Is Capital Optimally Allocated in the Overall Process of European Innovation?

By Ugur Muldur*

in : Revue d'Économie Industrielle, No. 94, 2001, pp. 115-153

The (hypo) thesis of the "European innovation paradox", a subject of controversy and discussion amongst a small circle of European economists, became popular in European political circles during the last decade of the 20th century. At European Union level, the first sign of this thesis initially appeared in the EC's 1993 White Paper *Growth, Competitiveness and Employment,* and the first indicators which bore it out were published in the first two *European Reports on S & T Indicators* (ERSTI, 1994, 1997). It subsequently became one of the strong arguments for changing European policies on research and innovation, as well as on education and industry, in various official or internal Commission policy documents: the Green Paper on Innovation (1996), the White Paper on Education (1996), the communication *Inventing Tomorrow* (1997), the Report on Competitiveness (1998), and the communication *The Competitiveness of European Enterprises in the face of Globalisation* (1998). In addition to publications, the fact that political circles were taking it seriously was shown by the increase in public initiative and action in support of innovation.

As yet, however, the European paradox has not been the subject of an in-depth theoretical and empirical analysis. In the absence of any examination of its theoretical basis and given the present lack of appropriate indicators, it has sometimes been regarded as the expression of a simple imbalance between scientific and technological performance in Europe. This thesis in fact supports the notion that the low return on research and innovation in Europe is the result of internal malfunctioning or the attitude of those involved. It does not, however, explain the main reasons for this low return or for the European economies' lower level of ability, compared with the American and Asian economies, to convert their investment in new knowledge into innovative products and commercial success.

The principal explanations today are based essentially on organisational, institutional and even cultural factors, and ignore the question of funding. For our part, we are

---

* Head of the Competitiveness, Economic Analysis, Indicators Unit, European Commission. The analyses and conclusions presented in this report are strictly personal. They do not necessarily reflect the views of of the European Commission. A different version of this contribution will appear in the report on European industrial politics published by the Conseil d'Analyse Economique in France.

putting forward explanations based on the allocative inefficiency now besetting European research and innovation. A comparison between investments made by the United States and the fifteen countries of the European Union in research, innovation and the diffusion of technology during the last three decades reveals an investment gap between Europe and the United States which is already wide and is still growing, as well as a relatively inefficient allocation of capital in the European process of "creative destruction".

1. How can the relative weakness of European technological performance be explained?

In recent years, many studies have accentuated the relative weakness of the technological and industrial performance of the European Union as a whole[2]. Compared with the United States and Japan, the scientific results the EU obtains relative to the resources invested in R&D remain excellent, but its technological and industrial results, whether measured by patents, the initial introduction and/or diffusion of technological innovation on the domestic markets, the growth of technological start-ups, the technological balance of payments, exports of high-tech products or the competitiveness of firms in certain high-tech sectors, such as electronics and information technology, have been either inadequate or in decline for several years. In the mid-1990s, the realisation that a significant and increasing gap had developed between European and American economic performance, particularly with regard to economic growth and job creation, strengthened European opinion that the continent was not gaining industrial and economic returns on its scientific investments.

It is now widely agreed that Europe is not succeeding in efficiently transforming new scientific knowledge into technological or organisational innovation and subsequently into commercial success. Although most analysts appear to agree on this point, opinions differ on the causes and remedies.

From an economist's point of view, poor business performance can be explained either by allocative inefficiency, - for example an insufficient or ineffective orientation of investments -, or by productive or organisational inefficiency, -for example malfunctioning in the process of transforming resources into production -, or by a combination of both. It must be accepted, however, that efficiency in terms of the allocation of capital to research and innovation does not appear amongst the current criteria, based solely upon organisational, institutional and cultural factors, used to analyse the relative weakness of European technological performance. Although this approach takes account of numerous issues facing European research and innovation at the present time, it appears to us to be incomplete. We also believe that, by adopting it, we may miss many of the fundamental origins of inefficiency and may therefore

---

[2] This relative weakness in technological-economic performance in relation to investment is not found in all Member States, in all industrial sectors or in all technologies. A detailed analysis of the European paradox by country and by industry appears in Part 2 of the *Second European Report on S&T Indicators, 1997*.

propose policies which would be inadequate in terms of achieving the objective, namely, to increase science and technology's contribution to growth, competitiveness and job creation within the European economies.

1.1. The Dominant Approach: the Weakness of our Technological Performance is Explained by Organisational, Cultural and Political Factors.

We take the risk here of reducing the wealth and diversity of the numerous approaches to the subject by combining them into one consensual approach. This view, shared by the vast majority of European experts, is that the European Union's weak technological performance is not the result of a quantitative or qualitative inadequacy of investment upstream. This leads to familiar claims along the lines "we are investing a lot but we are not getting a high enough return". If, therefore, the levels of public and private funding and human scientific resources are considered to be adequate, not to say excellent, the fundamental problem is simply the ability to convert the various resources into innovation and into commercial and industrial success. This boils down to saying that our research and innovation systems are not producing good results despite significant human and financial investments because they face organisational, institutional or cultural difficulties. It is true that there are numerous organisational, institutional, legal, political and other barriers which can make this conversion difficult. These various types of inefficiency, which for the sake of simplicity can be called "organisational", have already been defined and analysed. Since it is not possible to list them here in full, we shall only refer to those which appear most important.

Firstly, a country's industry may fail to benefit in full from the scientific performance of its universities and public research centres if the channels used to diffuse and transfer knowledge between the various phases and sequences of the entire research and innovation process are poorly organised, with the result that there is inadequate cooperation between firms and universities, mismatching between the areas of scientific research and industrial specialisation and an absence of public incentives to encourage researchers to exploit their discoveries or to persuade firms to use the new knowledge to improve their product ranges and their production techniques.

It is vital for information and knowledge to circulate freely in the R&D/innovation process and in the exploitation of innovation. According to many analysts (for example David and Foray, 1995 and 1996, Foray 1997), it is the responsibility of the public authorities to improve the infrastructure and capabilities for diffusing knowledge between economic operators and between regions to ensure that the projects undertaken produce positive results. Cooperation between firms is also important in that an insufficiency in this connection can lead to a very weak or inefficient commitment on their part to R&D and innovation (Spence, 1984; Aspremont and Jacquemin, 1988; Stokey, 1995). Without effective links and channels (cooperation between enterprises and universities, strategic alliances between companies, the establishment and development of new innovative companies, university spin-off, etc.),

a large proportion of new knowledge and innovative projects is likely to remain unused or blocked in research centres or enterprises, in the form of registered but unexploited patents.

According to many European economists, the problems involved in coordinating R&D at regional, national and European level represent another major source of organisational inefficiency. Imitation or needless duplication of research programmes by the Member States or between various national research centres can also be a source of wasted effort and hence poor performance at European level (Soete, 1999). The numerous organisational, cultural or legal barriers to innovation which have been examined in detail in a number of national and European reports on innovation policy can be also included in this category. There is also major malfunctioning in the marketing and distribution of innovative products, examples being unsuitable national policies on internal regulations, foreign trade and competition, risk aversion of investors, barriers to entrepreneurship, the strategies of large dominant firms which seek to impede the entry and/or the development of innovative firms in their markets and social or trade union resistance to the introduction of new products or processes into the production and consumption systems. These are examples of the many economic, regulatory or social factors which can slow down the exploitation or diffusion of innovation (Lorenzi and Bourlès, 1995).

Organisational inefficiency within the innovative process can therefore arise from all kinds of obstructions or defects in the linking of public policies, economic and institutional structures and the behaviour of operators involved in innovation, either within a specific stage of the process (R&D, innovation or diffusion) or throughout the process. There is no question that these factors play a significant role in the functioning of national research and innovation systems (Amable, Barré and Boyer, 1997). Policy recommendations by advocates of this approach are in general aimed at optimising the operation of these systems, hence their many suggestions such as promoting cooperation between firms and universities, improving co-ordination between regional, national and European projects, increasing the mobility of researchers, improving infrastructure sharing, establishing centres of excellence in research centres, providing public support for innovative SMEs, improving intellectual property regulations, introducing more appropriate policies on innovation, competition and foreign trade, etc.

This approach is therefore based on observations and arguments which are economically sound and difficult to contest: the impact of investment on the improvement of the scientific, technological and economic performance of a given country or region may indeed be weak because of the inefficient organisation of the process of innovation, regardless of the allocation of capital within the research and innovation process. However, the fundamental question remains - will the undoubtedly necessary organisational changes suggested by this approach be sufficient to improve European research and innovation? In other words, are we sure that all the causes of the problem of low return on European research and innovation have been identified? We think not.

1.2. Our Approach: Our Poor Performance Can also be Explained by Allocative Inefficiency.

If we accept that "the allocation of a country's capital is optimum if the resources are directed towards uses which provide the highest social return", we must examine the profitability of investment in technological change and innovation. Since the mid-1950s, particularly since Solow's acclaimed analysis (1957), which attributed approximately 90% of growth to technological change and only 10% to increases in capital, economists have been interested in measuring the social and private return on investments in the total innovation process. Numerous recent publications on this subject reach convergent conclusions (BLS, 1989; Nadiri, 1993; Martin et al, 1997; Guellec, 1999). The direct return on investment in the R&D phase is estimated at approximately 30% to 40%, whereas the indirect return, measured by the diffusion of technological innovation between sectors, appears to exceed the direct R&D yield by 50% to 100%. (Terleckyj, 1974; Scherer, 1982; OECD, 1996).

The measurement of the effects of the international diffusion of technology on the growth of national productivity through imports of R&D-intensive goods is a matter which has also been raised, firstly by Coe and Helpman (1993), and subsequently by other authors, such as Bernstein and Mohnen (1994), who highlighted the presence of the indirect impact of this diffusion at international level, alongside the indirect external effects of non-incorporated R&D (Soete and Verspagen, 1992).

It now appears evident that the social return on R&D investment is not only very high but is also greater than its private return. It is therefore natural for all countries and all firms to invest a significant portion of their income in R&D. However, R&D expenditure in the industrialised countries varies between 1% and 3% of GDP. In 1997, it stood at 2.8% in Japan and 2.7% in the United States, against an average of 1.8% in the European Union, where the highest level was found in Sweden, with 3.8% and the lowest in Greece, with 0.5%. This 1% to 3% range has remained unchanged over the last thirty years. It is only the order of the industrialised countries which has changed, depending on their performance and the period concerned. It is therefore something of a paradox to observe that at a time when every country's objective is its preparation for the knowledge-based economy, investment has not seen a major qualitative increase over the last three decades. This is of even greater concern with regard to the industrialised countries, where R&D intensity has stagnated or decreased in recent years.

The knowledge that the portion of the industrialised countries' national income devoted to funding this high social-return activity is not increasing - and in some countries is very low - leads to questions regarding the efficiency of capital allocation in these countries. It could in fact be considered that inefficiency in the funding of R&D hinders the optimum allocation of capital. Such inefficiency exists on a macro-economic level as well as in the distribution of the total budget allocated to this sphere between the various fields of research and innovation and between the various phases and sequences of the process.

By widening the disparity between the social and private return, factors such as brakes on the appropriation of profits by investors or the existence of numerous externalities can therefore discourage private investors from investing in research and innovation projects (on this subject, see Arrow, 1962; Mansfield, 1968; etc.). The combination of monetary and financial factors, such as swings in the relative levels of long and short-term interest rates, restrictive public policies, the short-sightedness of financial markets, and other factors such as rising research and innovation costs or shorter product life-cycles, can also direct firms towards investments with short-term profitability and incremental innovation (on this subject, see Muldur, 1991; Aoki and Dosi, 1992; OECD, 1993; Aglietta, 1995; Rosenberg, 1996; Soete, 1996). Poor risk diversification or inadequate protection against risk is another source of allocative inefficiency. This source can lie in a financial system malfunction which undermines the ability to cover and minimise risk (lack of venture capital or re-insurance mechanisms, non-existent or illiquid second and third financial markets, inadequate cooperation between financial intermediaries, loan syndication and co-financing techniques) or in the absence of public investment in highly precarious spheres of research and innovation.

Inefficiency is, however, above all the result of a poor distribution of public and private resources. This poor distribution can appear on two levels. The first is the distribution between the various areas of research and innovation. The total resources allocated can become fragmented, for example in the absence of a selective policy, which can result in under-investment (or over-investment) in certain areas. In such cases, although all areas of research and innovation are funded, the return will be low where the critical mass has not been attained. The second is the distribution of the total budget between the various phases, segments or sequences of the process as a whole. The risk incurred in this case is not the actual distribution of investment but a needless concentration of investment upon certain phases or processes to the detriment of others, thus reducing the efficiency of the entire process. The balance between basic research, applied research and development is then jeopardised. We shall not dwell on the need for a balanced distribution of funds between these various areas, which is a decisive factor in the efficiency of the process. However, it is for example observed that in the case of unduly high concentration of investment in knowledge development, a country can improve its scientific performance in the long term, but the accumulation and rapid renewal of scientific and technological knowledge can also make investment selection and application more difficult, as a result of the more rapid obsolescence of the existing scientific knowledge. Firms would have difficulty in choosing between various potential investment combinations, as a result of uncertainty concerning the possibility of receiving a return on their investment costs. The same problem would arise in the case of over-production of innovation to meet a given need. Given that the market will *ex post* select one or more of these new competitive combinations and not the others, the average return on the funds invested in research and the development of innovation would tend to fall and would reduce the incentive for economic operators to innovate.

