very focused on electronics, audiovisuals and telecommunications, and performs well in patenting individual key technologies in these fields, not least in electric vehicles (where it has 40% of EPO patents versus the EU's 20%) and flat screens (51% against Europe's 22%).

- In the meantime there are a number of new players emerging on the world scene. The dynamic economies of Asia, particularly Korea and Taiwan, have expanded their patenting activity at a phenomenal rate across a number of sectors. The rapid emergence of China as a patenting force should also be noted, although its patent numbers are still relatively low. Within the European Union, it is the smaller countries (notably Finland) whose patenting is growing most rapidly.

3. ***There is some evidence to support the so-called European Paradox - that the EU's healthy performance in scientific research is not being translated into strong technological and economic performance - but the picture varies across different member states and industries. Moreover, a new paradox emerges: Europe's exports of high-tech goods are growing rapidly, in spite of its rather moderate in technological return on investment.***

- The EU performs well compared with Japan and the US in terms of its scientific output (publications) per unit of related expenditure. However, its technological return (patents divided by business R&D expenditure) is less impressive, falling well below the US and Japan in terms of US patents, and above the US and Japan in European patents, but with the US rapidly closing the gap.

- Significant differences are observed between Member States. The paradox is most clearly confirmed for Belgium, Greece, Spain, Sweden and UK, countries with high scientific output, but below average technological returns on investment. France, Italy and Portugal perform below average in both science and technology output, while Austria and Germany appear to be technologically successful without any strong science-push (as measured by publications). The best performers are Denmark, Finland and the Netherlands, who boast high levels of both patent and publication output.

- The picture also varies at sectoral level. In certain industries (computers, electronics, pharmaceuticals) Europe is obtaining substantially fewer patents per unit of business R&D expenditure than its competitors. On the other hand, chemicals and motor vehicles are sectors which yield relatively good returns for the EU, especially in terms of European patents. However, when one looks at the eight R&D-intensive sectors combined, Europe's performance is seen to be behind that of the US and Japan. In terms of US patents, the EU produced 201 patents per unit of business R&D expenditure during the period 1991-94, compared with 206 in 1986-90; meanwhile the USA and Japan increased their patent return dramatically, the USA from 305 to 437, and Japan from 460 to 532. While the EU still leads in terms of EPO patents per unit expenditure (333 during 1991-94 compared with 285 in 1986-90), the USA and Japan have again registered massive increases in patent productivity: the US growing from 115 to 203, and Japan from 247 to 295 over the same two periods.

- Some of Europe's performance in this regard could be explained by the relative weakness of the linkage between its science and technology. Looking at scientific publications cited in European patents (a measure of the underlying science used in patented inventions), the EU has less science linkage than the US and Japan. This, in turn, is largely the result of the EU's sectors of patent specialization - electrical machinery, motor vehicles and aerospace - which are all associated with low science intensity. Nevertheless, some member states do perform well - *e.g.* UK with its strong inventive activity in modern chemistry.

- However, moving closer to the marketplace, when high-tech trade is examined another paradox emerges. In spite of its very modest performance in technological output, the EU's exports of high-tech products are found have grown rapidly during the 1990s. Perhaps surprisingly, it is in computer and electronics products (and notably integrated circuits) that the largest increases have been observed. This growth is also quite concentrated in terms of Member States, with much of the export rise being attributable to the Netherlands and UK. One of the hypotheses which might explain these somewhat unexpected trends is that of re-exportation, namely that foreign multinationals choose the EU as a home base for the assembly and re-exportation of their final product possible to Eastern Europe or some parts of central Asia. A second hypothesis is that of growing intra-firm trade, that is trade between firms belonging to the same multinational group but located in different countries.

- Despite these positive trends, there are some reasons for caution. The EU still has an overall trade deficit in high-tech products. Europe's R&D intensive sectors also export a lower proportion of high-tech products than do the US and Japan, in other words they are more geared to the medium- and low-tech end of the market.

4. ***Multinationals continue to play a major role both in employment and in R&D expenditure. However, unlike their US counterparts who are now creating employment, EU multinationals have been shedding jobs much faster than the sectoral average.***

- In 1995 the European, US and Japanese multinationals whose main activity was in the aerospace industry accounted for 31% of R&D expenditure and 65% of the jobs in this sector. In the IT-related industries (computers and electronics) the giants account for more than 40% of total spending on R&D, but provided less than 40% of the jobs. In the automotive industry they were responsible for 80% of the total R&D spend, but less than 60% of the employment. The true employment effect may, however, be somewhat larger than these figures suggest: in the automobile industry, for example, multinationals tend to form clusters with their local suppliers thus creating employment.

