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# Is Europe Becoming the Most Dynamic Knowledge Economy in the World?

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## Abstract

The paper discusses the condition and perspective of the European Union in the knowledge economy and the feasibility of the goal given by the European Council at the Summits held in Lisbon (March 2000) and Barcelona (March 2002), that is, to increase European R&D expenditure up to 3 percent of GDP by 2010. The paper focuses on two aspects: comparative performance with its direct counterparts, in particular the US..; and intra-European distribution of resources and capabilities. A set of technological indicators is presented to show that Europe is still in a consistent delay when compared to Japan and the U.S., especially in R&D investment and in the generation of innovations. A small convergence occurs in the diffusion of Information and Communication Technologies (ICTs), the sector most directly linked to the concept of the "new economy." In the field of knowledge collaboration, Europe reveals opposing paths in the business and in the academic worlds. Within Europe, the level of investment in scientific and technological activities is so different across countries that it does not merge into a single continental innovation system.

**Keywords**: Technological Change, New Economy, U.S., ICT, Innovation Systems

## Introduction

At the Lisbon Summit in March 2000, the European Council declared its intention of making the European Research Area (ERA) the greatest knowledge economy in the world. At the Barcelona Summit in March 2002 it was stated that Europe should reach a ratio of R&D to GDP equal to 3 percent by 2010. How realistic are these targets? And, how is Europe doing in the technological race five years after the first announcement of these goals?

The aim of this paper is to present some evidence on the dynamics of technological change in Europe, compared to the performance of its direct competitors, the United States and Japan. It is often argued that a new cluster of innovations, Information and Communication Technologies (ICTs), and associated productivity growth are leading us into a "new economy" that will deliver an expansion of employment and improved standards of living (for an overview, see Temple, 2002). On the basis of the impressive performance of the U.S. economy in the 1990s, it has often been suggested that the wealth of nations will rely on their ability to adjust to these transformations, and that those countries not able to adjust will be marginalized and will lose the competitive race. The accompanying prediction says that Europe will have slower long-term economic growth than the U.S. because of its insufficient effort at adjusting to the rules of the "new economy" (Daveri, 2002). In other words, if the old continent continues to lag behind the U.S. and Japan in technological dynamism, this could jeopardize the achievement of the "European dream" in domains such as welfare, public education and health care (see Rifkin, 2004); hence the need to upgrade, in the most aggressive way, the European knowledge base.

The idea that there is a "new" economy is certainly fascinating, and it is not surprising that it has been so prominent in the business world, in the political community and in the press. John Maynard Keynes knew very well that expectations play a fundamental role in fostering the business cycle, and the hope that something so intriguing as a "new" economy could be with us has helped some corporations to support their stock market prices, some politicians to be elected or re-elected, and the media to increase their sales.

The academic community is certainly not immune from these tendencies, although its function should be to take ideas that have spread too quickly with a pinch of salt,[1] and it is no surprise that a good share of the optimism vanished with the stock market recession that began in September 2000. A dose of skepticism does not imply sharing the belief that there is nothing new under the sun: now and then something new does occur in economic and social life. Major changes have taken place in the last decade and some key components can be singled out, in particular:

1) The exploitation of knowledge has become more and more systematic, with an increasing propensity by business companies to search out profit and growth opportunities in the exploitation of know-how (Granstrand, 1999; Suarez-Villa, 2000).

2) The transfer across space of commodities, financial resources, expertise and information has become much easier; while technical feasibility has increased exponentially, economic costs have been dramatically reduced (Antonelli, 2001; Freeman and Louca, 2001; Held and McGrew, 1999).

3) The number of players able to enter into old and new fields has also increased, leading to an accelerated pace of economic competition (Mowery and Nelson, 1999).

These three aspects combined have something in common with what has been labelled a "new economy," but we have included in the definition neither the assumption that ICTs will automatically translate into steady productivity growth nor that stock market values should increase spectacularly (see Freeman, 2001). In fact, scholars who study long-term economic and social development have preferred to use terms such as "knowledge-based economy," which emphasizes the role played by know-how and

[1] For a critical assessment of the over-optimism about the new economy, see Freeman (2001).

competencies in the economic sphere. We prefer to use the term "globalizing learning economy" (Lundvall and Borras, 1998; Archibugi and Lundvall, 2001), since this seems better to capture the key role played by human learning in the economic and social landscape and to connect technological innovations to the social infrastructures and competencies needed to exploit them. The term "globalizing" (rather than "global" or even "globalized") should help to remind us that the vast majority of the world's population of the world is still excluded from access to know-how that has already become obsolete in other parts of the globe (UNDP, 2001).

Whatever term we use, we have to face a new reality: long-term economic growth, employment and welfare on the old continent will be more and more associated with its capability to generate, acquire and diffuse new knowledge. It is therefore not surprising that there is a major policy concern within governments, businesses and trade unions about ways to promote scientific and technological activities, to foster innovation in firms, and to upgrade the competencies of human resources. These are seen as key conditions for increasing employment and retaining market shares in an enhanced competitive world economy.

This is eloquently reflected in the so-called "Lisbon Strategy," which focuses on a wide range of topics but puts the "knowledge economy" at the core of its economic policy. The European Council in Lisbon (March 2000) set the strategic goal for the next decade "to become the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment." The European Council in Barcelona (March 2002) further quantified these targets and agreed that "overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3 percent of GDP by 2010. Two-thirds of this new investment should come from the private sector."[2]

These targets certainly go in the right direction, but it must also be stressed that they are very ambitious (for an assessment, see Soete, 2002; Schibany and Streicher, 2003; European Commission, 2003). Unfortunately, the European Summits have not been sufficiently explicit about the instruments made available and some basic questions remain unaddressed (for a much needed attempt to assess the Lisbon Strategy, see the Kok Report, 2004). In particular: a) how will the private sector be induced to increase its own R&D so substantially? b) how should the growth in R&D be distributed among the various member countries? c) what role should individual governments and European Commission institutions play?

In order to develop a proper innovation strategy, Europe must face the fact that it is composed of a number of states which retain substantial autonomy.[3] What the old continent is gaining in terms of variety and diversity, it is losing because of lack of cohesion and central policy decision making. Europe is an agglomeration of different innovation systems. While some regions of the European Union are strongly integrated in knowledge transmission, others continue to be peripheral and excluded by major technology transfer flows. The recent enlargement from EU15 to EU25 has definitely increased the variety of innovation systems. One of the core issues that should be addressed both at the national and at the European policy level, therefore, is how to integrate the different local and national components into a single innovative system comparable to the American or the Japanese one.

While all capitalist economies are undergoing the transformations associated with the knowledge-based economy, Europe is also engaged in major institutional changes. For decades European integration was driven by a variety of common policies such as a custom unions, a common agricultural policy and, more recently, a common monetary policy. But despite the efforts undertaken with the various multi-annual Framework Programmes since the early 1980s, European integration is not yet driven by science

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[2]All documentation on the Lisbon Strategy is available at http://europa.eu.int/comm/lisbon_strategy/index_en.html

[3]Amable and Petit (2001), Maurseth and Verspagen (1999), Garcia-Fontes and Geuna (1999) and, more broadly, the chapters collected in Archibugi and Lundvall (2001) present some evidence and considerations about the lack of a proper European Innovation System.

and technology policy. No more than 4.6 percent of the European Commission's total budget is devoted to Research and Technological Development (RTD), and this accounts for less than 6 percent of the total amount spent by EU governments on RTD (Sharp, 2001). In spite of the growing amount of resources that the EU has dedicated to RTD, this is still a small portion of the budget. Science policy is one of the many fields where "European inertia" is dominant (see Banchoff, 2002).