According to this new approach, inadequate investment, a poor distribution of investment by area, sector or level of application in the process, or an inadequate choice of investment instruments may be behind the low return on European research and innovation. In this field, where costs are rising rapidly and where critical mass plays an undoubted role, this approach is also worth considering. Unfortunately it is now a minority view amongst European policy-makers and specialists in research and innovation policies. It is, however, not intended as a substitute for the main approach and is merely aimed at supplementing it. It highlights the fact that there can be complex relationships between the sources of organisational and allocative inefficiency and that in the same way as allocative inefficiency can result in organisational inefficiency, so the prior existence of organisational inefficiency can discourage public investors. We shall not dwell on the complex subject of the causal links between the various forms of inefficiency. In the following sections, however, which contain a comparative analysis of capital investment in research and innovation, we shall see that some sources of allocative and organisational inefficiency are complementary and interactive, that some co-exist independently and that the presence of some depends entirely on that of others.

2. A Comparative Analysis of European and American Investment in R&D, Innovation and the Diffusion of Innovation

While it appears necessary to analyse the efficiency of capital allocation in Europe in this area of high social return, we should be aware that, with the exception of some academic work aimed at determining the theoretical optimum level of investment in this field, we have little to guide our assessment of the optimum volume and distribution of investment required to meet the objectives of each industrialised country. For the time being, the comparative approach seems to be the only coherent way of evaluating the results of the R&D and innovation of the industrialised countries. In applying this comparative method, it is, however, necessary to be careful only to compare like with like. The level of technological investment varies from one country to another in accordance with numerous factors such as economic structure, industrial specialisation, the size of the domestic market, factor endowment, etc. In this respect, the United States and Europe appear to be comparable economic entities, despite some structural differences. Our main objective, in the following sections, will be to compare the efforts made by the United States and the European Union to fund the whole innovation process.

In order to compare the efforts of the industrialised countries, we must take into account the entire innovation process, which comprises three complementary stages - R&D, the execution and initial introduction of innovations into the market, and the diffusion of innovation throughout the productive system. It consequently appears necessary to form a comparative assessment of European and American investment in the three main innovative phases. We shall therefore select a specific investment indicator for each phase. We shall use R&D expenditure, as defined in the Frascati

Manual, as an indicator for the R&D phase, venture capital investment for the second phase and gross fixed capital formation (GFCF) for the diffusion of technology.

Two other comments on methodology are called for before proceeding to compare the investments made on both sides of the Atlantic in these various stages of the innovation process. Since innovation is the result of a long cumulative process, comparisons must be made over a long period, not only because R&D activity is spread over several years, but also because the initial introduction and diffusion of the innovation resulting from this work also requires several years or several decades. Our comparative analysis will thus cover a thirty-year period from 1967 to 1997.

In international comparisons, R&D expenditures are generally related to GDP. This relationship, revealing R&D intensity, makes it possible to compare effectively the capital allocation between countries. The disadvantage of this indicator is, however, that it masks disparities in the absolute value of investment and the trends, sometimes contrasted, in national production and R&D expenditure. With regard to R&D, however, the cumulative nature of R&D investments and their sensitivity to critical mass are central. Additionally, since the initial outlay involved in entering certain technological areas has increased considerably over recent decades, international disparities in the absolute value of investment are also a good indicator of allocative efficiency. This is because even if a small country is more R&D intensive than a large country, unless it concentrates its total investments in a limited number of fields, it will be weaker in all fields compared with the large country, despite the fact that the latter devotes a lower level of its national income to R&D. As a result of the cumulative and continuous nature of new knowledge acquisition, a small difference of 0.5% in the level of R&D investment between two countries with comparable GDPs may, over several years, result in wide disparities in their results.

Finally, analysis is made difficult by numerous methodological and statistical problems. Despite all the efforts made by international and national institutions, the statistics on research and innovation, investment and performance are still insufficient for an in-depth analysis of this complex process. We therefore suggest that they should be considered as simple indicators.

2.1. The Formation of a Massive 1260 billion dollar gap in R&D Investment over the Last Thirty Years

In the first phase, from 1967 to 1975, Europe attempts to catch up

At the end of the 1960s, Europe realised that it had gradually fallen far behind in R&D during the thirty “glorious” post-war boom years. J.J. Servan-Schreiber's well-known book, "The American Challenge", published in 1969, illustrates perfectly this European realisation that a technological gap had developed during a period when its economic performance had been just as good as that of the United States. In 1967, the annual difference between total R&D expenditure by the United States compared with that of the fifteen countries of the present European Union reached the historic record of 50

billion dollars (at 1990 constant prices and exchange rates). The relative fall in the gap after that date is initially explained by a severe stagnation in investment, particularly Federal investment, in the United States. Budgetary and commercial deficits soared with the result that America was unable to prevent its R&D investment falling from 3.1% to 2.3% between 1964 and 1975. It is also explained by the growth in European investment, which was to remain broadly higher than that of the United States between 1967 and 1975, despite contrasted national trends. The growth in R&D investment as a percentage of GDP was highest in Germany, rising from 1.4% in 1964 to 2.2% in 1975. There was equally rapid growth in Belgium and Sweden. In France, where it was high between 1964 and 1969, it understandably slowed between 1970 and 1975. Against this, R&D investment in the United Kingdom began to decline, falling from 2.4% to 2.1% between 1967 and 1975. The gap between American and European expenditure thus fell to 27 billion constant dollars in 1975, the narrowest if has been over the past thirty years. At the same time, the EU's accumulated backwardness in R&D expenditure compared with the United States reached 337 billion constant dollars.

The second phase (1976 to 1992): Europe hangs on but Reagan launches his star wars campaign

The rapid growth in German and Japanese technological competitiveness began to worry the Americans. German R&D investment caught up with that of the United States at the end of the 1970s and was to remain on more or less the same level until German unification. The Japanese set their sights even higher. During the 1950s, their objective was to catch up with the Europeans. They achieved this for the first time ever in 1970, when Japan's average investment moved definitively ahead of that of the seven most R&D-intensive European countries[3]. Japan's second objective - to overtake the Americans - was achieved in 1989. They were running out of steam, but even during the recession they were careful not to let their level of R&D investment fall below that of the United States.

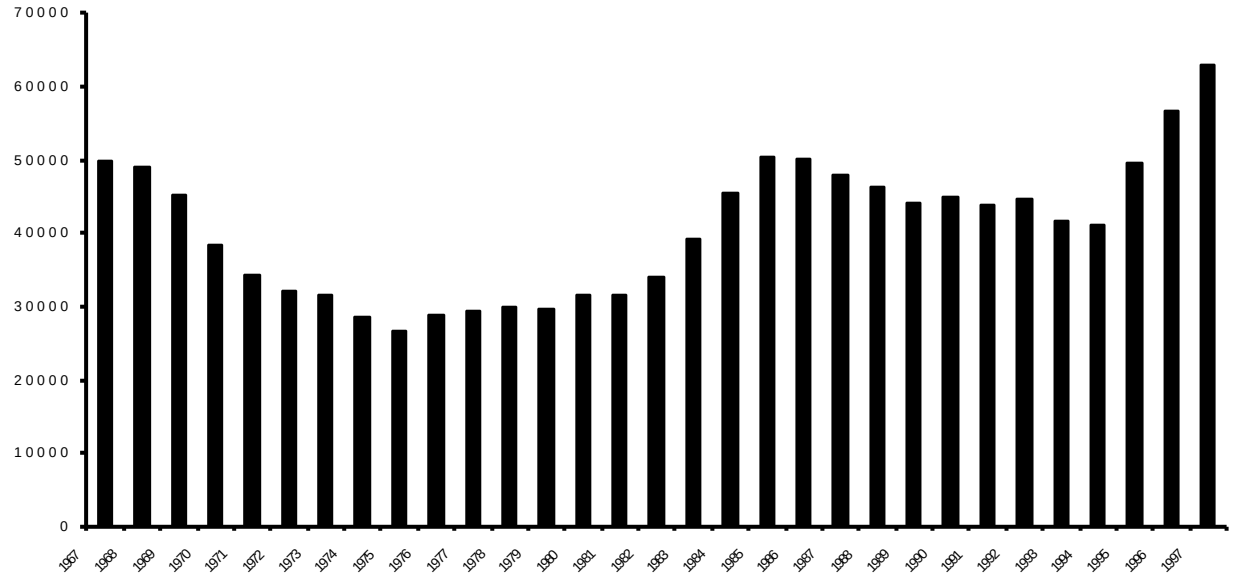
In this period of economic and monetary instability, the European countries re-embarked upon economic and monetary union and continued their investments in R&D in response to American and Japanese competition. R&D investment in the seven European countries, having been stable during the 1970s (approximately 1.8%), subsequently increased to 2.23% in 1989. All the European countries made huge efforts not to be left behind in the technological race. Along with these seven countries, the other Member States of the European Union also started increasing their R&D investment appreciably, spurred on by multiannual R&D framework programmes.

Despite this European Community effort, the investment gap, which had remained at an average of 30 billion constant dollars per year between 1976 and 1982, soared under the two Reagan administrations. At the same time as encouraging American firms to

[3] Sweden, Germany, France, the United Kingdom, the Netherlands, Belgium and Italy.

restructure and restore the enterpreneurship and private initiative, also somewhat stifled in the United States during the period of mass production, the Federal government opened the public coffers in defence of American competitiveness[4]. R&D investment levels then rose from 2.4% to 2.9% between 1981 and 1986 and the investment gap with the EU-15 reached 50 billion dollars annually during the Reagan years. The effects on public R&D expenditure of the 1985 Gramm-Rudman-Hollings Act, which compelled the Federal government to eliminate the budget deficit by 1992, were not felt until the Bush administration. Many European economists who criticised "Reaganomics" failed to see that during the stock market boom of the 1980s, the United States had succeeded in investing in R&D over 465 billion dollars (1990 prices) more than the fifteen European countries combined. Between 1976 and 1989, Europe's accumulated investment gap reached a level of 540 billion constant dollars. The American gazelles, from Intel to Microsoft were developed during this period, subsequently becoming giants in their sectors. This huge difference in investment for the future was clearly instrumental in bringing about the new age of the 1990s.

Figure 1: **The R&D investment gap between the United States and the European Union** (*GERD in PPP at 1990 prices and exchange rates)*



Notes: (1) Estimates where data are not available. (2) UE-15 excluding Luxembourg (G.D.). (3) Post-1991 data relates to reunified Germany. (4) Data on Greece are not included within the UE-15 total from 1967 to 1978.
Sources: own calculations based on data from national sources, Eurostat and the OECD.

The third phase: the Americans announce that they have entered a new era of growth!

There are several reasons why, during the first tumultuous years of the 1990s, the annual investment gap was to narrow in the initial R&D stage of the global innovation process. Firstly, alongside the effects of the fall of the Berlin Wall and the Gulf War

[4] For a detailed analysis of American R&D policy from Reagan to Clinton, see Muldur, 1997.

on the economic growth of the industrialised countries, the Americans were tackling the reduction of their budget deficits, this time more vigorously. This affected the allocation of Federal funds to research, but the increase in investments in R&D by American industry offset the relative fall in Federal support. During this period, the European economy was severely affected by the constraints involved in restoring fundamental balances and real interest rate levels. European economic performance reached rock bottom in 1993 and then began to improve as progress was made towards the Maastricht criteria, which were necessary to restore Europe's monetary sovereignty. Without the right mix of macro-economic and structural policies, these European imperatives could have been counter-effective in terms of growth, employment and technological progress. It was principally for this reason that the European Council, in the conclusions of its Florence meeting, urged the Member States *"to step up their efforts at budgetary consolidation ..... making a selective restructuring of expenditure that encourages intangible investment in human capital and in research and development, innovation and the infrastructure essential to competitiveness."* (SN/300/96).

The opening was narrow. Public and private investment in R&D investment did not get through. It began to decline slightly as a percentage of GDP between 1990 and 1997. The proportion of public national budgets invested in research began to fall appreciably in most of the Member States (ERSTI, 1997; EC-Key Figures, 1999). European industry followed this downward trend. R&D investment in the EU-15 fell below the 2% barrier, a level which it had exceeded since the beginning of the 1980s. With the exception of Sweden, Finland and a few other European countries with very low levels of investment, investment in R&D either grew more slowly than national income or even fell in absolute value. Allocative inefficiency thus increased in Europe. Between 1987 and 1997, R&D expenditure as a percentage of GDP fell in Germany from 2.9% to 2.3% and in the United Kingdom from 2.2% to 1.9%. Whilst the Netherlands and Belgium succeeded in maintaining its level, the level of R&D investment in France fell from 2.5% in 1993 to 2.2% in 1997.

The annual investment gap between the European Union and the United States climbed to a new high. From some 41 billion in 1993, it firstly rose to 56 billion in 1996 and then to 63 billion in 1997, and may break a new record in 1998 by exceeding 70 billion (in PPP). From 1990 to 1997, the accumulated gap was 386 billion (PPP at 1990 prices and exchange rates). We shall specify the fields and sectors in which this disparity was concentrated in the following sections.