- During the first half of the 1990s, in every EU sector except pharmaceuticals, total sector employment has been falling by at least 2-4% a year. And it is the leading European multinationals who appear to be shedding jobs much faster than the sectoral average, especially in pharmaceuticals (-8%), computers (-9%) and aerospace (-11%). However, in the US the picture is reversed. The period of downsizing and restructuring is now over, and the multinationals are now creating jobs, particularly in those industries where sectoral employment is falling.

- While Japanese multinationals appear to be increasing their emphasis on research it seems that European multinationals are publishing less than their US counterparts and are focusing more on patenting, *i.e.* development, activities. This publication-patent gap suggests that basic science in Europe is still being driven by universities and public research institutes, and threfore that there may be a need to improve the interface between university and industry.

5. ***There is evidence that movements in personnel (job creation and job losses) are more significant in innovative SMEs than in non-innovative SMEs. As for new technology-based firms (NTBFs), so far there are no real European success stories in terms of employment creation, but they do have an indirect positive impact on the economy.***

- An analysis based on a sample of SMEs backs up certain findings from other studies concerning the relationship between innovation and employment. While there is no significant difference between innovative SMEs (using a stringent definition) and non-innovative SMEs as regards their average employment growth, the evidence suggests that the innovative activities of the former group lead to larger movements in personnel in terms of employment creation or job losses.

- The impact of new technology-based firms on the renewal of European industry seems to be marginal, in contrast to the US, where one only has to mention the names of Microsoft, Apple Computers, Intel and Dell to appreciate the effect of NTBFs on the US economy. So far there have been no equivalent EU success stories in terms of growth and job creation. However, European NTBFs do play an indirect role, having a significant impact on knowledge creation in Europe and providing high-quality careers for many PhDs.

PART III: European Diversity, Convergence and Cohesion

1. The use of 'technology scorecards' allows one to evaluate the technological systems of the EU Member States. Among the most R&D-intensive member states, France has an R&D system that is largely government based, the German system is most oriented to applied research and the UK system is most favourable to the enterprise sector ; the Irish R&D system is the fastest growing ; R&D in the small member states is very dependent upon a limited number of multinationals.

- Of the group of four EU countries that spend most on R&D, Germany and France (with R&D expenditure of 2.3% of their GDP), and the UK (with 2.1%) are well in front of Italy, the lowest of the four with 1%. It is in Germany that research is the most financed by business enterprises, which account for 61% of total financing, compared with 48-49% for the three others. Germany and the UK are the countries with the highest rate of employment of research scientists in the business enterprise sector. France has the highest level of scientists per thousand employees (12.65 compared with 12.14 for Germany, 11.85 for the UK and 6.37 for Italy), and also the strongest concentration of researchers in the private research sector.

- The Cohesion-4 countries include Portugal, Spain, Ireland and Greece. Except for Ireland, these countries uniformly have a very weak R&D system. Ireland has a very strong private sector, however, with 69% of its R&D investment carried out by enterprises, the second highest percentage in Europe after Sweden. At the same time, the Irish government gives relatively little direct support to R&D activities. After Greece, Ireland has the lowest level of GBOARD, at less than 1% of total government expenditure. The Irish R&D system seems to rely very much on the presence of foreign multinationals.

- The R&D systems of most of the smaller EU member states are strongly reliant on the presence of a few big enterprises, and consequently the private sector plays a very significant role in their R&D systems. Sweden, for instance, depends on the private sector for 78% of its R&D. In Belgium over 90% of BERD is financed by the enterprises themselves; only Finland has a higher percentage. In short, there is a large gap between public and private sector investment in Belgium, which is also reflected in the very small number of R&D personnel working in the government or higher education sectors.

2. Budgetary pressures form the major challenge to each member state's innovation and technology policy, and there is a need to organise policy objectives more efficiently.

- In most EU Member States, the percentage of GDP devoted to the financing of R&D has been decreasing steadily since 1985. In addition, the expectations of society and of the private sector regarding R&D and innovation have changed. The current hot topics are environmental R&D, technology transfer to small firms, and the fostering and promotion of a favourable environment for R&D investment, notably by means of fiscal measures.

- In order to improve the efficiency of R&D policies, many member states have put increasing emphasis on technology foresight and forecasting activities. The main conclusion from these exercises is that research should concentrate more closely on a limited number of “knowledge themes”.