In the next section we present a broad set of data describing the technological status of Europe, with regard both to investments – by means of the expenditure on R&D – and to performance in innovative activities – by means of other technological indicators. We compare EU15 and EU25 with North America and Japan, and we highlight recent evolution. Particular attention is devoted to ICTs, since this sector is more strictly linked to the concept of the "new economy" and it represents the main infrastructure of the knowledge society. In a following section we analyze the phenomenon of scientific and technological collaboration since we assume, on the one hand, that it reveals a lot about the "attractiveness" of various regions of the world and, on the other hand, that it is a key policy asset for designing an EU strategy. Finally, in the last section, we discuss the strategies Europe is using to achieve a more prominent role in the globalizing learning economy.

## I. Which News about the European Technology Gap?

Like North America and Japan, Europe is a leading player in the generation of scientific and technological competencies. The combined R&D budget of the EU25 is more than two-thirds that of the U.S. one, and nearly the double that of Japan. In terms of scientific articles, the output of the EU is substantially higher than the U.S.'s, but this strongly reflects the size of the EU, which has a population much larger than the U.S. or Japan (see Table 1). Tables 2 to 6 report intensities for advanced countries and they show that there are increasing signals that Europe is losing ground in the most dynamic and technologically advanced part of the economy. The evidence presented shows the performance of EU15 and EU25 in comparison to the U.S., Japan and a few other advanced countries. The aim is to assess: a) the evolution over time of the three main geographical areas in the technological race; b) intra-European variety in technological expertise; and c) the occurrence of convergence or divergence within Europe.

### *R&D and patents*

The concern about an increasing technological gap is certainly not new: as early as the 1960s we heard about "the American challenge" (Servan-Schreiber, 1968), and similar concerns were reiterated in the 1980s and in the 1990s (see, for example, Patel and Pavitt, 1987; Archibugi and Pianta, 1992). Europe is certainly not the only region concerned about its technological performance. Similar worries were echoed in America (Kennedy, 1988; Pianta, 1988; Nelson, 1989) and, if we were able to read Japanese, we would find comparable statements in the Far East as well. But saying that the neighbor's grass is always greener cannot dismiss the issue of poor performance by the European economy in key aspects of knowledge-based production.

Table 2 reports some data about R&D intensity. As regards gross R&D expenditure (GERD) as a percentage of GDP, the EU25 intensity is equal to 1.83 per cent, substantially lower than the U.S. (2.71) and Japan (3.11). In the second half of the 1990s Japanese R&D intensity grew more than in the U.S., while the intensity of the EU15 has grown very little. Within EU25, there emerges a clear divide between North and South. The country with the highest level, Sweden, has an R&D intensity that is almost eight times higher than the country with the lowest one, Latvia. Equally widespread gaps persist in the EU15. The coefficient of variations has held steady, indicating that there has not been overall convergence.

A similar pattern emerges in terms of business R&D (BERD) as a percentage of the Domestic Product of Industry (DPI), reported in the right-hand columns of Table 2. In this case, the difference between the first and the last EU25 country is even higher: Sweden has a BERD intensity twenty-five times higher than Poland. Some contrasting tendencies also emerge: industrial R&D has decreased in Eastern European countries such as Poland and Slovakia, while it has increased in almost all Western European countries. As a consequence, the coefficient of variation has increased for EU15 and, even more, for EU25.

Table 3 shows the patents granted in the U.S. and applied for in Europe per million people. Overall, the data show a remarkable increase in the number of patents at both Patent Offices as a consequence of the increasing competitiveness over intellectual property rights (see Andersen, 2004). For patents granted at the U.S. Patent Trademark Office (USPTO), the high ratio reflects the fact that inventors and firms are patenting in their own domestic market, but for Japan and European countries, it is reasonable to assume that they have a comparable propensity to patent in the U.S., since for both of them the U.S. is an economically crucial market. It emerges that Japan has a ratio more than four times higher than the EU25 average. Not even the European countries with the highest propensity to patent, that is, Switzerland and Sweden, have the same intensity as Japan. Many European countries, both in the East and in the South, report no or negligible patent activity in the U.S. The dispersion within the EU is extraordinarily high. It is difficult to find other aspects of economic and social life where the distance between the top and the bottom European countries is so wide (on regional variations in the European Systems of Innovations, see Chesnais, Ietto and Simonetti, 2001; Cantwell and Iammarino, 2003).

Patents granted in the U.S. are complemented by patent applications at the European Patent Office (EPO). Even in the European market, Japan has a patent propensity above the average of the members of the EU (respectively, 135 and 114 patents per million people), and the U.S. is also close to the EU average (107 patents per million people). The higher growth rates in patent applications at the EPO for both EU15 and EU25 shows that the construction of the European market is on its way, but with remarkable regional variations. Eastern and Southern countries do not yet seem to participate in the generation of commercially exploitable innovations. This is hardly surprising in light of the very low business R&D performed. In Southern countries such as Spain, Portugal and Greece, business R&D seems to be limited mostly to imitation and learning.

While patents reflect inventive and innovative activities that are proprietary in nature and mainly developed for commercial purposes, scientific literature informs mainly about the activities of the academic community. However, scientific literature has become more and more relevant for high-technology industries in the last few decades and it is an important source of industrial competitiveness (see Tijssen, 2001). Table 4 reports the number of scientific and technical articles published in the sample of journals monitored by the Science Citation Index of the Institute for Scientific Information. It is often said that the Science Citation Index is biased in favor of the English-speaking academic community, and this is probably true, but many top-ranking countries are not-English speaking. In this aspect of S&T activity, the European gap with the U.S. is smaller. In terms of intensity, the EU25 average is below the U.S. (respectively, 493 and 700 articles per million people) and above Japan (444 articles per million people), but EU25 scientific production has grown in recent years, while the U.S. scientific production has declined.

Within EU25, the ratio between the highest (Sweden) and the lowest (Latvia) country is 17 to 1: the European dispersion in indicators of academic activities (mainly funded with public money) is substantially lower than for technological activities (mainly funded by business companies). Over time a limited convergence has occurred at both the EU15 and EU25 levels. This improved European performance in the area of academic activity reflects the overall satisfactory level of human resources, confirmed by the proportion of graduate or Ph.D students in science and technology (European Commission, 2003).

Unfortunately, as shown by the *Third European Report on Science and Technology Indicators* (European Commission, 2003), Europe does not easily succeed in turning this rich variety of human resources into an adequate proportion of researchers in the work force, especially in the business world.

Many talents nurtured in Europe, with taxpayers' resources, do not find adequate jobs on the continent, and often find it convenient to move to the other side of the Atlantic.

Summing up, what does this battery of indicators tell us?