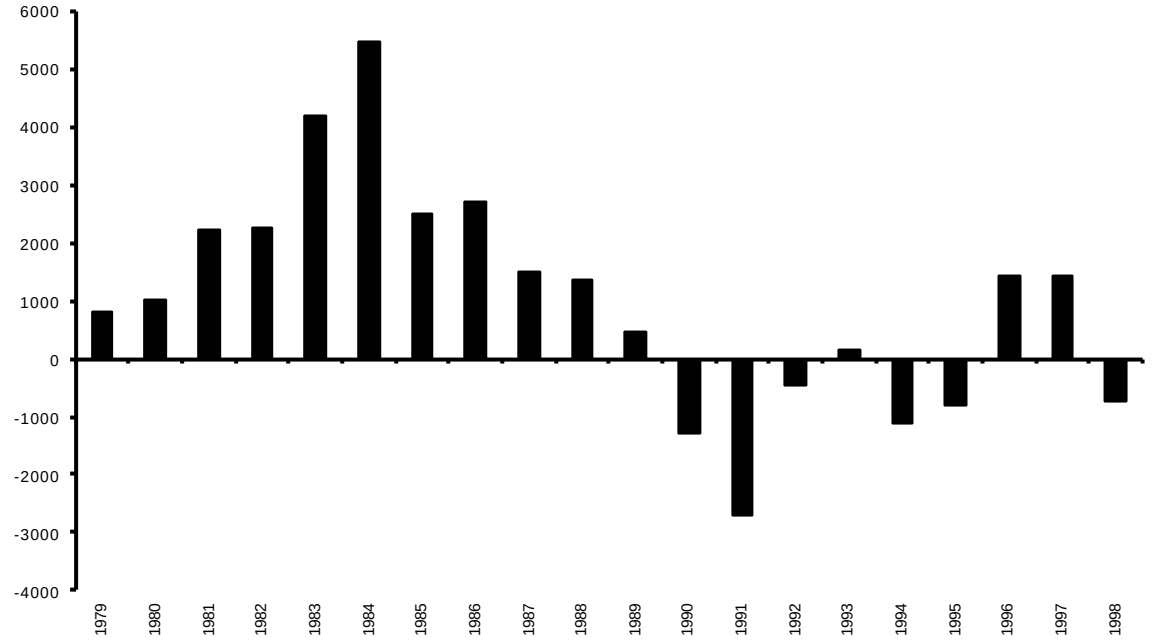
2.2. Trends in European and American Investments in Venture Capital

The venture capital market began its ascent in the United States during the 1970s. In 1975 investment in this type of capital had already exceeded 250 million current dollars. It increased tenfold in eight years, reaching 2.5 billion in 1983. It is interesting to note that during this period, large American enterprises, such as Xerox, were also using this process to participate in independent initiatives and in the development of

their own employees' projects. Hence, the share of corporate venture capital in total investment was higher at the beginning of this new market than it was subsequently. Numerous public initiatives had already begun before 1975, but it was between 1975 and 1985 that the Federal Agencies introduced structures which were more suitable and better equipped with human and financial resources. The Small Business Administration created a fund in 1976 to enable university centres to assist small firms by the transfer of knowledge and technology. In 1979, the Department of Commerce set up funding programmes for State and regional bodies to support business start-ups and a fund to assist innovative entrepreneurs on a technological level. Between 1977 and 1982, the predecessor of the Small Business Innovation Research Program (SBIR) was tested by three Federal Agencies. This funding programme for innovative companies was extended on a broader scale and was adopted by all eleven Federal Agencies in 1982.

In the 1980s, financial institutions and American pension funds in particular began to inject massive amounts of capital into the venture capital market. The electronic stock market (NASDAQ) took off at this time. The flood of capital was such that it was necessary to take action to ensure that demand kept up. The public authorities stepped up the pace. From 1980 at least 107 centres were set up in some fifteen states to provide new entrepreneurs with infrastructure, services and start-up capital. In 1985, the Department of Energy entered into agreements with venture capital companies with the aim of involving them in financing innovative projects coming from public research laboratories. The success of the Federal SBIR encouraged at least thirty American states to establish their own. The ATP began in 1988 under the aegis of the Department of Commerce and the experimental venture capital programme (DARPA) was introduced by the Department of Defence in 1989.

Figure 3: The gap in investment in venture capital between the United States and the European Union (in million USD of 1990)



Note: (1) Estimated data for the UE-15 for the years 1979 to 1983.
Sources: own calculations from EVCA Yearbooks, NVCA Yearbooks and various national sources.

As a result, the innovation production channel, as an alternative to that of the large established enterprises, expanded rapidly from the middle of the 1970s. Schumpeterian entrepreneurs, who were identifying high-return niches and innovation projects in competition with the large enterprises, were provided with a framework which encouraged their achievements. The first gazelles since the post-war thirty-year boom period gradually surfaced between 1975 and 1985, with initial venture capital support, provided either by the government (Apple, Intel, Federal Express, Compaq, Chiron, etc.)[5] or from the private financial sector (Microsoft, Digital Equipment, Genentech, Computervision, etc.). Some of these gazelles were to expand rapidly to become the new giants of American industry during the 1990s. The very heart of the American high-technology industry was revolutionised in the space of some fifteen years, and the gazelles of this era, having become the dominant established enterprises in their own sectors, had in turn to face competition from new gazelles, such as Netscape and many others, which emerged between 1985 and 1995.

What was happening in Europe at this time? In the 1970s, venture capital was seen by Europe as a typically American novelty. The large European companies, which were facing new forms of competition, were evidently not interested in the establishment of a new production and initial marketing channel for innovations other than to their own. The banking and financial institutions also took little interest during

[5] See Tibbets, 1996, for analyses of initiatives arising from public programmes.

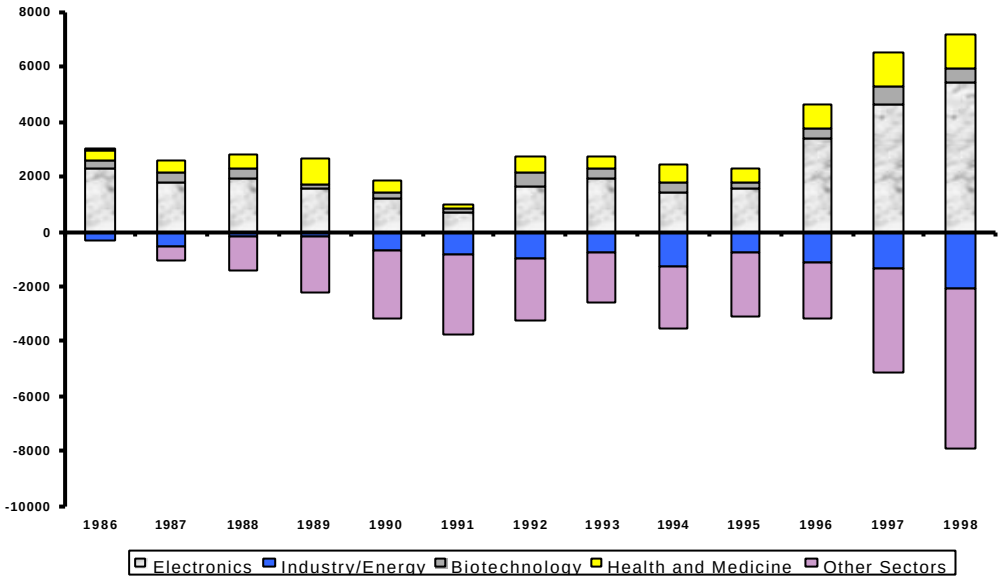
the 1970s in this cluster of small firms, which were very often taken under the wing of specialised financial institutions. There were obviously some initiatives (OECD, 1996), but these can be considered to be the exception rather than the rule. They lacked critical size, they did not understand the new channel's rules, which were fundamentally different from those of the banking system. What is more, the various levels of inefficiency - with regard both to organisation and allocation - were so interlinked that for a long period the financiers said that they were prepared to invest but that there were not enough good innovative projects with a high return and a sufficiently low risk, or that there were no real entrepreneurs in Europe because the mentalities were different. On the other side of the coin, entrepreneurs were complaining of lack of seed capital, aversion to risk on the part of European bankers and the vast number of administrative, economic, financial and fiscal barriers which had to be overcome. Concerns surfaced: the growth of pension funds, stock options etc. were seen by some as threatening to cause the European model to explode.

Such prevarication and uncertainties resulted in Europe lagging behind in establishing an alternative channel for the execution and financing of innovative operations. And just as the build up of allocative and organisational inefficiency in the initial R&D phase had resulted in the brain-drain from Europe to the United States during the 1950s and 60s, so the charms of Silicon Valley, American venture capital and NASDAQ tempted the second-phase innovators, already quite numerous, to emigrate to the new continent to form their enterprises, which were subsequently listed on NASDAQ.

At the beginning of the 1990s, the European press was reporting hundreds of success stories of European innovators who had set up their companies on the other side of the Atlantic. As at the end of the 1960s, Europe again realised that the European innovation paradox still existed and that a policy change was needed to re-stimulate the entire innovative process. European governments set to work to try to correct this new weakness in the markets. Public initiatives, both political and fiscal, were aimed at encouraging the financial markets to co-operate with the governments to establish an alternative initial funding channel for innovation, based on enterprise start-up, venture capital and the new electronic markets. This new innovation policy therefore began in Europe much later than in the United States. Initiatives first appeared in countries such as the United Kingdom and the Netherlands and subsequently spread, during the 1990s, to the whole of the European Union. Europe caught up with the United States, and even outstripped it in some years, in terms of the total volume of investment in venture capital.

This new alternative channel is now, however, faced in Europe with a problem which does not exist in the United States. This is the lack of critical mass, in the venture capital markets as well as in the new electronic markets, such as the Nouveau Marché, Easdaq, AIM, Neuer Markt, etc., in that these markets remain essentially national. In comparison with the United States, the European venture capital markets seem to be caracterised still by risk aversion in financing new start-ups and innovation in high technology sectors.

Figure 3: Gap in venture capital investment in advanced technology between the United States and the European Union (in million USD of 1990)



Note: (1) UE-15: Estimated data per sector for 1990.
Sources: own calculations as in figure 2

It is, for example, estimated that in 1998, the gap between the two sides of the Atlantic in seed and start-up capital invested was nearly three billion dollars. As shown in Figure 3, the other major weakness of the European venture capital channel is the sectorial distribution of the funds invested. European venture capital is directed more towards projects in low-tech sectors, whilst a sizeable deficit is evident in the investment of venture capital in sectors such as electronics, biotechnology, health and medicine.

As with R&D financing, it is therefore difficult to say that there is an optimum allocation of venture capital to the initial introduction of innovations on to the markets, except that in this area, Europe appears to have caught up during recent years in terms of the total volume invested. However, the distribution of funds between the various activities (seed, start-up, development, etc.) on the one hand and between the various sectors on the other appears to raise problems which can only be explained by the presence of sources of allocative inefficiency, such as those related to an unequal distribution of risk or the choice of financing instruments.

2.3. American and European Investment in the Third Phase of Technological Diffusion - a Recent Split

It is not easy to assess the capital allocated by each country to investment in the third phase of technological diffusion. During this stage, innovative products and processes begin to spread over national and international markets. In one way or another, a significant portion of new technology, designed and produced during the previous two

phases, therefore enters each country's stock of productive capital in the final phase of the innovation process.

2.3.1. Investment in productive capital

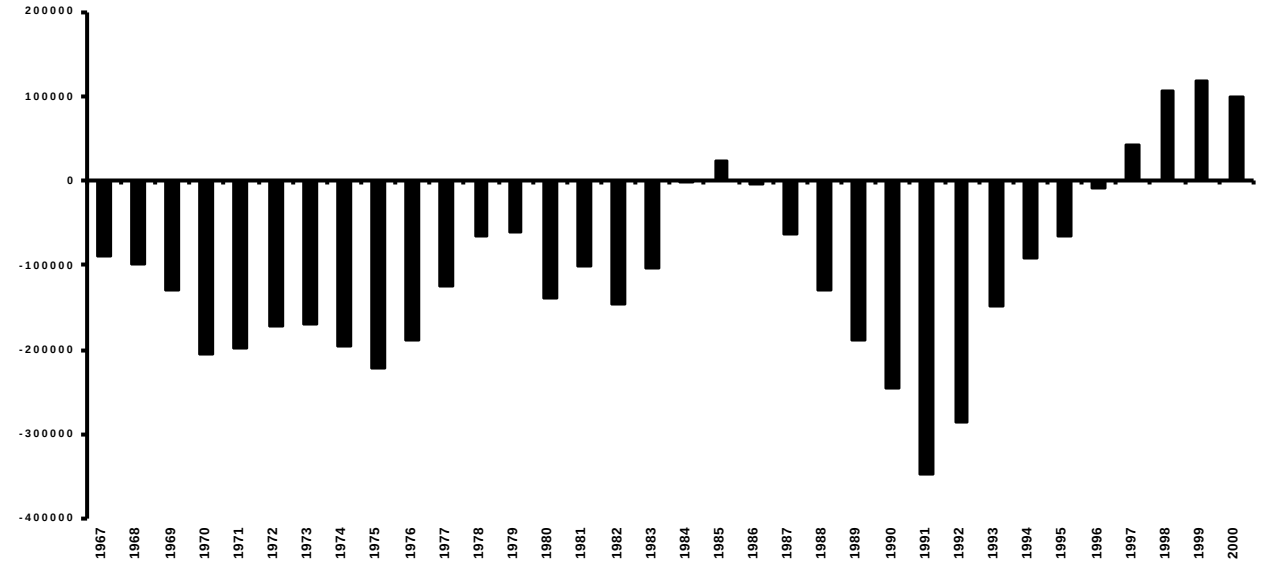
Gross fixed capital formation (GFCF) is not a perfect indicator but, as we shall see, it is nonetheless very useful in assessing the investments made by each country's enterprises at the phase of the diffusion of innovation. Capital investments made each year enable the productive capital of each country's enterprises to be renewed, regenerated and increased[6].