- State aid and indirect financial schemes are the main intervention mechanisms for public R&D support. State aid represents about 1.8% of the European GDP and 3.5% of total public expenditure. On average, 7% of this total aid figure is focused on R&D. However, there is a considerable disparity between the member states. In the Netherlands and Denmark, R&D amounts to almost 30% of the total public support. Greece, Italy and Ireland lag behind and spend no more than 2% of their total support on R&D.

- Over 30% of state aid (in 1993) was spent to remove interregional disparities. Although SMEs are often considered by policy makers to be a high priority target, they have received increasingly less state aid since 1989. In 1993, only 7.6% of the total budget was allocated to them, compared with 14% in 1989. Moreover, this funding was scattered over a large number of programmes. SMEs accounted for almost one fourth of all state aid programmes.

- The European Venture Capital industry is resurging after a period of slowdown. There has been a blossoming of New European stock exchanges which target mainly small and medium-sized companies. Harmonization of these financing schemes will probably be needed in order to achieve economies of scale and to raise the average seed deal size from the 280 kECU currently prevailing in Europe to the 932 kECU average recorded in the US.

3. ***A small number of technology-intensive regions continues to dominate Europe, but the technological gap is narrowing between the least R&D-intensive and medium R&D-intensive regions. However, many factors other than R&D determine economic cohesion within the EU.***

- A small number of regions dominates the R&D landscape in Europe. Among them, one finds Baden-Württemberg, Île de France, Rheinland, Bayern and Nordhrein-Westfalen, Vorarlberg, Hamburg, Rhône-Alpes and Alsace. There is a gap between these regions and all the other ones. It could be said that they ‘dominate the European R&D system’. Despite this continuing dominance, the intra-EU technology gap is decreasing.

- The former East German Länder (Thüringen, Sachsen, Brandenburg and Mecklenburg) have experienced the largest average annual growth rates in GDP per head. Each of them grew at a rate of over 9% per year. At a considerable distance they are followed by the catch-up regions: Ireland, Algarve, Alentejo, Centro (P) and Kriti. The latter group experienced an average growth of about 5% in the nineties. After them, the majority of regions follows under the leadership of the Dutch regions, Friesland, Noord-Brabant and Utrecht, which enjoyed annual growth rates of close to 3%. At the bottom end, many of the Greek regions are found. Ipeiros, Dytiki Makedonia and Sterea Ellada each suffer from decreases in economic welfare above 1% annually.

- According to their economic and technological performance, the EU regions can be into four groups: the *stars*, the *question marks*, the *cash cows* and the *sleeping birds*. The first group contains most of the technology leaders described above. Economic performance and technological output go hand in hand in these regions. The sleeping birds are the more agricultural zones in Europe in which R&D plays only a minor role. The cash cows comprise the EU's industrial heart, but suffer from economic growth problems. Finally, the question marks are those regions that could have a high R&D potential in the future.

- Objective 1 regions increasingly participate in the Framework Programmes, but this is mainly through their universities and research institutes. In contrast, the participation share of the enterprise sector is falling. The educational sector receives 41% of the total R&D budget from the Framework Programme aimed at objective 1 regions, compared with only 27% in the other European regions. Objective 1 regions tend to integrate themselves in networks with the leading EU regions, but produce few spill-overs to local industry.

4. ***Economies in Transition are focusing increasingly on basic research and less on applied research. Despite the increase in Foreign Direct Investment in these countries, R&D remains largely concentrated in the government sector.***

- Central and Eastern European countries need structural changes if their transition to a market economy is not to cause a further deterioration of their R&D bases. In some countries such as Russia and Romania, over 50% of R&D expenditure is consumed by the salaries of the researchers. Despite this, salaries do not match what can be earned outside in the private sector. As a result, researchers either find a second job or look for better opportunities outside research.

- For the lack of reliable alternatives, government R&D funding remains the cornerstone of national S&T policies in EIT countries. Nevertheless, the budgetary appropriations for many Eastern European countries is at the level of certain southern European states, such as Greece, in the early eighties, at less than 1% of total expenditure. One might conclude that in these countries R&D has not yet acquired a high priority in state policy.

5. ***Mediterranean countries form a very heterogeneous group, among which Israel is without doubt the technological leader, followed at a considerable distance by Turkey. The other countries have, for various reasons, a negligible S&T system.***

- Israel - with its 1540 European and 1997 US patent applications during the period 1990-1994 - produces about twenty times as many EPOs and 80 times as many USPTOs as all the other Mediterranean countries put together (Morocco, Algeria, Tunesia, Egypt, Lebanon, Syria, Turkey, Malta, Cyprus, Albania).