- First, the evidence has allowed us to quantify how Europe is lagging behind the other two major areas, both for investment and performance in technology. In total R&D investment, Europe is even increasing the gap with Japan and not reducing it with the U.S. This is a particularly worrying signal since R&D is one of the main inputs for the generation of knowledge and therefore an engine of long-term economic and social growth.

- Second, the gap is more evident in business-related indicators than in publicly funded research. The indicators of technological activities, such as business R&D and patents, provide mild signs of catching up. In scientific publications Europe is reducing its gap with the U.S. Other indicators on human resources (European Commission, 2003) confirm the impression of potentially good intellectual capital in the EU that does not translate into more researchers in the work force, especially in the industrial sector.

- Third, there are huge differences among European countries. In almost all the indicators taken into account, a group of small- and medium-sized countries, such as Switzerland, Sweden, Norway, Finland, the Netherlands and Denmark, show performance that is on a par with or even higher than the U.S. and Japan. Switzerland and Norway are not members of the EU, and the others are rather small to be able to "lift up" the EU average.

- Fourth, it is evident that the integration of ten new member countries (plus the former East Germany [DDR]) has just started and that these countries are at a very different overall technological level from the EU15 group. Eastern countries such as Slovenia, the Czech Republic, Estonia and Hungary are on a par with and sometimes even above Southern European countries such as Italy, Spain, Portugal and Greece, but the overall European area at the periphery of scientific and technological advance, so far limited to Southern Europe and Ireland, has now become larger. Growth rates in the ten new countries have, on average, been slightly higher than the EU15, but, overall, the low-tech area of the EU has considerably increased.

*Challenges for Europe in ICT*

We now turn our attention to the ICT sector, the most closely associated with the new economy (Daveri, 2002). Here Europe, despite originally being laggard in comparison to the U.S. and Japan (see Gambardella and Malerba, 1999; Fagerberg, Guerrieri and Verspagen, 1999; Vivarelli and Pianta, 2000), is slowly catching up. Table 5 shows that the U.S. and Japan, respectively, invest 7.2 percent and 7.5 percent of their GDP in ICT while EU25 invests 6.5 but, in the second half of the 1990s, EU25 continued to grow at an annual rate of 4.1 percent, higher than Japan (2.2 percent) and in the opposite direction from the U.S., which has experienced a decline (–1.7 percent). Within the EU, a mild but significant convergence has occurred both among the fifteen and the twenty-five countries. The Eastern European countries for which data are available show an even greater growth rate. Consequently, EU25 dispersion has been substantially reduced.

If we consider the composition of the ICT sector, while the 1980s experienced the dramatic rise of Japan and other East Asian economies in hardware technologies (for an overview, see Freeman, 1987; Mathews, 2000), in the 1990s the U.S. managed to recover its traditional economic leadership in knowledge-intensive industries by exploiting and disseminating ICT in the service sector. Within the triad, Japan and the other East Asian economies continue to have a prominent position in the generation of the "hardware" component, while the U.S. has a dominant position in the "software" one. Europe has neither. It should however be noted that Europe has recently augmented expenditure in the software area, following a general trend towards so-called "weightlessness," that is, the increase of the share of soft components in ICT (Daveri 2002, European Informative Telecommunications Observatory, 2001).

An indicator of the diffusion of technology complements these data: Internet penetration. In fact, ICT is important not only for the highest gain in productivity it directly performs, but also because, thanks to its diffusion, it enables other sectors to increase their productivity; in other words it entails positive externalities. Besides, while both R&D and patent-based indicators capture the technological activities developed in the manufacturing industry, Internet use is an indicator that provides information on both the manufacturing and the service components of the economy. Table 6 shows that the penetration in the U.S. and Japan is much higher than in the EU. Although the EU is catching up, it is still at levels below its counterparts. In Europe, however, the Nordic countries have a higher penetration than the U.S. The ratio between the country with the highest (Sweden) and the lowest (Latvia) penetration is more than 4 to 1. Not surprisingly, the trend shows a marked convergence among EU countries, with Eastern European countries catching up. An indispensable infrastructure for the diffusion of knowledge like the Internet is essential to Eastern European countries to acquire technical expertise from the core countries. Summing up, in ICT Europe is delayed with respect to the U.S. and Japan but is reducing the gap.

## II. International Technological and Scientific Collaboration

The section above has shown that intra-European variety in knowledge is very high, and some consistently developed regions are counter-balanced by others that are unable to generate the technological innovations that they use. It therefore becomes crucial to identify the channels that allow the dissemination of technical expertise across the continent. One of them is represented by collaboration among economic agents located in different regions.

In the last decade, a new source of knowledge has become progressively more important: technological collaboration among firms. While the academic community has always had a tendency to share its knowledge with other partners, it was assumed that corporations were much more reluctant to share their know-how with potential competitors. The need to split the costs and risks of technological development, along with the need to acquire the expertise of other partners, have acted as strong motivation to undertake strategic technology agreements. Strategic technology agreements are defined as: partnerships that a) involve a two-way relationship, b) tend to be contractual in nature with no or little equity involvement by the participants, and c) are strategic in the sense that they are long-term planned activity (Mytelka, 2001, p. 129).

Strategic technology agreements are not only a source of knowledge; they also inform where companies seek expertise. Some evidence on the available statistics on inter-firm technological collaboration is reported in Table 7, based on the database developed by John Hagedoorn and his colleagues (see Hagedoorn, 1996, National Science Foundation, 2002). As many as 60 percent of the total strategic technology alliances recorded are international in scope. This form of generating technological knowledge has considerably increased its significance, and the number of recorded agreements nearly tripled between 1980-82 and 1998-2000.

The largest and most increasing portion of alliances take place within the U.S.: 45.8 percent of all the strategic technological alliances recorded in 1998-2000 occured among American firms only, against 24.6 percent in the 1980-82 period (NSF, 2002). Moreover, U.S. firms have strong ties on both the Atlantic and the Pacific shores: in the 1998-2000 period, U.S. companies participated in as many as 84.7 percent of the recorded technology alliances. On the contrary, the share of intra-European strategic technological alliances has substantially declined: they accounted for 18.2 percent in 1980-82, and less than 10 percent in 1998-2000. They have even decreased in absolute terms in the last decade (from seventy-four in 1989-91 to fifty-three in 1998-2000).

European policymakers should be concerned by the strong propensity of European firms for American, rather than European, partnerships. It is not necessarily a bad thing that European firms have agreements with American ones, but it is certainly worrying that there are so few intra-European agreements. Policies carried out at the European level, especially at the European Commission level, to foster cooperation in R&D and innovation on the continent, have not been able to push for a greater cohesion of European industry (Narula, 1999). The first possible explanation would be that the absolute amount of resources devoted to science and technology is much greater in U.S. firms and that, obviously, firms engage in technology alliances with partners who have adequate expertise. The greater flow of alliances in the U.S. would therefore just be the outcome of the amount of investment in knowledge by U.S. companies. In order to control for this factor, we divided the number of European alliances undertaken by the total amount of, respectively, European, U.S. and Japanese business enterprises' R&D expenditure (BERD). This provides an indicator of the propensity of European companies towards collaboration in each of these regions. The results are reported in Table 8.