A comparative analysis of GFCF in the United States and the European Union therefore rounds off the analysis of R&D and venture capital investment in the two previous phases, which relate to the production of new knowledge and the initial introduction of innovation on to the markets. This indicator enables us to assess the investment made in diffusing technological progress, or, to put it another way, in modernising the stock of productive capital. In order to explain the investment and performance differences between the United States and Europe, we have calculated the trends in the annual disparity between gross fixed capital formation in the United States and the European Union (PPP 1990 prices and exchange rates). The following figure shows the trend in this disparity since 1967. It can be observed that this time, until recent years, European investments were almost always higher than those of the United States. Investment can once again be viewed over three periods. From 1967 to 1983 the fifteen European countries invested each year approximately 140 billion more than the United States (constant PPP dollars). At the beginning of the second period (1983-1995), this disparity initially disappeared, between 1984 and 1987, and then rose again in 1991 to over 300 billion dollars in favour of the European Union.

---

[6] It obviously assumed here that all enterprises behave rationally and purchase each year the most advanced products and equipment available. We are aware, however, that this is not always the case. Certain enterprises, like certain underdeveloped countries, in fact prefer not to buy high-tech products as a result of a lack of trained personnel or the difficulty and cost involved in maintaining them. This phenomenon in part explains why, at a given moment in time, several types of organisation and several technologies can exist side by side and remain competitive in their socio-economic environment.

Figure 5: Gap between the United States and the European Union in terms of gross fixed capital formation
(USD m, PPP 1990 prices and exchange rates)



Notes: (1) Estimated figures for the United States for the years 1997-2000, and for the EU for the years 1998-2000 (Eurostat). Sources: based on Eurostat data.

During the 1990s, a clear change in GFCF trends appeared on both sides of the Atlantic. In Europe, investment fell by 1% in 1991/1992 and by 6.6% in 1992/1993. It then grew at an average rate of 3% a year between 1994 and 1999. In the United States, a new era of growth in productive investment began in 1991. Two new features distinguish this period from the earlier one. These are the duration of growth, which was uninterrupted for eight consecutive years, and the average rate of growth, which settled at around 7.4% per year, following the example of the post-war thirty-year boom period. The combination of these two contrasted trends put the disparity in favour of the United States for four consecutive years for the first time for forty years. The total gap between American and European investments was 267 billion dollars (1990) between 1996 and 1999 and should continue at the same rate during the year 2000 according to Eurostat estimates.

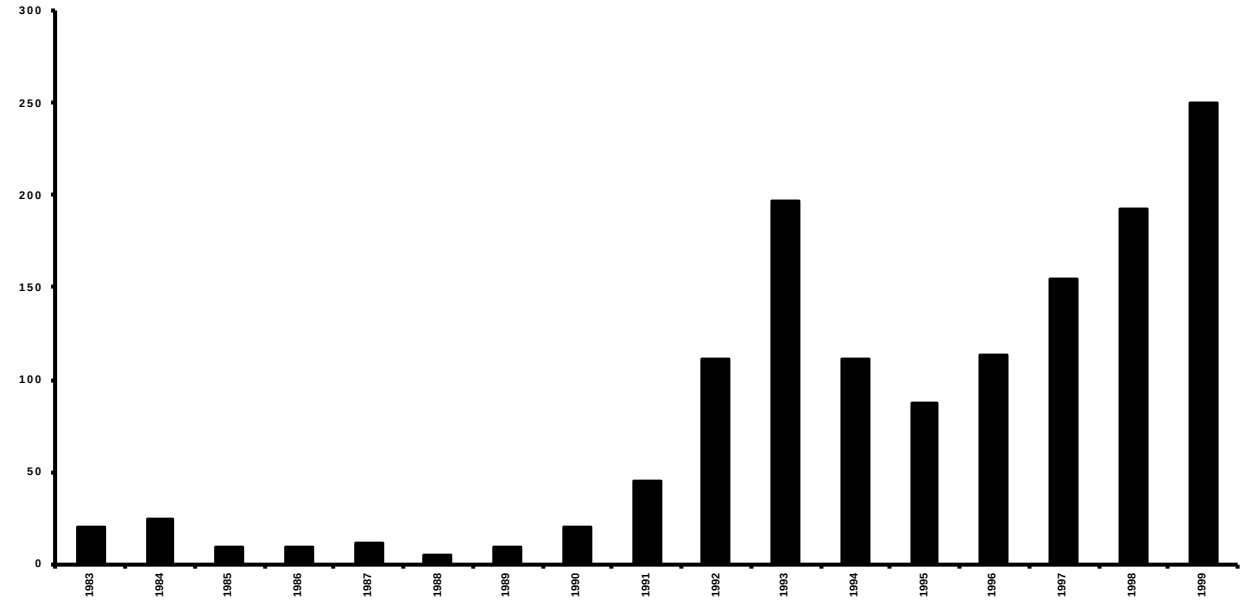
This reversal in trend is highly significant. The appearance, for the first time since the 1960s, of this gap in GFCF is of far-reaching importance in understanding the possible divergence of US and EU trajectories in industrial and technological development which appear to have taken place during the second half of the 1990s. Before drawing conclusions from this, we should attempt to study the technological diffusion gap using other indicators.

2.3.2. Investment Trends in the Diffusion of New Technology

With the growth in the part played by information and communications technology (ICT), the availability and reliability of the indicators have improved during recent

years (see in particular publications by the EC (EITO, 1998), the OECD, the World Bank and numerous companies such as IDC, Dataquest, etc.). Using these various sources, we have again attempted to assess the trends in the differences between the United States and Europe in investments in ICT.

Figure 5: Gap between the United States and the European Union in ICT (in million dollars)



Note: (1) Data for 1999 are estimates. Sources: WITSA (1998) and EITO(1998)

This new indicator shows in addition that the gap in the diffusion of information and communications technology also increased markedly at the beginning of this decade. From some 13 billion (in current dollars) a year on average during the 1980s, it initially grew to 100 billion a year between 1990 and 1994 and reached an average of 160 billion during the period from 1995 to 1999. When the focus is placed solely on the diffusion of the ICT, therefore, the annual investment gap in the third phase is higher than what is observed. A classification produced by IDC (WITSA, 1998) which relates this expenditure to GDP revealed that with the exception of the United Kingdom, which shared first place with New Zealand (8.4%) ahead of the United States (8.3%), all the other European countries invested a distinctly lower proportion of their GDP; Sweden (in 9th place with 6.9%), the Netherlands (6.4%), Denmark (6.2%), Ireland (5.7%), France (in 16th place with 5.7%), Germany (in 25th place with 4.9%), Italy (in 30th place with 4%) and lastly Greece and Spain (3.7%).

According to a study carried out for the European Commission, the difference was slightly lower than these estimates. The European Union and the United States devoted 4.9% and 6.1% respectively of their GDP to diffusion of new technology in 1996.

Other per capita data on the diffusion of information and communications technology (from computers to Internet access) also indicate that Europe has fallen further behind the United States in recent years. All these indicators confirm at any rate that the

technological content of productive investment has risen faster in the United States than in Europe in recent years.

2.4. A Large Investment Gap throughout the Overall Process of Research and Innovation

So far, we have analysed the investment gap between the United States and the European Union at three distinct phases, i.e. research, innovation and technological diffusion. Combining these various types of tangible and intangible investments can give an idea of how the total investments of each of these two great world powers have developed over the last three decades.

For the first phase, we will keep total R&D expenditure (GERD) as it is, since it is relatively comparable and reliable[7]. For the second phase, we will use solely venture capital investments in high R&D intensive sectors (electronics, information technology, communication, biotechnology, etc.) in order to eliminate investments which do not really relate to the second phase of the innovative process as defined. The only problem here is that the European data prior to 1985 and the American data prior to 1979 are either incomplete or unreliable. Using some partial European data and by regressing the 1985-1997 data, we have estimated European expenditure between 1979 and 1984. We have therefore been able to calculate the investment gap (constant PPP) for the period from 1979 to 1997. As already stated, this indicator does not, however, provide an exact estimate of the investment gap which we believe exists between the United States and Europe, mainly because of the lack of data relating to Business Angels investments and those of public bodies such as ANVAR in France.

Generally speaking, the indicator we have used for the diffusion of the technology phase is reliable as it covers all technological equipment. We know, however, that investments in technological services, such as software, are still not included in gross fixed capital formation, either in the United States or in Europe. We have therefore tried to include the investment gap between the two regions in ICT services within the indicator, assessing them on the basis of available data (WITSA, 1998 and EITO, 1998). The gap connected with these investments in information and communications technology services widened from 33 to 72 billion (current dollars) between 1992 and 1998.

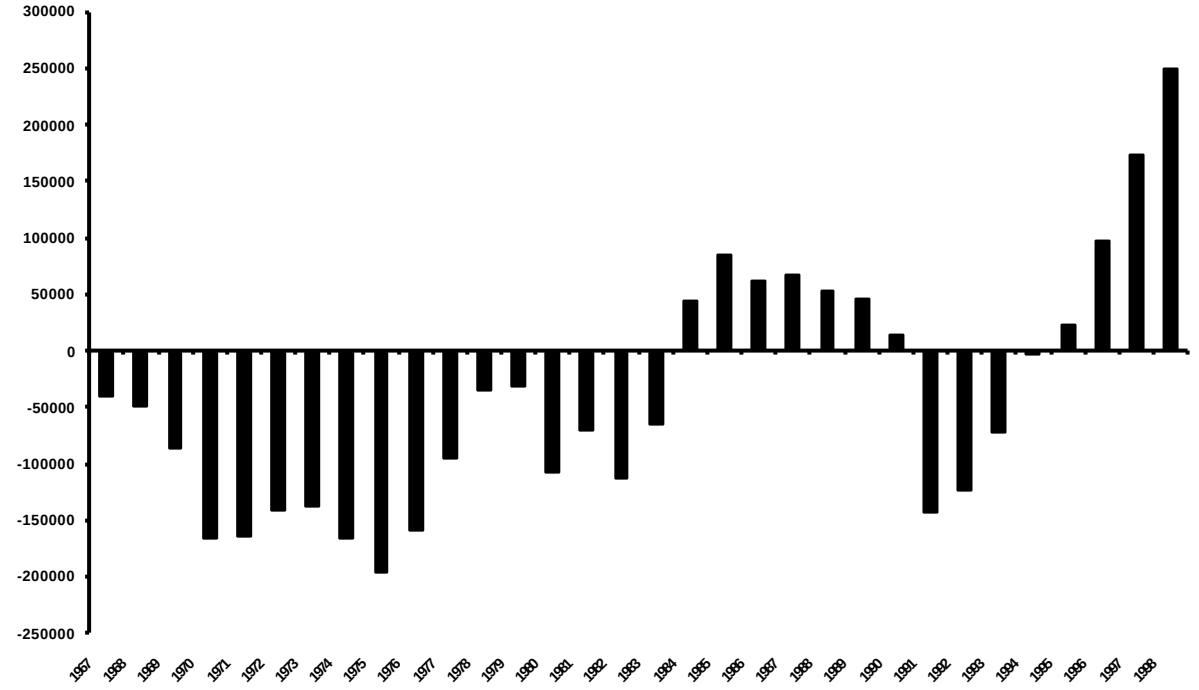
As seen in Figure 4, European gross fixed capital formation increased considerably during the period from 1985 to 1992, probably because of the effects of completion of the single market. Knowing, however, that there was also a speculative growth in real-estate investment in some European countries during this period, we have tried to

---

[7] We are aware that some public expenditure, such as research tax credits or some forms of public assistance or innovation expenditure, is not included in these R&D figures. However, since we are working essentially on the difference between the aggregate data of the United States and the EU-15 and since the expenditure not included represents only a very small proportion of total R&D expenditure, we consider that the relatively minor effects of not including this expenditure cancel each other out or modify only very slightly the general trends observed.

correct the consequential effect on the formation of fixed capital in Europe. Using Eurostat data, we analysed the trend in the share of real-estate investment in GFCF and found a spectacular increase during this property boom period. We then eliminated this excess rate of real-estate investment from the period as a whole.

Figure 6: Gap between the United States and the European Union in various kinds of tangible and intangible investments (million PPP, at 1990 prices and exchanges rates)



Note: (1) The GERD and GFCF figures are calculated in PPP at 1990 prices and exchange rates. (2) Data relative to investments by the venture capital market and expenditure on services have only been included since 1986 and 1985 respectively. (3) The 1998 GERD is estimated.
Sources: own calculations from various data sources ; national sources, EUROSTAT, OECD, EVCA yearbooks, NVCA Yearbooks, WITSA (1998), EITO (1998).