- Israel, Egypt and to a lesser extent Morocco are relatively internationally-oriented. One in three national patent applications in Israel and Egypt are filed by non-residents, i.e. foreign subsidiaries of multinationals. In Morocco this is one in four. The proportion of foreign R&D is steadily increasing in each of these countries, and has almost doubled over the last ten years. In contrast, the Turkish S&T system remains very local. Only about 5% of all patents were filed by foreign subsidiaries in 1995, the same as in 1985. Despite this low foreign presence, the Turkish S&T system is the fastest growing in the Mediterranean block. National patent applications have almost tripled over the last decade to 1048 in 1995. This is still less than half the Israeli output of 2701.

- Israel is called the Mediterranean Dragon. The country has a human resource potential in R&D which is at the level of Austria and Belgium. In combination with its relatively low unemployment rate and high GDP per capita, this makes the country a very strong economic and technological bloc.

Part IV : European cooperation in R&D : actors and issues

1. During the last ten years, cooperation in R&D - both international cooperation and cooperation between large firms, SMEs and universities and research centres - has become a fundamental feature of European research and innovation systems. The EU's successive Framework Programmes for Research and Technological Development (FPRTD) have been a decisive factor in this development.

- The funding of R&D carried out through the numerous different channels of European cooperation such as the Framework Programme, EUREKA and the various European or international research structures (CERN, COST, EMBL, EMBO, ESA, ESF, etc.) represented 16.2% of total government expenditure for the EU and EFTA countries in 1995, compared with 6.2% in 1985.

- The FPRTD occupies a central position in this Europe of variable geometry in S&T. Not only does it represent a major source of funding for all European firms and universities, but also an increasing number of international organizations and European research institutions take part in the Framework Programme and obtain financial and logistic support from the EU. The coordination of national and Community R&D policies is also developing in accordance with article 130h of the Treaty.

2. The Framework Programme has gradually become the principal driving force behind scientific and technological cooperation in Europe.

- Between 1990 and 1996, more than 200,000 cooperative links were established between enterprises, universities and research centres as a result of the last two Framework Programmes for Research and Technological Development of the European Commission. Around 90% of these links are transnational and involve multiple actors belonging to different sectors of activity. The Framework Programme has become one of the major pillars of European cooperation and integration in the field of science and technology.

- The total number of participations in shared-cost actions has grown from 13064 in the 2nd FPRTD (1987-1991) to 18360 in the 3rd FPRTD (1990-1994), and then to 20674 during the first three years of the fourth Framework Programme (1994-1996). Enterprises of all types accounted for 36.6% of total participations in shared-cost actions in the 4th Framework Programme, compared with 35.8% in the 3rd. The share of universities and public and private research institutes fell slightly from 61.3% to 54.4% between the two most recent Framework Programmes. However, the share of international organizations and new research actors (hospitals, museums, libraries etc.) grew from 2.9% to 9.1% of all participations.

- Within the enterprise category, a readjustment in favour of SMEs has taken place over the first three years of the 4th FPRTD compared with the 3rd FPRTD. The share of SMEs in all participation has risen from 14.5% to 17.3%, while that of the large enterprises has fallen from 21.3% to 19.3%. In terms of Community funding, the share of SMEs has remained stable, but that of the large firms has dropped from 34.2% in the 3rd FPRTD to 26.8% in the 4th. Along with these 3573 SME participations, the 4th FPRTD has also encouraged more than 1500 participation from SMEs that have an insufficient internal R&D capability through its “Technology Stimulation Measures” designed specifically for this type of SME.

- The participation of the different actors in the specific programmes has also gradually diversified. The concentration of enterprise participation in certain specific programmes, and that of universities in others, is giving way to stronger cooperation between large firms, SMEs, universities and research centres across all specific programmes. In addition, cooperative links between large companies or between universities is being superseded by cooperative links between enterprises and universities and between large firms and SMEs.

3. In recent years, Community funds allocated to R&D have become an important source for the financing of R&D investment in the EU.

- The budgetary appropriations for R&D of the European Commission, including that part of the Structural Funds devoted to R&D, represented 9.7% of government civil R&D expenditure of the fifteen member states on average for the period 1995-96, compared with 4.6% for 1987-1990. The Community funds allocated through the Framework Programme alone amount to around 5.4% of the government expenditure of the fifteen during 1995-96. As for those funds distributed via shared-cost research actions (excluding JRC, concerted actions and accompanying measures), they represent 3.8% of the total.