Although the attractiveness of the U.S. economy proves to be a bit smaller in relative terms, European companies' greater propensity for American partnerships is confirmed. There are 1.07 European-U.S. partnerships for each billion $U.S. BERD, while the equivalent figure for intra-European partnerships is just 0.62. Moreover, the European business community has considerably changed its propensity for partnership over the last ten years: in the 1980-82 and 1989-91 periods, European companies had a larger propensity for European rather than American partners. The figures were, respectively, 0.80 and 0.61 agreements for each billion $U.S. BERD in 1980-82, and 1.03 and 0.86 in 1989-91. The lower part of Table 8 reports the propensity of American companies to undertake alliances. U.S. companies are now keener to embark on joint ventures with European partners, and this is a result of the overall increase of their engagement in collaborations, but internal partnerships continue to be relevant. If the new economy is represented – among other things – by strategic technology partnerships, the evidence suggests that this strongly leans towards the U.S. rather than towards Europe or Japan.

Partnerships and collaborations promoted by public research institutions and universities play an equally crucial role in the international dissemination of knowledge. They can take a variety of forms: joint research centers, exchange of students and of academic staff, sharing of scientific information. One of the ways to measure this is by looking at internationally coauthored scientific papers. A dramatic increase in internationally coauthored papers – also facilitated by the diffusion of the Internet and e-mail communication – is evident in all countries (Table 9). From 1986 to 2001, the percentage of internationally coauthored papers has doubled in the majority of countries, and this represents a clear signal of globalization in the generation of knowledge. European countries are individually keener to collaborate than the U.S. and Japan. This is not surprising, given the smaller size of the scientific community in each country. From a dynamic viewpoint, the rate of increase has been higher in the U.S. and Japan than in European countries, but this is due to the fact that the U.S. has lowered the growth of national scientific articles (see Table 4 above and NSF 2002, table 5.41). These data clearly show that the academic community in Europe is a valuable asset for the acquisition of knowledge and expertise beyond the borders of countries. Eastern European countries, which in 1986 had limited access to collaboration outside their bloc, have started to undertake joint programs: in 2001, more than half of the scientific papers generated in Eastern Europe were the result of international collaboration, with an internationalization that is equal to, and sometimes even greater than, Western European countries of the same size.

Does the academic community also share the same preference as European firms have for American rather than for European partners? Table 10 reports the distribution of internationally coauthored collaborations in the Triad.[4] EU15 is by far the greatest collaborator for the American academic community. In 1995-97 as many as 60.3 percent of U.S. internationally coauthored papers involved a EU15 partner.

[4]Unfortunately, we do not have more updated data for EU25 at this level of disaggregation.

Also, Europeans have a strong propensity to collaborate with each other. This fact could be misleading, since a paper coauthored by a Dutch and a Belgian is classified as "international," while a paper coauthored by a Californian and a New Yorker is classified as national. But what is significant in these data is the evolution over time (and this is not affected by the different size of the countries): by comparing the first period (1986-88) to the last one (1995-97), it emerges that intra-EU collaborations are increasing in proportion (from 56.6 to 69.4 percent of all internationally coauthored papers), while EU-U.S. collaborations are decreasing for the EU as a whole (from 31.9 to 29.0 percent) as well as for each EU15 member country. Looking at the data from an American perspective, the above tendency is enhanced: the share of intra-U.S. articles in all U.S. coauthored articles declines from 78 to 68 percent, while coauthorship with authors based in the EU15 has grown from 11 to 19 percent (National Science Foundation, 2000, table 6.51).

We therefore note an inverse tendency: the European business community has an increasing propensity for technological alliances with U.S. firms, while the European academic community has an increasing propensity for intra-European partnership. One of the main policies used by the European Commission in the last decade, through the instrument of the Framework Programmes, has been to promote collaborations among European institutions and firms. The data reported suggest that these policies have been much more successful in creating a European Research Area (ERA) in academia than in business. The limited resources the European Commission disposes of (about 4,000 million euro a year in the last approved Sixth Framework Programme) have not been enough to meet the needs of European industry, while they have proved to be more effective as regards training and the promotion of researchers' mobility.

There is a third important form of collaboration, which is between enterprises on one side, and universities on the other. The advantage of this kind of cooperation is that it allows a quick conversion of scientific knowledge into commercial applications with a direct and immediate economic return. One way to measure it is by looking at the share of university R&D financed by industry. The EU shows a little progress, but it still mantains a consistent delay, with respect to the U.S. and Japan, in the overall resources for financing R&D expenditure of universities, (European Commission, 2003; Garcia-Fontes and Geuna, 1999).

## III. A Single Europe for Science and Technology?

The evidence confirms that in some vital areas of knowledge and competence-building Europe is lagging behind. Contrary to what happened for many periods since the end of the Second World War, in the 1990s Europe stopped decreasing its gap with the U.S. In the most recent years, Europe has increased its gap with Japan even more. While Europe is catching up in the diffusion of ICTs, its distance from the United States and Japan in terms of the generation of business innovation continues to be steady. It is therefore understandable that a major policy concern in Europe is identifying the strategies that would allow catching up and upgrading its scientific and technological competence.

In addressing a European strategy for innovation, it should be remembered that the continent has vast regional disparities, and that they are much wider in terms of scientific and technological competencies than in other aspects of economic life such as income, production or consumption. In the last fifteen years, Europe underwent major political changes that also affected its science and technology capabilities. Germany, which for a long time was the technological engine of Europe, has had to face a major regional problem: the integration of the East. The UK, soul of many centers of scientific excellence and the European country with the highest number of Nobel laureates, has underfunded its universities for more than twenty years.[5] The 1995 enlargement has integrated into the EU three small and highly dynamic countries, Sweden, Finland and Austria, but the 2004 enlargement brought in ten countries without such a sophisticated dowry of scientific and technological infrastructures. The scientific community in Eastern Europe suffered hardship for many years, and the transition to capitalist economies has been particularly tough, given the academic competencies developed during the socialist regimes. Overall, EU25 has a larger population and an expanded market, but more vulnerable scientific and technological capabilities and a reduced R&D intensity. The peripheral areas, once confined to Southern Italy, Spain, Portugal and Greece, have now been extended to the East.

The enormous differences across European member countries make it clear that fully exploiting the advantages of knowledge is crucial to developing strategies for the transmission and diffusion of competencies across areas. Only by reducing regional disparities will it be possible to obtain overall European scientific and technological competence comparable those of the U.S. and Japan. A stronger integration among national policies, as well as between the academic and the business communities, is needed, which in turn requires major changes in the institutional setting and in the incentives existing in publicly funded research centers.

We have seen that in Lisbon European governments committed themselves to transforming Europe into the most competitive and dynamic knowledge-based economy in the world, and that in Barcelona they set a more ambitious target of raising R&D expenditure up to 3 percent of GDP by 2010. At the same time, the business sector has been asked to contribute most of this effort, which, by 2010, should finance two-thirds of the total R&D expenditure (while in 2002 business-financed R&D in the EU25 was just 55.4 per cent, see OECD, 2004).