Figure 6 shows the evolution of the total gap between American and European investments in the entire innovative process. It is observed at first that total European investment was higher than American investment between 1967 and 1983, but that this positive gap was obtained through relative over-investment in the phase of technological diffusion, which more than offset the under-investment in the phases of research and innovation. This strategy may be explained by the combination of several factors. During this period, European R&D investment was, of course, already focused on the defence-space-nuclear trio and on a few large enterprises and public research centres. As there was no genuinely unified European single market and as a result of other sources of organisational inefficiency outlined above, European enterprises appear to have long preferred to import American technological and organisational innovation rather than invest significant amounts of capital in the two first phases of their own process of knowledge acquisition and innovation. When the aim is to try and close the economic and technological gap, this strategy makes sense as time is saved in modernising the productive system and economies made on the long-term capital that

would normally be invested in this high-risk area. This European strategy of massive investment in technological diffusion has enabled it on the one hand to cushion the potential counter-effects of its under-investment in R&D and in innovation proper and on the other to achieve a growth in productivity as high as that of the United States. Consequently, European enterprises turned either towards incremental innovation, which would not appreciably devalue their stocks of industrial assets, or towards innovation in order to increase their productivity, or simply towards producing and diffusing American innovation, particularly innovative products, but without introducing new forms of organisation as the Americans had done at the beginning of the twentieth century and the Japanese after the second world war.

On the other hand, the beneficial effects of this European industrial strategy seem to have been exhausted by the beginning of the 1980s. As shown in Figure 6, the net gap in both tangible and intangible investments became negative for the European Union for the first time, initially between 1983 and 1989 and then increasingly so after 1994. Between 1995 and 1998, the American economy invested approximately 540 billion (PPP) more than the European economy in R&D, venture capital and new equipment. In order to understand this change in trend, we should explain the difference in the short-term and long-term effects of the two strategies applied in the United States and in Europe.

Several factors played a part in this change in trend, which seems to have occurred in the 1980s. The European strategy was based more on imports of technological and organisational innovation already introduced and tested on the American markets than on the production of local innovation (which would have called for long-term, high-risk investments). It also led to an adverse technological balance of payments and trade balance in Europe in R&D-intensive sectors. A number of OECD studies have revealed deficits in Europe's trade with the United States and Japan in high technology sectors throughout this period. The increase in global competition stemming from the appearance on the scene of Japan and the countries of South-East Asia resulted in European enterprises losing market share both on their domestic and foreign markets, which they had dominated until then. The removal of defensive customs and non-tariff barriers within the context of increased globalisation and the debts accumulated during the 1970s, as well as the rise in the destabilising effects of capital market competition seem to have prompted them to turn away - at least more so than their American and Japanese competitors - from long-term high-risk investments and to concentrate instead on external growth and on a strong increase in fixed capital, which could increase their productivity and their financial performance in short term. The final factor of change, but by no means the least significant, was the general backwardness of European financial systems in finding innovative methods of financing start-ups, innovation and SMEs, which were in general undercapitalised. Whilst the top of the industrial pyramid was weakening as a result of the appearance of these various forms of competition, which were beginning to replace industrial relations within industry (Petit, 1998), its base was not able to change and develop in order to remedy shortcomings in technological investment and job creation.

The change in the American economy seems to have occurred in a radically different way from that of the European economy during the 1980s and was characterised by significant economic, financial and technological change. Although confronted by the same trends, i.e. financial liberalisation, industrial deregulation and increased world competition, the American economy did not reduce its efforts to boost intangible investment and succeeded in renewing its industrial structures through restructuration and new technological start-ups with easy access to venture capital within a statutory context, thus encouraging their rapid expansion. As mentioned above, this change in industrial structure benefited from a high level of public investment in research and innovation.

We believe that this American strategy, which can be defined as over-investment in research and innovation in contrast with the strategy of most of the European countries, played a key role in the improvement of American economic performance during the 1990s. After a short downturn resulting from the need to reduce its deficits, the United States managed to revive both its tangible and intangible investment in all three phases of the overall innovation process. Admittedly, the American economy is not at present totally shielded from financial crisis. It may, however, manage to clear its worrying balance of payments and trade balance deficits and at the same time maintain its level of economic growth and rate of technological investment. Whatever the future holds, the main question for Europe relates to whether it will be able to continue the high level of investment in research and innovation and productive capital now imposed upon it by the United States, without falling behind in the competition for economic and technological leadership.

3. The Main Differences in R&D Investments by Actor and by Field

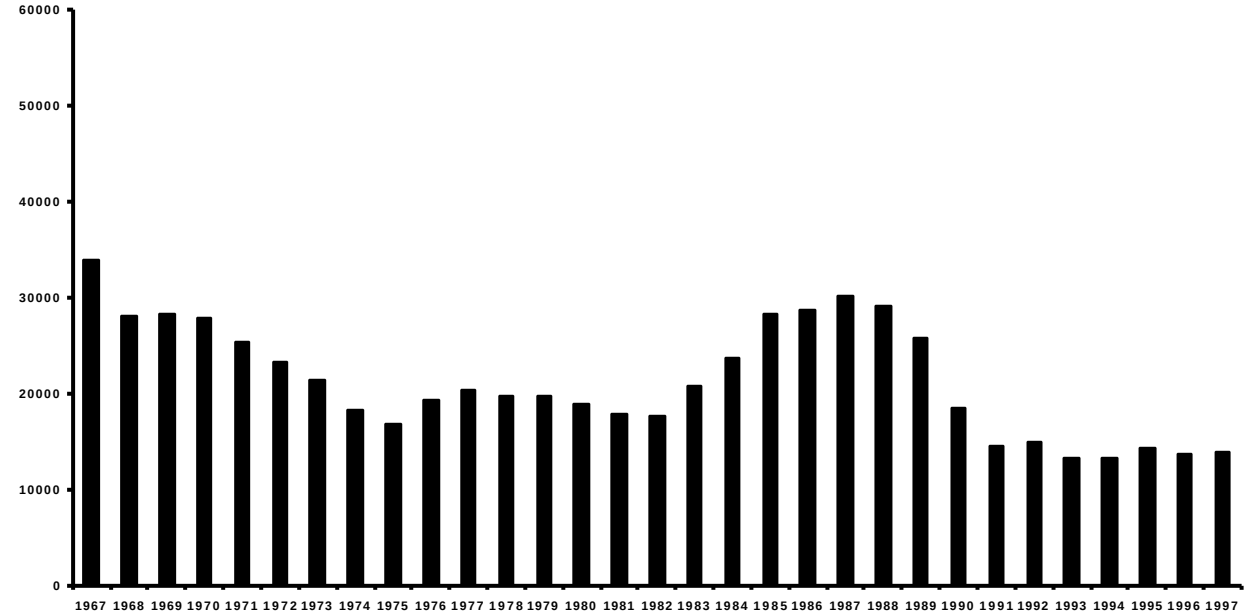
In the previous section, we highlighted the inadequacy and poor distribution of capital invested in the three main phases of the innovative process, namely R&D, innovation and technological diffusion. We can now examine the distribution of public and private funds between the three phases. We then find that public support is directed mainly at the first and third phases through subsidies to production, export, regional development, etc. implemented within the context of industrial sector-based policies followed by horizontal policies since the end of the 1980s. Until recent years, the proportion of European public funding devoted to the second phase was very low compared with that devoted to the other two phases. Compared with the United States, it is clear that there is a strikingly uneven distribution of European private resources between the three phases, which confirms that European enterprises appear to have long neglected investment in research and innovation compared with investment in the distribution of new products and processes, and new forms of organisation and distribution often developed abroad. The attitude of the European financial markets has sharpened this tendency since the mid-1980s by encouraging enterprises to favour investments which are profitable in the short term.

We shall analyse below R&D investments by actor and by field in order to identify on the one hand the factors responsible for this European under-investment compared with the United States and on the other the fields in which this investment gap is now becoming a cause for concern.

3.1. Who Is to Blame - the Governments or the Markets?

The most worrying phenomenon of the rapid growth of the "wide gap" in R&D investment during the 1990s is that this gap can no longer be explained, as in the past, by differences between American and European public support, for example during the 1960s or 1980s (Figure 7). At the end of the 1960s, over 60% of the discrepancy in R&D investment resulted from differences in government investment. For the reasons given above, this disparity among public investments gradually decreased during the 1970s. It accounted for only 28% of the overall gap in 1979, against 56% in 1970. Following the rapid rise in Federal expenditure under the two Reagan administrations, the public investment gap represented a high proportion of the total gap. It was not until the 1990s that this gap narrowed again, stabilising at around 14 billion dollars.

Figure 7:Gap between the United States and the European Union in government R&D investments
(USD million , PPP at 1990 prices and exchange rates)



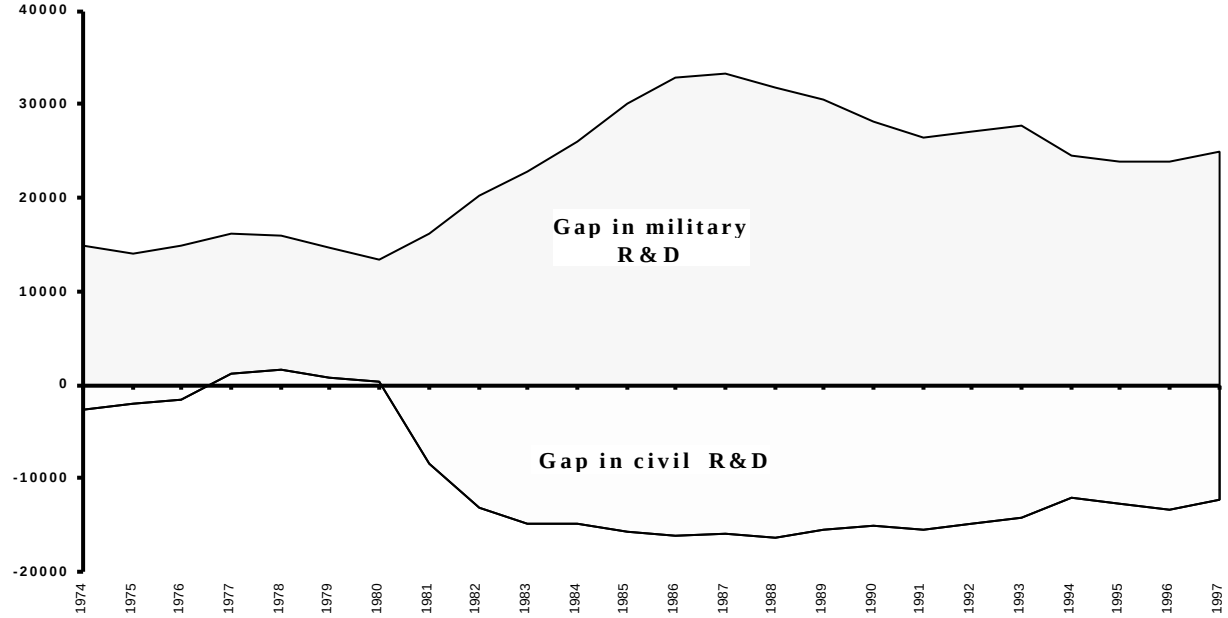
Notes: See those for Figure 1.
Sources: own calculations from Eurostat and OECD data.

It will also be observed that total European public expenditure does not include Community funding[8]. In terms of overall allocation of funds, the public authorities

[8] Because in OECD data, this normally appears under the category of R&D financed by foreign sources. It can be observed, however, that the inclusion of Community expenditure has little impact on the gap,

cannot be considered at fault after 1975, since public under-investment in Europe is confined to the period prior to 1975. Apart from the Reagan years, the difference between American and European government expenditure has never been very high and it has represented a decreasing percentage of the overall investment gap in recent years. This is even more apparent in the following figure, which compares the gap in public expenditure on civil and military R&D and reveals a fundamental difference in that although the disparity is negative for Europe in military R&D, it is however positive in civil R&D. This indicates that European governments were more active than the American Federal government in reducing the poor distribution of risk which is one of the major causes of allocative inefficiency, whereas the Americans appear to have left this to the military industrial sector, which is responsible for the distribution and "dual use" of results obtained from military R&D.

Figure 8 : Gap between the US and the EU in civil and military R&D financed by public sources (in million, PPP at 1990 prices and exchange rates)



Notes: (1) See the notes to Figure 2. (2) There is a break in sequence between 1981 and the previous years. (3) Spain is not included in EU-15 from 1974 to 1980. (4) Portugal is not included in EU-15 from 1974 to 1984. (5) Austria is not included in EU-15 from 1974 to 1980. Sources: own calculations from national, Eurostat and OECD data.

Whilst it is difficult, when considering allocative inefficiency on a macro-economic level, to hold the public authorities responsible for under-investment, the same does not apply with regard to the sector-based distribution of public funds and the growth of organisational and institutional inefficiency.