- This relatively rapid increase in Community funding in relation to government funding is due on the one hand to the rise in the share of funding allocated to R&D from the general budget of the European Commission, and on the other hand to the relative decline in the share of R&D spending in the total public expenditure of the member states. The latter has fallen from 3.5% in 1985 to 2.6% in 1995-96 whereas the share of R&D in the general budget of the CE has risen from 2.1% to 5.1% during the same period.

- The proportion of Community funding in relation to national R&D expenditure varies widely from one member state to another, and from one region to another, given the strong disparities that exist in national spending between member state and between regions. For example, total Community funding (including the Framework Programme and part of the Structural Funds) amounts to more than 20% of public R&D expenditure in countries like Greece, Portugal and Ireland.

4. The pattern of Community research differs markedly from that of inter-governmental and inter-enterprise cooperation, and from international cooperation forged by and between researchers.

- The effects and importance of geographical, socio-cultural and linguistic proximities, as well as the power relationships between large and small countries, are lessened under the Community cooperation model, which instead promotes balanced and multilateral cooperation involving multiple actors and common objectives.

- On the one hand, the group of countries that form the core of the Community cooperation system has gradually expanded from three member states - Germany France and UK - to include first Italy and then Spain. On the other hand, the number of member states that are peripheral or weakly integrated in the cooperation network has fallen from five to two. This indicates the importance of the centripetal effect exerted by the Framework Programme. It can also be observed that the structure of cooperation between countries is less and less dependent on geographical, cultural and linguistic proximity. Participants of very different traditions, cultures and size can cooperate around a set of common objectives.

- In contrast, the core of the cooperation network resulting from the EUREKA programme is limited to one country - the United Kingdom - around which gravitate groups of countries linked according to the size of their economies, their industrial and technological specialization and their geographical location. A considerable number of countries find themselves as an occasional or peripheral partner.

- Cooperation established directly between firms in the form of technological alliances, and between researchers in the context of co-publications exhibit completely different patterns from the two other types of cooperation discussed above. In inter-firm technological alliances, apart from the UK, no other member states appears amongst the main group of players which includes the US, Japan and Canada. In international co-publications, the US, Canada, Germany and UK together form the central core of international cooperation. The other European countries are in the position of following or peripheral countries, dispersed in different sub-groups according to their geographical location or by their level of development. Some of the added value of the FPRTD therefore appears in the transnational S&T cooperation pattern that it promotes.

5. ***The increasing globalisation of technology is reflected in the growing number of international technology alliances. Technology alliances have become as important as R&D competition. Europe is a leading worldwide partner in the formation of these alliances along with Japan and the US.***

- A technology-based alliance consists of an agreement in which two or more firms unite to pursue a set of agreed goals while retaining their strategic autonomy. Each partner shares control over the performance of the assigned tasks, and the ensuing benefits. Finally, all partner firms contribute on a continuing basis in key strategic areas (such as manufacturing, distribution, technology, ...). In order to qualify as a be technology-based alliance, technology should be one of these key areas. 29% of all alliances between enterprises are technology-based, 46% are pure co-production agreements and 24% relate to marketing.

- Technology-based alliances are an international phenomen. For every national alliance, there are 1.31 international ones. More than 65% of such international alliances since 1980 relate to three new core technologies: information technology, biotechnology and new materials. Amongst the members of the European Union, only 8% of alliances are purely national, while 24% of the alliances are between the member states. The majority of international technology-based alliances (68%) are between members and non-members of the EU. Portugal (43%), Greece (100%) and Spain (71%) are the countries with the highest proportion of technology-based alliances with other EU member states. The UK, Germany and Ireland cooperate most intensively with non-EU member states. They respectively have 73%, 76%and 70% of all their alliances with countries outside the EU.

- The EU is not lagging behind the other major economic systems in its propensity for form technology-based alliances. The total number of EU alliances grew from 646 in the period 1988-1991 to 1718 in the period 1992-1995, an increase of 270%. In the same period, the NAFTA total grew from 1958 to 5618 (290%) and the DAE total from 574 to 1394 (240%).

- Only one-third of alliances are within the same industry, while two-thirds are set up by firms that belong to different industries. One can therefore conclude that alliances are primarily established to combine different technological skills, and only in the second instance to share R&D costs (within-industry alliances).