It is self-evident that there is considerable divergence between the announcement of the political target and the instruments made available. Too little commitment has been made to reach such an ambitious target, and it is certainly peculiar that governments (which have direct control of public expenditure) put the largest burden on the business community. The aim of 3 percent in the R&D/GDP ratio, moreover, appears very difficult to achieve without a major commitment of all the main economic players (national governments, European business community and EU institutions). For example, it implies an increase in research personnel of the magnitude of about 100,000 people a year, which seems difficult to realize within the current EU qualified workforce (Schibany and Streicher, 2003). The Kok Commission (2004) has recently attempted a much-needed assessment of the targets set in Lisbon and Barcelona. The Report, on the basis of the recent evolution of the world economy, has urged national governments to increase their commitments, but there is a significant shift: understanding the Lisbon and Barcelona targets as "desirable" rather than "achievable."

Each country makes its own attempts to upgrade its scientific and technological potential, and certainly the achievements of any one of them are more likely to generate externalities that can be beneficial for the whole European Union. The evidence reported in the paper clearly indicates that a small club of European countries has a scientific and technological intensity on a par with, and often superior to, to the U.S. one. The Scandinavian countries have followed a distinctive approach to competence-building based on: a) a highly competent and qualified labor force, generated through massive investments in education and training; b) a specialization in high-tech industries, through R&D investments in ICT, biotechnology, and electronics; and c) close collaboration between the business sector on the one hand, and government and the academy on the other (European Commission, 2003). This model should inspire European policymaking much more than the American one, which is based on firms competing for market

[5]In the second half of the 1990s, UK expenditure for tertiary education was stagnant and, in 1999, UK expenditure for tertiary education as a percentage of the GDP was lower than the EU15 average and half that of the U.S. See European Commission (2003), pp. 217-18.

share and public procurement and R&D public investment concentrated in national priorities such as defense and space.

There is also much to learn from the policies of individual nations. A small country like Ireland is managing to improve its technological potential by making the country attractive for multinational corporations and is slowly moving out from the group of the R&D-laggard countries. This is not the first time that European governments have preferred to follow an autonomous route to catching up, and when this has happened the whole EU has received indirect benefits. European nations are so linked to each other that science and technology outcomes and policies are bound to a common European faith.

The most direct national route to achieving the Lisbon and Barcelona targets will be to increase governments' financial commitments, but this conflicts, among other things, with the Maastricht parameters on public expenditure. Indirect measures include tax incentives to industry, but it is doubtful what "leverage" effect they will display. Surely a greater effort from private sector is necessary, as is also demonstrated by the low level of venture capital financing in Europe in comparison to the U.S. and Japan (European Commission, 2003). This form of financing is particularly significant for the promotion of innovative activities by small firms (the so-called start-ups).

With regard to policies that can be directed from Brussels, there is an apparent trade-off between the use of resources for the diffusion of knowledge in the peripheral parts of the continental economy (widening) or for generating new knowledge in the core countries (deepening). The various Framework Programmes (FPs) have however partially managed to overcome this trade off. Through the FPs, the European Commission progressively revises and enlarges the areas of intervention enhancing intra-European cooperation in the so-called pre-competitive research fields. This may serve the twin objectives of inducing learning in the peripheral areas and advancing knowledge in the core areas.[6]

In the last approved Sixth FP, the greatest bulk of resources has been dedicated to Informative Society Technology and Nano-technologies (4,925 million euro for the next four years). The strategic importance of this sector has been recognized, not only for the new jobs and business that 3G wireless communication systems, software architecture and opto-electronics networks can create, but also because it perfectly meets the request of "ambient intelligence," that is, the target of linking economic growth and welfare purposes. The other "priority" research areas, biotechnology, environment and energy, are devoted to the same aim.

If these actions are admirable, it is also true that the instruments in the hands of the European Commission are too limited. The ambitious targets will require a much larger commitment of national resources in terms of the funding of existing centers of excellence (especially when they have been kept under severe financial restriction), to generate the human resources needed for both the public and the business institutions, to start up new problem-oriented institutions. Regulation, standards, procurement, competition, real services and large-scale co-operative civilian projects seem to be essential instruments for creating a European Research Area in addition to the (limited) financial instruments (Lundvall, 2001).

It is evident that successful management of the learning economy will require a much higher political commitment that should be comparable to the efforts European governments have devoted to cre-

[6]For a long time the meaning and effectiveness of pre-competitive research have been debated (Geuna, 2001). Financing research in one firm or one country could imply advantaging some organizations and to disadvantaging others, thus infringing the very same EU competition policy. But in the field of science and technology, the outcomes are likely to provide benefits to stakeholders larger than those getting the funding. In fact, the European Commission funding schemes generally require the involvement of firms and institutions from several member countries.

ating a single currency. Lundvall (2001) has suggested establishing a "European High Level Council on Innovation and Competence Building" chaired by the President of the EU and with at least as much political weight as the European Central Bank. This will be a clear sign in Europe that there is a political commitment to become "the most competitive and dynamic knowledge-based economy in the world" in a decade. But words without facts will only allow us to observe at the end of the decade that the aim of R&D at 3 percent of GDP has not been reached and that the European technology gap has further increased.

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**Table 1. Some indicators of size in the Triad, latest available year.**

| | USA | EU 15 | EU 25 | Japan |
|---|---|---|---|---|
| Population | 291,044,000 | 379,744,000 | 453,900,180 | 127,210,000 |
| GDP in million current international US $ PPP | 10,871,090 | 10,130,480 | 11,100,791 | 3,582,515 |
| Gross Domestic R&D Expenditure in million current US $ PPP | 277,100 | 189,464 | 198,596 | 106,838 |
| Scientific and technical articles | 228,015 | 277,403 | 296,646 | 64,073 |
| Internet users | 158,891,319 | 134,625,097 | 150,798,005 | 57,090,350 |

NOTE: PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States.
Population and GDP refer to 2003, Gross Domestic R&D Expenditure and Internet users to 2002, Scientific articles to 2001.

Source: OECD Statistics, Main Science and Technology Indicators 2004-1 for Gross R&D expenditure; NSF 2004 for scientific articles; Worldbank, World Development Indicators 2004 for the other indicators.

**Table 2. Gross R&D expenditure as a percentage of GDP by country, 2001-02 and 1996-97, and Business Expenditure on R&D as a percentage of GDP, 2002 and 1998.**