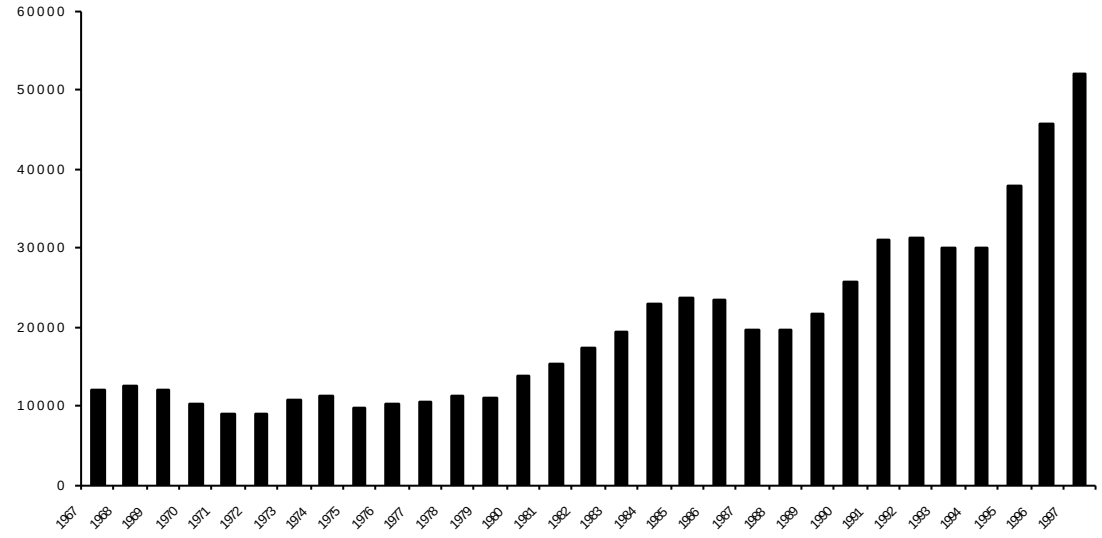
---

narrowing it by around one to two billion dollars between 1984 and 1997, given that it represents only some 2% to 4% of public R&D expenditure of the fifteen Member States.

On the other hand, Figure 9 shows that the trend in the R&D investment gap between American and European companies is almost the opposite of the previous trend and that, after remaining relatively stable from 1967 to 1979, it increased rapidly under the influence of the financial euphoria at the beginning of the last decade, rising from 30 billion PPP at the beginning of the present decade to 52 billion in 1997.

There can therefore be no denying that in Europe the markets failed to invest in this intangible activity with long-term profitability. European financial markets and enterprises appear to have encountered problems in keeping up with the pace of technological competition, which quickened after the mid nineteen-eighties.

Figure 9: Gap between the US and the EU in R&D financed by Business Enterprises (in million, PPP at 1990 prices and exchange rates)



Notes: (1) See the notes to Figure 2.
Sources: own calculations based on national sources, Eurostat and OECD data.

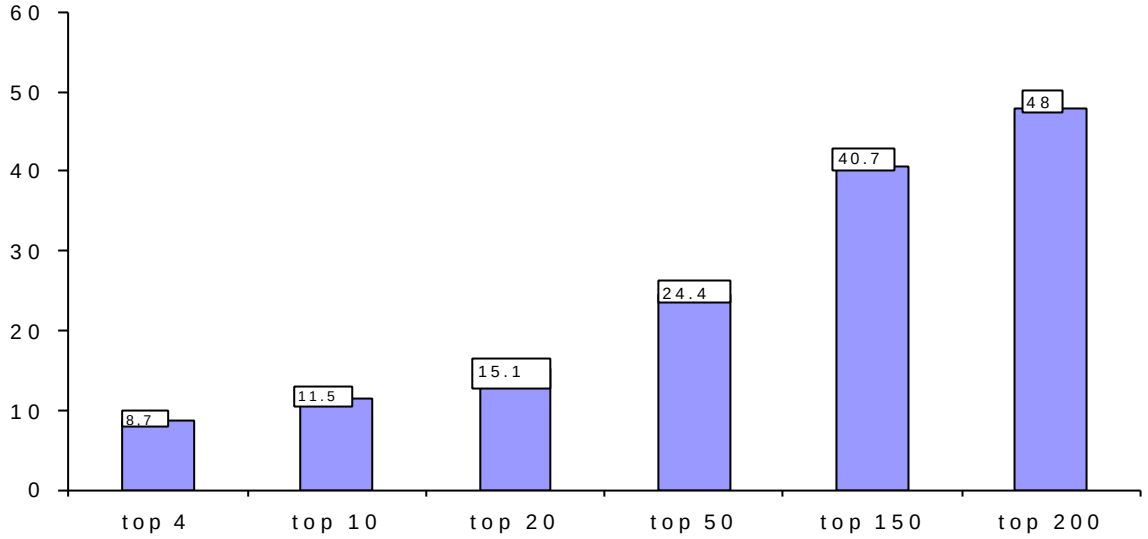
3.1.1. R&D Funding by Companies According to their Size

We initially tried to compare the R&D investment gap between American, European and Japanese companies, all sectors combined, using consolidated data per industrial group[9]. The following figure shows that the gap between the United States and the EU in technological investment increases the further down the specific industrial pyramids we descend.

---

9 Although the estimates of R&D expenditure of industrial groups are less reliable than the sector-based data gathered and published by the statistical authorities in each country, their main advantage is that they show genuine investment gaps, in accordance with both the nationality of the capital and the size of the companies. In the earlier data, expenditure by resident enterprises under foreign control is included in each country's internal R&D expenditure (GERD). As a result, they do not enable investment gaps to be measured in accordance with the nationality of the companies' capital. Work in progress by the OECD on globalisation indicators reveals the significance of this factor.

Figure 10: Gap between American and European company R&D investment in 1997 by size (billion dollars at current prices)

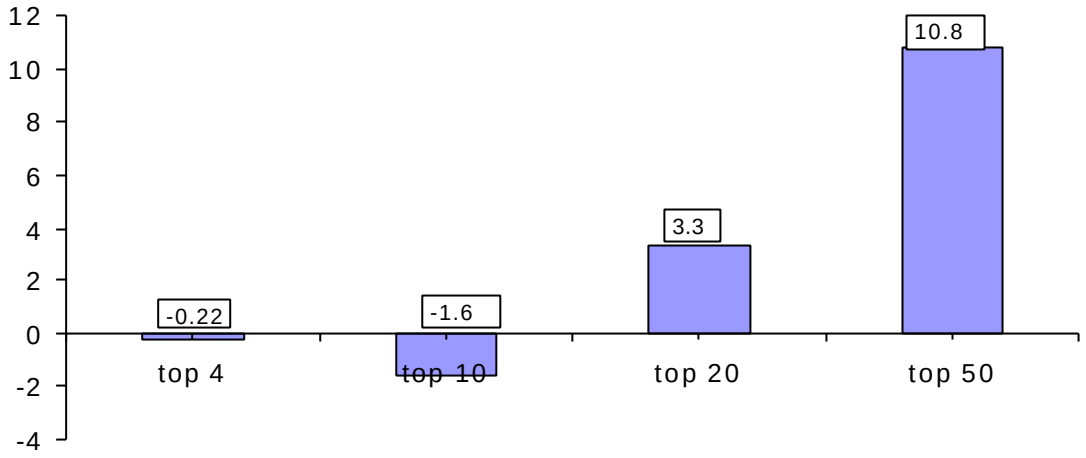


Sources: own calculations based on available company data (DTI, DABLE, R&D Magazine, Amadeus, etc.)

The gap between the R&D expenditure of the top ten European companies and the top ten American companies is four times lower than that observed between the top two hundred companies on both sides of the Atlantic. The investment gap results in the first place from insufficient R&D investment by medium-sized European companies. The R&D expenditure of the top ten American companies represents only 40% of the total expenditure of the top hundred, against 64% in the EU. Put another way, the European company in 70th place in the European list based on the size of the firms'. R&D investments would fall to the 120th place in the list of American R&D giants, while the European company in 100th place would not even be included in the list of the American top 200. This concentration of investment in the nation's top companies is even more pronounced in Japan.

As seen in Figure 11, in which European and Japanese companies are compared by size, this failure by smaller firms to participate in industry's total investment in R&D is much more significant in Japan than in Europe. Large Japanese companies spend more than the European leaders of the same category. On the other hand, there is a striking lack of competitiveness in the lower segments of the Japanese industrial pyramid, where a large majority of small businesses are sub-contractors or technologically dependent. This can be seen, for example, by comparing the expenditure of the top twenty or the top fifty.

Figure 13: The 1997 R&D investment gap between European and Japanese companies by size (billion current dollars)



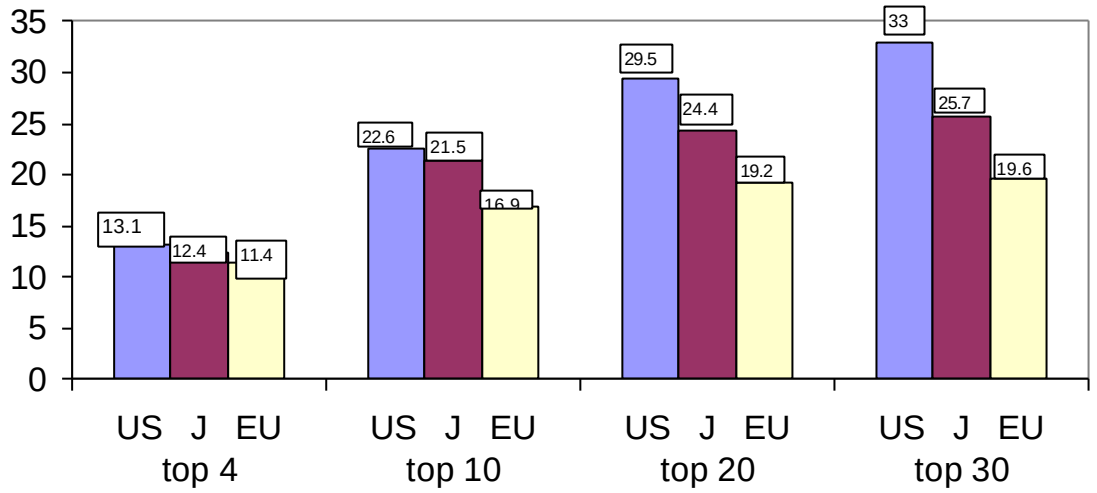
Sources: Combination of available enterprise data (DTI, 1998 ; DABLE, R&D Magazine, Amadeus, etc.)

Compared to the European Union and Japan, American companies' investments in R&D are therefore much better distributed between the top and the base of industrial structures. The industrial and technological competitiveness of the EU and Japan depends much more on the investment and performance of the large companies. The United States derives many advantages from the existence of a large number of small and medium-sized local enterprises with a substantial capacity for investment in R&D and innovation. Since the firms follow a much wider range of technological opportunities, competition on the domestic market is keener and if large companies drop out, the American economy has no shortage of other dynamic firms to maintain its technological lead. This type of industrial structure, which consists of top companies, can be challenged on a technological level by established or new firms. This appears to constitute an overall competitive advantage, particularly within new industries which are characterised by strong competition and continually changing technology. An analysis of the growth of the American electronics or information technology sectors provides numerous examples of this. We know that these industries' top ten firms have been renewed on several occasions over the last forty years, declining dominant companies having been replaced by challengers who have backed different and alternative technological options to those of the large companies.

We have endeavoured also to compare the R&D expenditure of American, Japanese and European enterprises within the cluster of sectors connected with electronics, which includes information and communications technology (equipment and services), electrical equipment, semiconductors and consumer electronics. This cluster approach improves the quality of the comparison, since the classification of diversified companies is easier and thus more reliable when all these different sectors are lumped together.

A comparison between the R&D expenditure' structures of the Triad in this industrial cluster, carried out for 1997, provides some interesting observations. It is firstly noted that the number of small and medium-sized firms with relatively high R&D expenditure in the EU and Japan is exceptionally small compared with the US. It is noted that the 20th European electronics company spends only around the same sum as the top 70th American company. The first 30 companies in the EU and Japan would not even make the top 100 in the US. It is extremely difficult to identify companies the first 30 companies because they cannot be traced in any of the usual databases available.

Figure 12: R&D expenditure by American, Japanese and European firms in the electronics sector in 1997 (billion current dollars)



Notes : the electronics sector includes information and communications technologies, electrical equipment, semiconductors and software services. Sources: own calculations based on available company data

Figure 12 shows that the concentration of R&D expenditure in the electronics is higher in Europe than elsewhere. The top four European firms manage to invest almost as much as the top four American and Japanese firms. The gap starts to become sizeable when R&D investment by the ten top companies from each member of the Triad is compared. While the top ten Japanese companies invest more or less as much as the Americans, R&D investment in the top ten European firms is some five billion dollars behind. When the comparison is enlarged to the top twenty or thirty, it is evident that the remainder of the European and Japanese electronics sector cannot keep up with American industry, the gap in relation to the Americans amounting to 7 and 13 billion for Japan and the European Union respectively. Total R&D expenditure of the top 20 American firms represents approximately 60% of the total R&D expenditure in this sector, against 91% in the EU. This shows that apart from the large European firms, the European electronics sector no longer has a strong technological and industrial base. The lack of competitive companies able to take over from the large firms and make up for their strategic errors, also explains why public investment in R&D long favoured the bigger firms, both in Europe and Japan.