6. ***The international mobility of students is extremely important for fostering a global research and educational system. Despite some major impulse schemes organized both by the member states and the EU, language barriers still remain a major problem. Not surprisingly, the UK is the largest host country for EU students. In contrast, Germany is the main host for Eastern European students. The US remains the most popular destination for EU students.***

- The three largest inter-country flows of EU national students are from Germany (9400), Ireland (9000) and Greece (8700) to the UK. For most other EU member states, the mobility patterns remain rather parochial, being restricted to adjacent countries such as Sweden and Finland, Belgium and the Netherlands, etc...

- The EU has supported individual scientists to acquire training in other member states. The Human Capital and Mobility and later, the Training and Mobility of Researchers program have been established as vehicles to encourage international mobility. The main destination remains the UK, with over 500 fellowships recorded under the two programmes to date. Other important destinations are Germany, Belgium, the Netherlands and Spain.

7. International research networks further support the globalization of technology. The propensity to be involved in international co-authorships depends on: (1) the overall size of the country's scientific and technical community ; (2) the willingness of the community to participate in an international context ; other factors such as language, cultural and political isolation.

- The EU has the highest number of internationally co-authored papers, showing the region's strong embeddedness in the worldwide scientific community. The US follows closely behind. However, Japan remains rather isolated in this regard.

- International collaboration is an efficient way to enlarge the R&D efficiency of a country. Particularly in those countries with a relatively weak S&T system, internationally co-authored papers are significantly more cited than nationally-oriented papers. In such countries, having a foreign author doubles the chance of being cited.

PART V : The European Union as a world partner

1. Although Europe is increasing its own internal scientific and technical links, it is also fostering ties with its major industrial partners.

- The European Union has signed S&T agreements of "mutual interest" with 6 industrialised non-member countries enabling their participation, without Community funding, in the 4th Framework programme. Ten specific programmes have thus been opened up in 1995 to 60 projects involving such participants.

- Collaboration with the EU is increasingly attractive for most industrialised countries : the share of papers co-authored with EU researchers is high in neighbouring countries (over 25% in EFTA), and low in more distant countries (9% in NAFTA, 6% in DAEs). The propensity of European researchers to co-publish with North America remains high but has decreased, implying a greater diversification involving other countries.

- At the industrial level, EU-owned subsidiaries remain the major research investors in the US, with a share of two-thirds of all foreign R&D investment in the US, representing nearly 8% of US business R&D expenditure. Japan's share has more than trebled over 10 years to 12.7%. Conversely, Europe is the major overseas target of US corporates which were responsible for two-thirds of R&D investment in the EU in 1993, while Japan's share has increased up to 7% in the same year. Japan now has more than 300 R&D establishments in Europe, while Korea has 20 around the world.

2. Co-operation initiatives of the member states, and particularly of the European Union, have helped to sustain a minimum scientific and technological base in the transition countries, and have stabilised the fall in government spending.

- Under the International Co-operation INCO Programme (n° 3 Area), the European Union has merged what were previously half-a-dozen separate R&D programmes set up after the fall of the Berlin's wall in 1992. Prioir to their merger, these programmes had been progressively extended to cover more and more Central and Eastern Europe countries and the Newly Independent States (PECO, COPERNICUS,...). These schemes involve a much larger number of projects (300 in 1996) than those issuing from the S&T agreements discussed above.

- The number of co-publications produced by the Economies of Transition with the members of the Triad has increased, with the EU as the main partner, and Japan the least frequent co-author. The emergence of Russia after 1990 is remarkable, with joint papers produced with the US and Germany increasing by a factor 10.

3. Europe's involvement and concern in relation to science and technology remain insufficient in the less developed "South" of the globe.

- In the 3rd Framework programme 1990-1994, co-operation with developing countries centred around encouraging the mobility of researchers, and tackling agriculture and health problems, which were common to all potential participating countries.

- In the 4th Framework programme 1994-1998, both these lines have merged into a single programme (INCO-DC), which devotes the same level of funding to cooperation with 70 developing countries as INCO-Copernicus does for 23 transition countries. At the same time, the scope has been broadened to include renewable and sustainable resources, as well as ad-hoc topics of common interest.

- Within the EU, France is still the dominant partner of developing countries in terms of S&T co-operation, followed by Germany and the Netherlands (the latter being well above the average for its size). The US is the largest individual funder of technical cooperation. The EU countries contribute twice as much as the US and Canada combined, and 5 times more than Japan.