| | GERD (% of GDP) in 2001-2002 | GERD (% of GDP) in 1996-1997 | Mean annual rate of growth from 1996-97 to 2001-02 | BERD (% of GDP) in 2002 | BERD (% of GDP) in 1998 | Mean annual rate of growth from 1998 to 2002 |
|---|---|---|---|---|---|---|
| USA | 2.71 | 2.57 | 1.1% | 1.87 | 1.94 | -0.9% |
| Japan | 3.11 | 2.80 | 2.1% | 2.32 | 2.10 | 2.5% |
| EU-15 | 1.89 | 1.81 | 0.9% | 1.34 | 1.14 | 4.2% |
| EU-25 | 1.83 | 1.73 | 1.1% | 1.17 | 1.08 | 2.0% |
| | | | | | | |
| Austria | 1.92 | 1.66 | 3.0% | na | 1.13 | na |
| Belgium | 1.99 | 1.84 | 1.6% | 1.64 | 1.35 | 5.0% |
| Denmark | 2.13 | 1.90 | 2.3% | 1.75 | 1.33 | 7.1% |
| Finland | 3.43 | 2.63 | 5.5% | 2.41 | 1.94 | 5.6% |
| France | 2.20 | 2.26 | -0.5% | 1.37 | 1.35 | 0.4% |
| Germany | 2.50 | 2.28 | 1.9% | 1.75 | 1.57 | 2.8% |
| Greece | 0.65 | 0.51 | 5.0% | 0.21 | 0.19 | 5.1% |
| Ireland | 1.16 | 1.31 | -2.4% | 0.80 | 0.90 | -2.9% |
| Italy | 1.11 | 1.03 | 1.5% | 0.55 | 0.52 | 1.4% |
| Netherlands | 1.96 | 2.03 | -0.7% | 1.03 | 1.05 | -0.5% |
| Portugal | 0.81 | 0.62 | 5.5% | 0.32 | 0.16 | 18.9% |
| Spain | 0.90 | 0.83 | 1.6% | 0.56 | 0.47 | 4.5% |
| Sweden | 3.67 | 3.67 | 0.0% | 3.32 | 2.74 | 10.1% |
| UK | 1.87 | 1.86 | 0.1% | 1.87 | 1.18 | 12.2% |
| | | | | | | |
| Czech Republic | 1.31 | 1.14 | 2.8% | na | na | na |
| Estonia | 0.60 | 0.57 | 1.0% | na | na | na |
| Hungaria | 0.99 | 0.69 | 7.5% | 0.36 | 0.26 | 8.5% |
| Latvia | 0.46 | 0.44 | 0.9% | na | na | na |
| Lithuania | 0.56 | 0.61 | -1.7% | na | na | na |
| Poland | 0.64 | 0.71 | -2.1% | 0.13 | 0.28 | -17.5% |
| Slovak Republic | 0.90 | 0.93 | -0.7% | 0.37 | 0.52 | -8.2% |
| Slovenia | 1.54 | 1.43 | 1.5% | na | na | na |
| | | | | | | |
| Canada | 1.81 | 1.69 | 1.4% | 1.05 | 1.07 | -0.5% |
| Norway | 1.66 | 1.66 | 0.0% | 0.96 | 0.92 | 1.4% |
| Switzerland | 2.73 | 2.73 | 0.0% | na | na | na |

EU-15

| | | | | | | |
|---|---|---|---|---|---|---|
| Coeff of Variation | 0.47 | 0.47 | | 0.64 | 0.59 | |
| Max / Min | 5.6 | 7.2 | | 15.8 | 17.1 | |

EU-25

| | | | | | | |
|---|---|---|---|---|---|---|
| Coeff of Variation | 0.58 | 0.58 | | 0.77 | 0.68 | |
| Max / Min | 8.0 | 8.3 | | 25.5 | 10.5 | |

NOTE: As regards the second column, for Greece, Ireland, Italy, Switzerland we have 2001 data only; as regards the third one, for Greece, Norway, Portugal and Sweden we have 1997 data only. Regarding the fifth column, data for Greece and Sweden refer to 2001; regarding the sixth one, data for Greece, Sweden and Norway refer to 1999.
The mean annual growth rates for BERD are adjusted to the effective number of years.

Source: OECD Statistics, Main Science and Technology Indicators 2004-1; Worldbank, World Development Indicators 2004.

**Table 3. Patents granted at the USPTO and patents applied at the EPO by country, 2002-03 and 1997-98.**

| | Mean annual granted patents at USPTO per million people 2002-03 | Mean annual granted patents at USPTO per million people 1997-1998 | Mean annual rate of growth from 1996-97 to 2000-01 | Mean annual applied patents at EPO per million people 2002-03 | Mean annual applied patents at EPO per million people 1997-1998 | Mean annual rate of growth from 1996-97 to 2000-01 |
|---|---|---|---|---|---|---|
| USA | 301 | 260 | 3.0% | 107 | 80 | 5.9% |
| Japan | 277 | 214 | 5.3% | 135 | 106 | 5.1% |
| EU-15 | 71 | 54 | 5.6% | 136 | 96 | 7.3% |
| EU-25 | 59 | 45 | 5.7% | 114 | 80 | 7.4% |
| | | | | | | |
| Austria | 70 | 48 | 7.8% | 120 | 88 | 6.4% |
| Belgium | 65 | 59 | 1.9% | 131 | 94 | 6.8% |
| Denmark | 89 | 68 | 5.3% | 153 | 105 | 7.8% |
| Finland | 161 | 102 | 9.6% | 297 | 155 | 13.8% |
| France | 66 | 57 | 3.1% | 120 | 92 | 5.4% |
| Germany | 138 | 98 | 7.0% | 265 | 183 | 7.7% |
| Greece | 2 | 1 | 8.1% | 5 | 3 | 9.0% |
| Ireland | 38 | 20 | 13.8% | 65 | 41 | 9.6% |
| Italy | 30 | 25 | 4.2% | 61 | 46 | 5.6% |
| Luxembourg | 81 | 49 | 10.3% | 350 | 239 | 7.9% |
| Netherlands | 84 | 65 | 5.3% | 356 | 217 | 10.4% |
| Portugal | 1 | 1 | 3.6% | 3 | 2 | 12.1% |
| Spain | 7 | 5 | 6.9% | 16 | 10 | 9.0% |
| Sweden | 179 | 118 | 8.6% | 287 | 181 | 9.7% |
| UK | 63 | 52 | 3.7% | 81 | 68 | 3.5% |
| | | | | | | |
| Cyprus | 1 | 1 | -0.6% | 29 | 17 | 11.4% |
| Czech Republic | 4 | 1 | 21.9% | 5 | 2 | 16.8% |
| Estonia | 3 | 0 | 48.4% | 3 | 2 | 3.7% |
| Hungary | 6 | 4 | 9.8% | 6 | 3 | 13.1% |
| Latvia | 1 | 0 | 33.1% | 1 | 0 | 9.4% |
| Lithuania | 0 | 1 | -9.2% | 0 | 0 | 9.1% |
| Malta | 5 | 3 | 14.1% | 28 | 8 | 28.7% |
| Poland | 0 | 0 | 1.7% | 1 | 0 | 22.1% |
| Slovak Republic | 1 | 0 | 22.9% | 2 | 1 | 13.1% |
| Slovenia | 9 | 6 | 6.6% | 19 | 10 | 14.5% |
| | | | | | | |
| Canada | 109 | 77 | 7.3% | 42 | 21 | 14.7% |
| Norway | 55 | 32 | 11.7% | 70 | 46 | 8.7% |
| Switzerland | 183 | 155 | 3.3% | 504 | 352 | 7.4% |

EU-15

| | | | | | | |
|---|---|---|---|---|---|---|
| Coeff of Variation | 0.73 | 0.69 | | 0.78 | 0.74 | |
| Max / Min | 158.3 | 124.9 | | 103.5 | 123.2 | |

EU-25

| | | | | | | |
|---|---|---|---|---|---|---|
| Coeff of Variation | 1.20 | 1.16 | | 1.22 | 1.20 | |
| Max / Min | 487.9 | 574.4 | | 821.0 | 853.0 | |

Source: Our elaboration on US Patent and Trademark Office data and on European Patent Office data.