In this technological race, only a handful of top European and Japanese companies succeed in more or less keeping up with the American giants. In order to invest huge sums of capital in R&D, they try to reduce their expenditure in other areas and increase their productivity, mainly by cutting down on human resources. The real problem for the European economy does not therefore arise at the lower levels of the industrial pyramids. This same phenomenon is also found in almost all industrial sectors, although less accentuated than in the electronics.

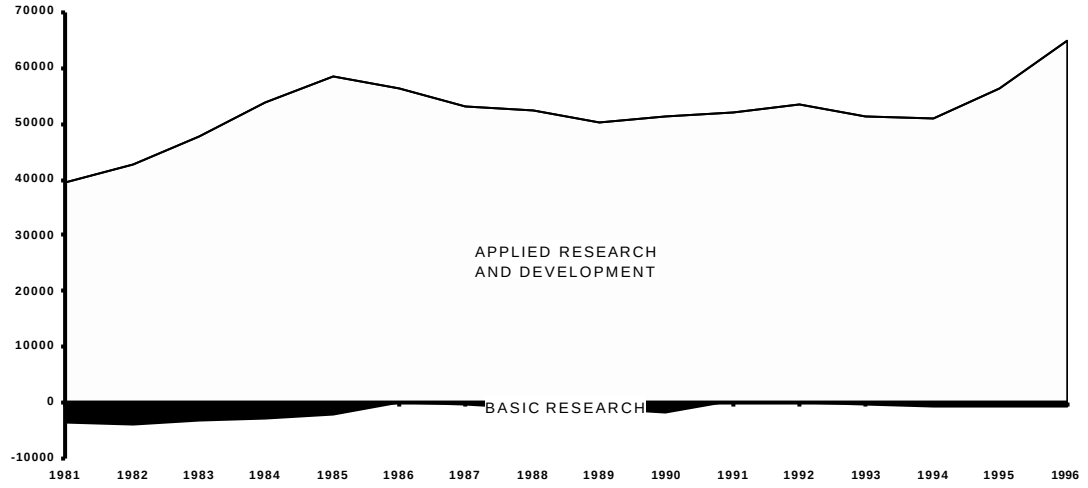
In Europe, the inefficiency in the allocation of resources appears to come more from market failings than from government shortcomings. If R&D investment by American companies continues at this pace for a number of years, it will not be surprising if the Americans suggest, in a future WTO round, that state aid for R&D be included on the yellow or red list. In that case, America would soon no longer require direct subsidies in this sphere and public R&D investment could be restricted exclusively to basic research or academic R&D.

3.2. The Inefficient Distribution of Investments by Field

With regard to the distribution of total R&D expenditure between the various fields, Figure 13 shows that the investment gap between the United States and the European Union is essentially attributable to the applied research and development stages. In Europe, it is governments which mainly concentrate investment on this segment and a large proportion of public funds are devoted to basic research projects or "pre-competitive" research. As a result, European Union investment rates in this area are in line with those of the United States, which ensures that its scientific performance does not deteriorate, as shown by the constant stream of Nobel Prizes awarded to European scientists, the growth in European scientific publications in comparison with other parts of the world and the dynamic rate of scientific discoveries (ERSTI, 1997; OST, 1998). Not only does the performance not deteriorate but, in many scientific domains, it is often superior to the one of the United States.

The concentration of the gap on the applied research and development phases results mainly from under-investment by European companies. This also explains European lower performance in terms of patents. Patents, of course, mainly arise from the phase of technological and industrial application. In the light of this information, the increased imbalance between European scientific and technological performance in recent years is thus neither a matter of chance nor particularly surprising.

Figure 15: Gap between the United States and the European Union in basic research, applied research and development (million PPP - current prices)



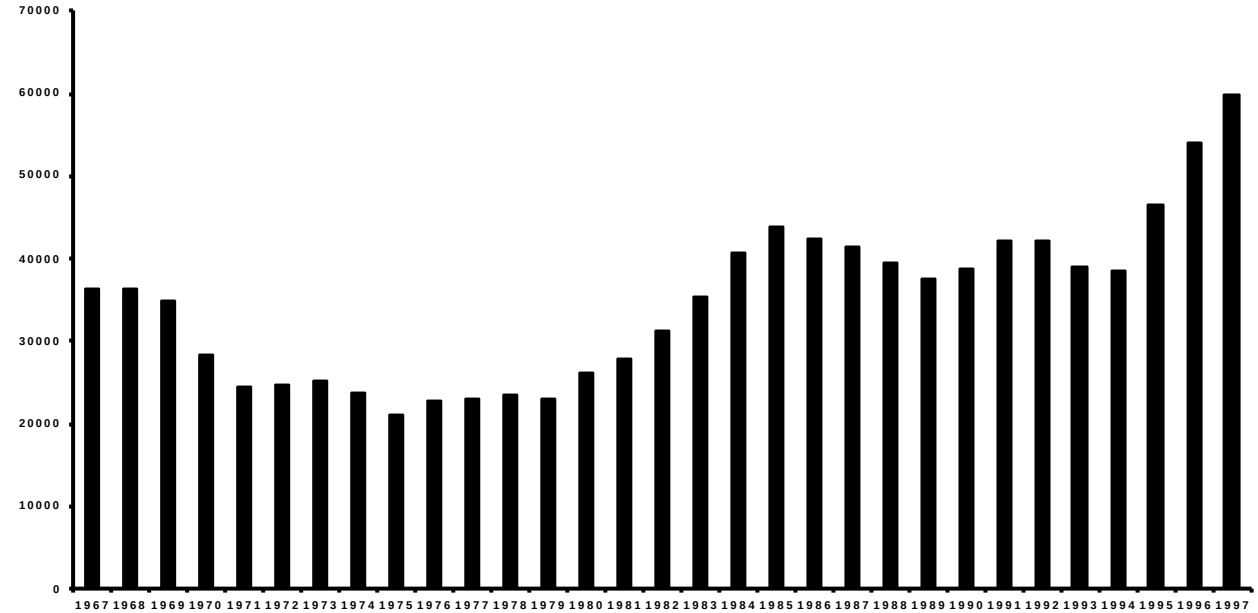
Notes: (1) Estimates have been made where data from some European countries for some years are missing. (2). EU-15 does not include Luxembourg. (3) Post-1991 data relate to reunified Germany. (4) Basic research: total non-BERD has been used for Belgium, Denmark, Greece, Finland and the United Kingdom because no data are available on basic research in these countries. (5) Applied research and development: total BERD has been used for Belgium, Denmark, Germany, Greece, Finland and the United Kingdom because detailed data for these countries are not available. The result is that the total for the EU-15 is probably slightly underestimated. Sources: own calculations based on national sources, OECD and Eurostat data.

3.2.1. The Investment Gap in High-Technology Industries is Widening!

The following figure portrays the R&D gap in the enterprise sector (BERD) regardless of the sources of finance. Although Europe as a whole has a larger public research sector than the United States and receives a higher percentage of public funds allocated to R&D, the portion of public resources allocated to business R&D is much lower in the European Union than in the United States. Although this percentage is falling on both sides of the Atlantic, the United States rate of public financing of business R&D is still well above that of the European Union, the rates standing at 17.8% and 10.4% respectively in 1995. Even so, the responsibility for this weakness cannot be attributed to R&D policymakers because they are subject to pressure from increasingly strict competition policies in this area.

On the other hand, European industries invest very little of their own capital in R&D compared with their American and Japanese competitors. The widening gap at this level is obviously a cause for concern. Whereas it stood at some 28 billion dollars at constant prices at the end of the 1970, it amounted to over 40 billion dollars in the mid-1980s and passed the 60 billion dollar mark in 1997 (Figure 14). In this cumulative process, the results of which are only revealed after several years of investment, such investment deficits are likely in the long term to prevent European industry from maintaining the technological competitiveness required by economic globalisation.

Figure 14: Gap between the United States and the European Union in business R&D investment. (BERD, million PPP at 1990 prices and exchange rates)



Notes: (1) Estimates have been made where data were not available. (2) EU-15 does not include Luxembourg (G.D.). (3) Post 1991 data relate to reunified Germany. Sources: own calculations based on data from Eurostat and the OECD.

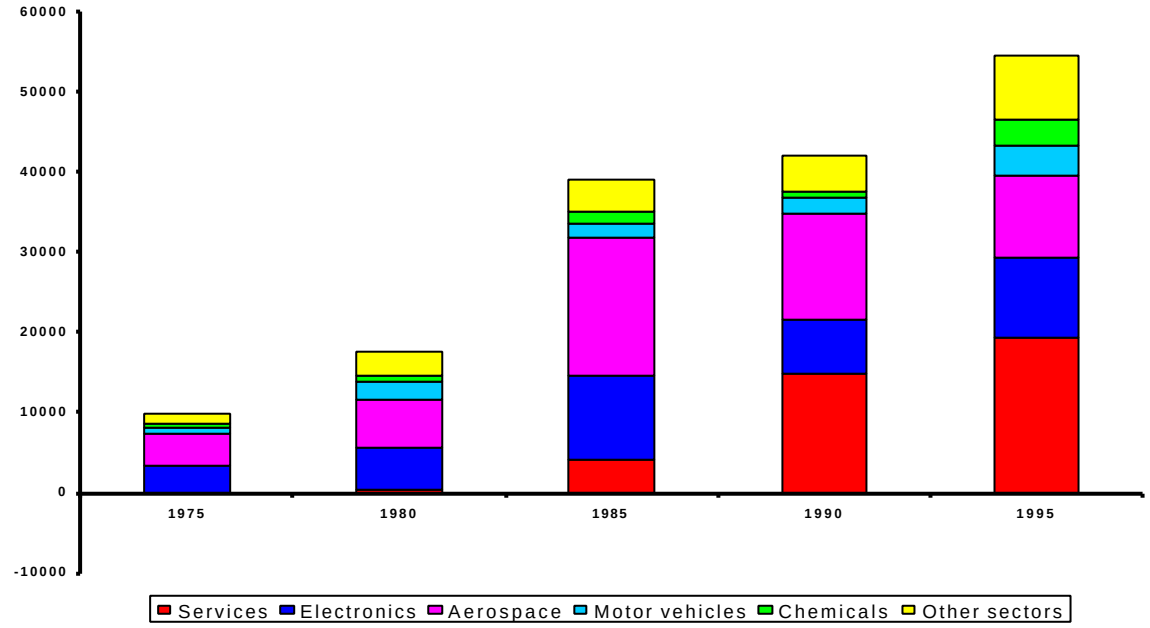
Our analysis by group of sectors[10] shows that gaps in certain areas have already reached such levels that any easy remedy is ruled out. This is seen in Figure 17, which shows the development of investment gaps in industrial R&D by field (PPP dollars at current prices).

- Firstly, it is observed that there is a significant widening of the R&D gap in service industries. In the 1970s, expenditure by European service companies was in general higher than that of the United States. The United States moved ahead in 1979. The gap remained relatively narrow during the 1980s. In recent years a quantitative change has occurred on a scale suggesting the beginning of a fundamental change in the two big members of the Triad. American expenditure rose from 7.8 to 27.9 billion between 1987 and 1995, whereas European service industry R&D expenditure continued to grow at the same pace as in the previous period, rising from 4.4 to 8.7 billion. The gap then widened to over 19 billion in 1995, a new record. Much of this can be explained by the difference between American and European R&D expenditure by software companies and engineering services, which are included under this heading.

[10] In order to increase the reliability of the comparative data, some sectors have been grouped together. For example, the electronics industry groups together the information technology, communications, electrical equipment and semiconductor sectors.

- The second group of sectors where a wide gap appears is the electronics or ICT cluster, which includes information and communications technology other than services, electrical equipment and semiconductors. The gap in this cluster has developed in three stages. It widened steadily between 1975 and 1985, then narrowed slightly during the second half of the 1980s - from 10.5 to 6.7 billion in PPP between 1985 and 1990, after which it again began to rise, reaching its previous 1985 level of some 10 billion in 1995. A more detailed analysis by sub-sector reveals that a significant part of this disparity results from information technology and semiconductors. Against this, the Europeans stood up better in telecommunications, consumer electronics and electrical equipment. In these three sectors, total European expenditure was even slightly higher than that of the United States between 1990 and 1994. Here too, however, the gap again became positive for the United States in 1995, at around 3.5 billion, the same as during the 1980s.

Figure 15: Gap in business R&D expenditure between the United States and the European Union, by sector (million PPP - current prices)



Note: (1) EU-15 does not include data for Belgium, Greece, Luxembourg, Austria or Portugal. Sources: data from OECD (ANBERD) and Eurostat

- The trend in the aircraft industry contrasts with other sectors. It is practically the only sector in which Europe has unquestionably closed the gap during the last few years. The gap in favour of America, which rose to 17.1 billion in 1985, primarily fell first to 13 billion in 1990 and then to 10 billion in 1995. An analysis in constant dollars would bring out this narrowing of the technological investment gap more clearly. Even so it still remains favourable to the United States.
- It is also seen that Europe stands up better in the motor and chemical sectors, where the investment gaps between the United States and the European Union are relatively narrow compared with other sectors. They stood at 3.8 and 3.2 billion dollars in 1995 respectively. In this latter group of sectors, where Europe has either

caught up or is not far behind the United States, the main question is whether the very strong growth in American R&D expenditure during the last seven years will continue at the same pace.