**Table 4. Scientific & technical articles by country, 2000-01 and 1995-96.**

| | Number of scientific publication in 2000-01 per million people | Number of scientific publication in 1995-96 per million people | Mean annual rate of growth from 1995-96 to 2000-01 |
|---|---|---|---|
| USA | 700 | 759 | -1.6% |
| Japan | 444 | 390 | 2.6% |
| EU-15 | 556 | 510 | 1.7% |
| EU-25 | 493 | 448 | 1.9% |
| | | | |
| Austria | 548 | 446 | 4.2% |
| Belgium | 571 | 534 | 1.3% |
| Denmark | 927 | 847 | 1.8% |
| Finland | 963 | 829 | 3.0% |
| France | 527 | 510 | 0.7% |
| Germany | 529 | 472 | 2.3% |
| Greece | 294 | 207 | 7.3% |
| Ireland | 425 | 343 | 4.4% |
| Italy | 376 | 325 | 2.9% |
| Luxembourg | 81 | 58 | 6.8% |
| Netherlands | 784 | 800 | -0.4% |
| Portugal | 195 | 104 | 13.3% |
| Spain | 374 | 300 | 4.5% |
| Sweden | 1,133 | 1,074 | 1.1% |
| UK | 824 | 805 | 0.5% |
| | | | |
| Cyprus | 88 | 65 | 6.4% |
| Czech Republic | 248 | 205 | 3.8% |
| Estonia | 250 | 171 | 7.9% |
| Hungary | 236 | 179 | 5.6% |
| Latvia | 67 | 64 | 0.8% |
| Lithuania | 76 | 52 | 8.1% |
| Malta | 76 | 42 | 12.6% |
| Poland | 143 | 118 | 3.8% |
| Slovak Republic | 182 | 215 | -3.3% |
| Slovenia | 448 | 231 | 14.1% |
| | | | |
| Canada | 736 | 832 | -2.4% |
| Norway | 716 | 675 | 1.2% |
| Switzerland | 1,149 | 1,052 | 1.8% |

EU-15

| | | | |
|---|---|---|---|
| Coeff of Variation | 0.51 | 0.57 | |
| Max / Min | 14.0 | 18.5 | |

EU-25

| | | | |
|---|---|---|---|
| Coeff of Variation | 0.73 | 0.82 | |
| Max / Min | 17.0 | 25.4 | |

NOTE: In order to avoid double counting, article counts are based on fractional assignments; for example, an article with two authors from different countries is counted as one-half article to each country.

Source: Our elaboration from National Science Foundation (NSF) 2004,
data from Institute for Scientific Information (ISI).

**Table 5. ICT expenditure on GDP, 2001-02 and 1996-97.**

| | ICT expenditure (% of GDP) 2001-02 | ICT expenditure (% of GDP) 1996-97 | Mean annual rate of growth from 1996-97 to 2001-02 |
|---|---|---|---|
| USA | 7.2 | 7.7 | -1.7% |
| Japan | 7.5 | 6.9 | 2.2% |
| EU-15 | 6.5 | 5.7 | 3.4% |
| EU-25 | 6.5 | 5.6 | 4.1% |
| | | | |
| Austria | 6.2 | 5.0 | 6.0% |
| Belgium | 6.8 | 6.0 | 3.5% |
| Denmark | 7.5 | 6.6 | 3.3% |
| Finland | 6.7 | 6.0 | 3.2% |
| France | 7.1 | 6.3 | 3.4% |
| Germany | 6.5 | 5.4 | 4.9% |
| Greece | 5.5 | 4.0 | 8.1% |
| Ireland | 5.1 | 5.6 | -2.3% |
| Italy | 5.0 | 4.2 | 4.7% |
| Netherlands | 7.2 | 6.8 | 1.5% |
| Portugal | 6.1 | 4.9 | 6.0% |
| Spain | 4.8 | 4.0 | 5.0% |
| Sweden | 8.9 | 7.7 | 3.7% |
| UK | 7.9 | 7.7 | 0.7% |
| | | | |
| Czech Republic | 8.4 | 5.9 | 9.1% |
| Hungary | 7.7 | 4.4 | 14.9% |
| Poland | 5.6 | 2.5 | 22.7% |
| Slovak Republic | 6.6 | 4.0 | 13.8% |
| Slovenia | 4.8 | 3.3 | 10.2% |
| | | | |
| Canada | 7.3 | 7.4 | -0.2% |
| Norway | 5.6 | 5.7 | -0.3% |
| Switzerland | 8.2 | 7.6 | 1.8% |

EU-15

| | | | |
|---|---|---|---|
| Coeff of Variation | 0.17 | 0.21 | |
| Max / Min | 1.86 | 1.95 | |

EU-25

| | | | |
|---|---|---|---|
| Coeff of Variation | 0.18 | 0.27 | |
| Max / Min | 1.86 | 3.14 | |

Source: Worldbank, World Development Indicators 2004 (data from ITU).

**Table 6. Internet users (% of population) by country, 2002 and 1997.**

| | Internet penetration 2002 | Internet penetration 1997 | Mean annual rate of growth from 1997 to 2002 |
|---|---|---|---|
| USA | 55.1% | 22.1% | 20% |
| Japan | 44.9% | 9.2% | 37% |
| EU-15 | 35.5% | 6.1% | 42% |
| EU-25 | 33.3% | 5.5% | 44% |
| | | | |
| Austria | 40.9% | 9.4% | 34% |
| Belgium | 32.8% | 4.9% | 46% |
| Denmark | 51.3% | 11.4% | 35% |
| Finland | 50.9% | 19.4% | 21% |
| France | 31.4% | 4.3% | 49% |
| Germany | 41.2% | 6.7% | 44% |
| Greece | 15.5% | 1.9% | 52% |
| Ireland | 27.1% | 4.1% | 46% |
| Italy | 35.2% | 2.3% | 73% |
| Luxembourg | 37.0% | 7.1% | 39% |
| Netherlands | 50.6% | 14.1% | 29% |
| Portugal | 19.4% | 5.0% | 31% |
| Spain | 15.6% | 2.8% | 41% |
| Sweden | 57.3% | 23.7% | 19% |
| UK | 42.3% | 7.3% | 42% |
| | | | |
| Cyprus | 29.4% | 5.1% | 42% |
| Czech Republic | 25.6% | 2.9% | 55% |
| Estonia | 32.8% | 5.5% | 43% |
| Hungary | 15.8% | 2.0% | 51% |
| Latvia | 13.3% | 2.0% | 46% |
| Lithuania | 14.4% | 0.9% | 74% |
| Malta | 20.9% | 4.0% | 39% |
| Poland | 23.0% | 2.1% | 61% |
| Slovak Republic | 16.0% | 1.9% | 53% |
| Slovenia | 37.6% | 7.6% | 38% |
| | | | |
| Canada | 51.3% | 15.5% | 27% |
| Norway | 50.3% | 29.4% | 11% |
| Switzerland | 35.1% | 7.7% | 35% |

EU-15

| | | | |
|---|---|---|---|
| Coeff of Variation | 0.35 | 0.75 | |
| Max / Min | 3.70 | 12.47 | |

EU-25

| | | | |
|---|---|---|---|
| Coeff of Variation | 0.42 | 0.87 | |
| Max / Min | 4.31 | 26.33 | |

Source: Worldbank, World Development Indicators 2004 (data from ITU).

**Table 7. Distribution of strategic technology alliances between and within economic blocs: 1980–2000.**

| | | Interregional alliances | | | | | | | Intraregional alliances | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Total** | Eur-Jap | | Eur-USA | | Jap-USA | | Subtotal | Europe | | Japan | | USA | | Subtotal |
| | | number | %age | number | %age | number | %age | | number | %age | number | %age | number | %age | |
| 1980-82 | 203 | 16 | 7.9% | 48 | 23.6% | 43 | 21.2% | 107 | 37 | 18.2% | 9 | 4.4% | 50 | 24.6% | 96 |
| 1989-91 | 404 | 25 | 6.2% | 101 | 25.0% | 57 | 14.1% | 183 | 74 | 18.3% | 7 | 1.7% | 140 | 34.7% | 221 |
| 1998-00 | 542 | 19 | 3.5% | 173 | 31.9% | 38 | 7.0% | 230 | 53 | 9.8% | 11 | 2.0% | 248 | 45.8% | 312 |

Source: Our elaboration from National Science Foundation, 2002.

**Table 8. Propensities for strategic technical partnerships, 1980-2000.**

**Propensity of European firms for European, US and Japanese technological partners**

| | Number of agreements involving European firms by BERD of the region (in billion US $ at constant dollars PPP) | | |
|---|---|---|---|
| Period | Europe | USA | Japan |
| 1980-82 | 0.80 | 0.61 | 0.71 |
| 1989-91 | 1.03 | 0.86 | 0.50 |
| 1998-00 | 0.62 | 1.07 | 0.32 |

**Propensity of US firms for European, US and Japanese technological partners**

| | Number of agreements involving US firms by BERD of the region (in billion US $ at constant dollars PPP) | | |
|---|---|---|---|
| Period | Europe | USA | Japan |
| 1980-82 | 1.03 | 0.64 | 1.90 |
| 1989-91 | 1.41 | 1.20 | 1.15 |
| 1998-00 | 2.03 | 1.54 | 0.65 |

Methodology: The number of strategic technological agreements recorded by the MERIT database have been divided by the Business Expenditure on R&D of the region expressed in constant 1992 purchasing power parity US billion $. It reads for example that in 1980-82 there have been 0.8 strategic technology agreements involving European firms for each US dollar billion of European BERD.

Source: Our elaboration from NSF, 2002 (data from MERIT database) and from OECD Statistics, Main Science and Technology Indicators 2001-2002.

**Table 9. Percentage of internationally co-authored scientific papers in selected countries in all scientific papers, 1986, 1994, and 2001.**

| | % internationally coauthored in 2001 | % internationally coauthored in 1994 | % internationally coauthored in 1986 | Annual growth rate from 1994 to 2001 | Annual growth rate from 1986 to 1994 |
|---|---|---|---|---|---|
| USA | 23.2 | 15.8 | 9.2 | 5.6% | 7.0% |
| Japan | 19.7 | 13.7 | 7.5 | 5.3% | 7.8% |
| | | | | | |
| Austria | 50.8 | 39.9 | 25.2 | 3.5% | 5.9% |
| Belgium | 53.6 | 43.6 | 29.9 | 3.0% | 4.8% |
| Denmark | 50.6 | 39.8 | 24.4 | 3.5% | 6.3% |
| Finland | 42.9 | 32.4 | 18.7 | 4.1% | 7.1% |
| France | 43.3 | 32.5 | 21.0 | 4.2% | 5.6% |
| Germany | 41.7 | 30.6 | 20.1 | 4.5% | 5.4% |
| Greece | 41.5 | 37.4 | 26.6 | 1.5% | 4.3% |
| Ireland | 46.7 | 36.8 | 26.7 | 3.5% | 4.1% |
| Italy | 39.7 | 32.7 | 22.9 | 2.8% | 4.6% |
| Netherlands | 44.9 | 32.0 | 19.8 | 5.0% | 6.2% |
| Portugal | 53.0 | 46.1 | 34.8 | 2.0% | 3.6% |
| Spain | 37.9 | 29.1 | 17.0 | 3.8% | 7.0% |
| Sweden | 46.3 | 36.2 | 22.2 | 3.6% | 6.3% |
| UK | 36.9 | 25.1 | 15.7 | 5.7% | 6.0% |
| | | | | | |
| Cyprus | 66.9 | 71.7 | 14.3 | -1.0% | 22.3% |
| Czech Republic | 51.6 | 42.9 | 17.2 | 2.7% | 12.1% |
| Estonia | 55.3 | 51.4 | 3.4 | 1.1% | 40.4% |
| Hungary | 54.8 | 48.7 | 29.0 | 1.7% | 6.7% |
| Latvia | 59.8 | 55.7 | 3.4 | 1.0% | 41.8% |
| Lithuania | 60.5 | 46.4 | 3.4 | 3.9% | 38.6% |
| Poland | 48.1 | 43.6 | 21.4 | 1.4% | 9.3% |
| Slovak Republic | 56.3 | 34.4 | 17.2 | 7.3% | 9.1% |
| Slovenia | 44.3 | 38.8 | 30.4 | 1.9% | 3.1% |
| | | | | | |
| Canada | 38.4 | 28.3 | 18.9 | 4.5% | 5.2% |
| Norway | 46.9 | 36.9 | 21.9 | 3.5% | 6.8% |
| Switzerland | 53.5 | 44.5 | 32.2 | 2.7% | 4.1% |

NOTE: National rates are based on total counts: each collaborating country is assigned one paper (a paper with three international coauthors may contribute to the international coauthorship of three countries).
We could not calculate the EU total, as it would contain multiple counting.
Since in 1986 they were not yet created, we attributed to Estonia, Latvia and Lithuania the percentage of URSS, as well as we attributed to Czech Republic and Slovak Republic the data of Czechoslovakia and to Slovenia the percentage of Yugoslavia.

Source: Our elaboration from NSF 2004 (data from ISI).

**Table 10. Distribution of internationally coauthored papers across collaborating countries, 1986-88 and 1995-97.**

(Rows report the percentage of the total number of international coauthorships of the country)
(Columns indicate the relative prominence of a country in the portfolio of internationally coauthored articles of every country)

| Country | 1995-97 | | | 1986-88 | | |
|---|---|---|---|---|---|---|
| | USA | Japan | EU15 | USA | Japan | EU15 |
| USA | | 9,6 | 60.3 | | 8,2 | 54.9 |
| Japan | 45.6 | | 39.4 | 54.0 | | 33.3 |
| EU15 | 29.0 | 4.5 | 69.4 | 31.9 | 3.1 | 56.6 |

NOTE: Row %ages may add to more than 100 because articles are counted in each contributing country and some may have authors in 3 or more countries.
With regard to European Union, internationally coauthored articles also include those among members countries.

Source: Our elaboration from NSF 2000, data from ISI.