Considering the strategic importance of the ICT sector, we looked for more information on the size of the gap between total investment expenditure in the United States and in the European Union. The investment gaps in this technological cluster, shown above, do not take into consideration either R&D carried out in the services related to these industries, such as software, or the nationality of the enterprises, so that R&D expenditure by IBM or Intel subsidiaries resident in Europe are included in the domestic R&D expenditure of the European countries concerned. In view of the increasing globalisation of the industrialised economies, we therefore needed to improve our understanding of the real gap between the United States and the European Union in this new technological field. Having obtained American expenditure as estimated by the US Congress Budget Office (CBO 1999), we tried to estimate the total expenditure of the fifteen EU countries using the same methodology as the US Congress Budget Office. Since the business data are not available per company, we shall present them as an aggregate for the entire ICT cluster.

It clearly emerges from a comparison of these two estimates that the total size of the investment gap in the electronics sector has reached gigantic proportions during the last few years. R&D expenditure by American companies is more than double that of European companies, and American investment in venture capital in this sphere is four times higher than that of the fifteen European countries. The estimates of public investment in this industry in 1997 once again confirm that it is difficult to blame to the European governments for this backwardness.

Table 1: The total R&D investment gap between the US and the EU in electronics, information technology, telecommunications and software in 1997 (billion current dollars)

Financing sources	**Funding in 1997, million dollars**		
	United States	*EU-15*	*Gap*
Industry	44.2	21.0	23.2
Venture capital	6.9	1.6	5.3
Public sources	1.2[1]	1.7[2] (EC: 0.63; Member States: 1.04)	-0.5
Total	52.3	24.3	28.0

Notes: (1) Solely Federal expenditure, including only that under the development programmes of the *High Performance Computing and Communications* Initiative and by the Department of Energy. (2) Including solely

Community and national expenditure on programmes exclusively concerned with information and communications technology. Since seven Member States do not have data broken down by NABS, the national expenditure relates only to that of eight Member States of the European Union, the figures for three of which relate to 1996. Sources: for American estimates: US Congress Budget Office (1999), for the EU, estimates based on data from the following sources: for industrial expenditure, combination of company data (DTI (1998), DABLE, R&D Magazine (1998), etc.) and OECD ANBERD data; for Venture Capital EVCA (1999); for public expenditure, FPRTD data and DG Research/Eurostat NABS data concerning budget appropriation.

This comparison also reveals that the R&D investments by companies and venture capital markets reached such a high proportion in this sector that public investment represents a relatively low fraction of the total investment. It is, however, interesting to note that President Clinton's Information Technology Advisory Committee – the PITAC– suggested in the context of preparatory work for the 2000 budget that American federal expenditure be doubled over the next five years in order to stimulate innovation in this area. The difference in general attitude between the Americans and the Europeans regarding R&D investment appears, however, to be far more fundamental than the gaps observed above.

4. Conclusion

Following the comparison between American and European investment in R&D and innovation between 1967 and 1997, a few preliminary conclusions should be drawn as a contribution to the current debate on European research and innovation policies.

In light of all the results presented, it appears difficult to maintain that the weakness of European technological and economic performance can be explained solely by organisational inefficiency. The dominant thesis in Europe today, which advocates reorganisation of European research and innovation systems without altering the size and distribution of public and private investments, ought to be rejected, especially as, after a long period of under-investment and inadequate allocation of resources, the distinction between the sources of the organisational and allocative inefficiency in the European research and innovation system have become blurred, resulting in difficulties in determining the causal relationship. We have, for example, highlighted the under-investment in R&D on the part of European industry compared with American industry. We have also shown that this is explained in the main by shortcomings in the lower stages of the industrial structures and not by a lack of investment on the part of large European companies. The under-investment by European SMEs in research and innovation could equally well be explained by allocative inefficiency (the lack of access to national programmes for SMEs, the SMEs' specific funding difficulties) as by organisational inefficiency (barriers to the start-up and development of new innovative enterprises, lack of cooperation with SMEs by universities and large companies, etc.). We therefore believe that any policy which does not tackle organisational and allocative inefficiencies at the same time will not bring about any lasting improvement in the European Union's technological and industrial performance. We consider that a substantial increase in public and private funds for SMEs will only achieve the desired result if this is accompanied by measures aimed at dismantling the barriers to

innovation, the business creation and the expansion of SMEs and that optimisation of the system's organisation cannot succeed in a context of chronic under-investment. We therefore need a comprehensive policy for reorganising and refinancing the European research and innovation system.

This "new policy" should also be *systemic*. At present not only do we need a new research and innovation policy, we also need a new *policy mix* of structural adjustment policies. This is necessary for several reasons. We know that the vast majority of sources of both organisational and allocative inefficiencies in the European research and innovation system cannot be brought to an end without changes in other structural adjustment policies, such as industrial policy, competition policy, foreign trade policy, education policy and banking and finance policy.

This "new policy" should also cover *the long term*. This is more an obligation than a deliberate choice. The EU is today so far behind its competitors in investment in research and innovation - over 70 billion current dollars in 1997 - that any wish to improve this European deficit in the short term would simply be a pipe dream. Such an objective is illusory not only in view of the need to comply with the European Stability and Growth Pact, it is not even desirable from the point of view of an efficient research and innovation policy. We are aware that even if we were in a position today to commit tens of billions of additional euros, this oversupply of capital would do nothing other than lead to a superficial increase in the costs of research and innovation unless there were measures to increase demand. An appreciable increase in the supply of capital in this area should always be preceded by actions designed to enhance human scientific potential or the number of enterprises wishing to take part.

For this reason, we consider that it would be more effective to introduce medium and long term objectives for individual Member States, as in Spain for instance, which is aiming to increase its R&D expenditure from 0.8% of GDP in 1997 to 1.2% in 2002. This new policy would be applied to all the Member States over a much longer time scale and would, for example, make provision for more rapid growth in research and innovation expenditure than in GDP, so that the R&D intensity of all the Member States would be above 2% of GDP in 2010. Without such a European policy, R&D intensity in the European Union may well fall to an average of around 1.5% given the level of technological development of the European countries applying for membership. During the next decade, unless we want to find ourselves with a technological intensity almost twice as low as that of the United States and Japan, this comprehensive effort to step up investment must be divided fairly between all the Member States of the European Union.

A series of quantifiable objectives that can be adjusted to each Member State should thus be set in all the areas concerned, both in terms of the number of higher education qualifications and the number of active researchers and engineers in the public and private sectors, and in terms of venture capital, start-ups and government support for SMEs and innovation. All these objectives should be discussed and coordinated at European level, taking into account the specific features of each Member State. We are therefore suggesting a method which has already been tried and tested within the

context of completion of the Single Market and the introduction of EMU: a set of common and clear objectives, with a precise action plan and reasonable target dates for attaining them.

Europe's economic, industrial and technological performance suffered for a long time from the lack of a single market and a single currency. Now that we have succeeded in using this method to correct these two structural weaknesses in the European economy, it appears essential to prepare a new comprehensive, systemic and long-term policy for structural adjustments on a European scale, so that Europe can once again take the initiative in terms of technological and industrial leadership and strengthen the bases of sustainable economic growth that will generate employment.

Bibliography

Aglietta, M., 1995, *"Macroéconomie financière"*, Repères, la Découverte.

Amable, B., R. Barré and R. Boyer, 1997, *"Les Systèmes nationaux d'innovation à l'ère de la globalisation*", Economica.

Aoki, M. and G. Dosi, 1992, *"Corporate organization, finance and innovation"*, in V. Zamagni (ed.), Finance and The Enterprise, Academic Press.

Arrow, K.S., 1962, *"Economic Welfare and Allocation of Resources for invention*" in Nelson R.R. (ed.), The Rate and Direction of Inventive Activity: Economic and Social Factors", NBER, PUP.

Bernstein, J. and P. Mohnen, 1994, "*International R&D Spillovers between US and Japanese R&D Intensive Sectors*", NBER Working Papers, No 4682.

BLS, 1989, "The Impact of Research and Development on Productivity Growth", US Bureau of Labor Statistics, Washington DC.

CBO (Congressional Budget Office), 1999, *"Current Investments in Innovation in the Information Technology Sector: Statistical Background"*, Memorandum.

Coe, D. and E. Helpman, 1993, *"International R&D Spillovers*", NBER Working papers, No 4444.

D'Aspremont, Cl. and A. Jacquemin, 1988, *"Cooperative and non-cooperative R&D in duopoly with spillovers*", American Economic Review, Dec., Vol. 78, No 5.

David, P. and D. Foray, 1995, *"Distribution et expansion de la base des connaissances scientifiques et technologiques*", Revue STI, No 16, OCDE.

David, P. and D. Foray, 1996, "*Information Distribution and the Growth of Economically Valuable Knowledge: a Rationale for Technological Infrastructure Policies*", in Teubal and others (eds.), Technological Infrastructure Policies: an International Perspective, Dordrecht: Kluwer.

Department of Trade and Industry, 1998 and 1999 *"The UK R&D Scoreboard"*.

European Commission, 1993, "White Paper: Growth, Competitiveness, Employment", OOPEC, Luxembourg.

European Commission, 1994, "European *Report on S&T Indicators*", EUR 15897, OOPEC, Luxembourg.

European Commission, 1997, "Second E*uropean Report on S&T Indicators*", EUR 17639, OOPEC, Luxembourg.

European Commission, 1996, "*Livre vert sur l'innovation*", Bulletin de l'Union européenne du 5/95, OOPEC, Luxembourg.

European Commission, 1996, "*Livre blanc sur l'Education*".

European Commission, Communication, 1997, "*Inventing Tomorrow*".

European Commission, Communication, 1998, "The *Competitiveness of European Enterprises in the face of Globalisation*", COM(1998)718 final.

European Commission, 1999, "*The Competitiveness of European Industry*".

European Commission, "*EC- Key Figures*", 1998 and 1999.

European Commission, 1996, "*Conclusions du Sommet Européen de Florence*", SN/300/96.

European Commission, 1998, Communication, "*Le capital-investissement: clé de la création d'emplois dans l'union européenne*", SEC(1998)552 final.

European Information Technology Observatory, March 1998 (and update October 1998) (European Economic Interest Grouping / EEIG), Eggebrecht-Presse, Mainz, Germany.

EVCA, 1999, European Venture Capital Association, 1999 Yearbook.

Foray, D., 1997, "*Generation and Distribution of Technological Knowledge: Incentives, Norms, and Institutions*", in Edquist Ch. (ed.), Systems of Innovation, Pinter.

Guellec, D., 1999, "*Economie de l'innovation*", Repères, La découverte.

Lorenzi, J.-H. and J. Bourlès, 1995, "*Le choc du progrès technique*", Economica.

Mansfield, E., 1968, "*Industrial Research and Technological Innovation*", Norton for the Cowles Foundation, Yale University.

Martin, B. and others, 1997, "The relationship between publicly funded basic research and economic performance", University of Sussex.

Muldur, U., 1997, "*La politique américaine de S&T*", Futuribles, No 220.

Muldur, U., 1991, "*Le financement de la R&D au croisement des logiques industrielle, financière et politique*", Programme FAST, FOP 277.

Nadiri, I., 1993, "*Innovations and Technological Spillovers*", NBER Working Papers, No 4423.

NVCA Yearbook, 1999, National Venture Capital Association, Venture Economic Information Services.

OECD, 1996, "*The OECD Job Strategy: Technology, Production and Job Creation*".

OECD, 1996, "*Government Programmes for Venture Capital*".

OST, Observatoire de Science et technologie, Reports 1996 and 1998.

Petit, P., 1998, "*Formes structurelles et régimes de croissance de l'après fordisme*", CEPREMAP Working papers, No 9818.

PITAC, President's Information Technology Advisory Committee, 1999, "*Information Technology Research: Investing in Our Future*", Arlington Va., National Coordination Office for Computing, Information, and Communications.

Rosenberg, N., 1996, "*Uncertainty and Technological Change*".

Servan-Schreiber, J.-J., 1967, "*Le défi américain*", Denoël.

Scherer, F.M., 1982, "*Inter-Industry Technology Flows and Productivity Growth*", The Review of Economics and Statistics.

Soete, L., 1999, IFRI Seminar, April.

Soete, L., 1996, Discussion paper in Federal Reserve Bank of Boston, Technology and Growth, Conference Proceedings, No 40.

Solow, R.M., 1957, "*Technical Change and the Aggregate Production Function*", Review of Economics and Statistics, No 39.

Stokey, N.L., 1995, "R&D and Economic Growth", Review of Economic Studies, No 62.

Terleckyj, N.E., 1974, "*Effects of R&D on the Productivity Growth of Industries: an Exploratory Study*", Washington D.C., National Planning Association.

Tibbets, R., 1996, "*50 examples of SBIR commercialization*", Mimeo, US National Science Foundation.

Spence, M., 1984, "*Cost Reduction, Competition and Industry Performance*", Econometrica, January, Vol. 52, No 1.

WITSA, International Data Corporation, 1998, "*Digital Planet: The Global Information Economy*".