EXECUTIVE SUMMARY

This reseach project aims at characterizing quantitatively the dynamics of the scientific and technological activities in the EU, highlighting some of their regional, national, EU and international systemic dimensions. It recognizes that socio-economic development is the result of the expression of the potential of knowledge-based activities in society ; it also recognizes that the dynamics of such knowledge activities are based on interactions patterns embedded both in regional set ups (geographical dimension) and in the multinational firm networks (institutional dimension).
Hence the design of this project, which addresses three complementary aspects of the emergence of a knowledge society in the EU.

The first part relates the regional dimension of the EU S&T activities with their technological interactions, both within countries, within the EU and with the Triad - through multinational firms. The second part focuses on the multinational firms technological strategies, with a comparison between the EU, the United-States and Japan. The third one investigates the scientific and technological networks built between firms and public research, within the EU, in the case of information and communication technologies.

••• part 1 - The dynamics of S&T activities in the EU regions - characterization, cohesion and convergence - a quantitative analysis

This part aims at characterizing the dynamics of the scientific and technological activities in the EU regions, in their relationship to economic growth.
To achieve that, a regional data base has been built, recording GDP per capita, scientific publications and European patents per capita, measured at two dates for the 15 EU countries split down into 445 'regions' ; in addition, for each region, the number of patents with local, national, European, extra-European (USA, Japan, other) linkage has been recorded [each patent has an inventor, located in a certain region (region A), where the research has been done, and an assignee (owner), a firm which can be independent, or the subsidiary of another firm ; in any case, there is an ultimate assignee (firm) in term of financial control, located in region A (local linkage), or in another region of the country (national linkage), or in another EU country (EU linkage), or outside the EU (extra-EU linkage)].

The research has consisted in preparing this data base and performing a number of analyses.

1. Economic, scientific and technological activities of the EU regions - characterization and typology

First, various comparisons among regions and classifications are made, leading to an overview of the activities of the EU regions :

- two regions perform more than 4 % of the S&T activities of the EU : Paris and London (ranks 1 and 2), which are the capital cities of geographically centralized large European nations, with 6 and 7 million inhabitants each ;
- then, between 1,9 and 3,1 %, come 6 German regions (ranks 3 to 8) corresponding to the large cities of this geographically decentralized country (regions

between 2,6 and 5,3 million inhabitants) (Munich, Düsseldorf, Frankfurt, Stuttgart, Köln, Karlsruhe) ;

- between 1,0 % and 1,6 % of total EU S&T activities, there is a third group, made of 13 regions (ranks 9 to 21), which consist of the following :
  - 5 capital cities (or economic capital city) of middle-sized (in terms of S&T) European countries : Sweden, Spain, The Netherlands, Finland and Italy,
  - 5 middle to large sized S&T active German cities,
  - 3 'campus - regions' : Cambridge and Oxford, in the UK and Essonne (Orsay-Saclay-Vallée de Chevreuse-Evry campus) in France (for clarity of presentation, we considered Essonne in this group, although its rank is 22).

This descriptive characterization is followed by a typology of the 445 regions into 4 and 8 clusters ('types of regions'). The stylized pattern of the EU regions - in 4 groups - regarding GDP per capita, scientific and technological activities show that, broadly speaking, there is correlation between GDP per capita, scientific and technological activities density. Nevertheless, at more detailed scale, the picture is more complex, and the classification in 8 groups shows three sub-sets of regions with patterns worth noticing (no science, no technology, no science nor technology).

2. Economic, scientific and technological activities of the EU regions - cohesion and convergence issues

Then, cohesion issues are addressed through an analysis of the concentration of GDP per capita, of the scientific and technological activities, at EU-15 (inter-country) level, at intra-country level and at the overall EU-445 inter-regional level. A dynamic analysis is performed, allowing to address the question of the convergence and divergence among countries and regions.

Concerning concentration of GDP per capita, scientific and technological activities :

- GDP per capita, at European (EU-445 level) is significantly more evenly distributed among regions than scientific and technological activities ;
- scientific activities are significantly more evently distributed among countries (at EU-15 level) than technological activities ;
- but within each EU country (intra-country concentration), the opposite is true : the technological activities are in general more evenly distributed than the scientific activities ;
- in total, at EU-445 level, scientific and technology activities have a broadly similar concentration index.

The overall view of cohesion regarding scientific and technological activities show that the EU-445 convergence rate of scientific and technological activities is of the same order of magnitude ; but the two components (inter and intra - country) have different relative weights in the two cases and country-specific situations can be observed.

The analysis of the dynamics of S&T activities in the EU regions shows that there is a convergence towards the European mean on all three parameters of GDP per capita, scientific and technological density per capita - this convergence being quite slow, the rate of the closing of the gap being of the order of 1 % per year for each one of the variables.

The other aspect of the dynamic analysis is that strong regions with relative decrease in science, tend to also to have a relative decrease - although a little less strong - in technology. Conversely, less developed regions having a positive trend in science consolidating an already significant position, show an even more positive and remarkable trend in technological activities. Finally, laggard regions in terms of scientific activities are still showing no progress in technology, even though some positive trend in science can be identified.

3. International technological linkages of the EU regions through the localization strategies of the multinational firms (MNFs) - characterization and typology

Now, the regions are characterized, in addition, by the geographic pattern of their 'technological linkages' (see above).

A description of the linkages of the regions is made, identifying the top 20 European regions in volume of patents controlled by European, North American and Japanese MNFs (1996).

From there, the profiles of the technological linkages of the 445 EU regions are indentified, trough a clustering (typology) in 6 groups : 4 kinds of profiles are characterized by the dominance of one geographical linkage (local, national, European, extra-European), one by the diversity of its linkages ('eclectic') and one by the inexistence of its technological activities.

4. The dynamics of the EU regions in relation to their technological linkages - cohesion and convergence issues

The technological linkages are related to the level and pattern of activities of the different regions.

It appears that the relative importance of the foreign technological linkages is independent of the technological level of the region. The breakdown between European and extra-European linkages are also independent of the technological level of the region.

This being said, it also appears that there is a strong relationship between the scientific and technological development of the regions and the profile of their technological linkages :

- the most developed regions tend to have the profiles 'eclectic' (35 %), local (30 %) and extra-European (20 %),
- less developed regions tend to have the profiles European (25 %), national (20 %), 'no technology' (20 %) and extra-European (15 %).

Regarding the foreign technological linkages, four results can be outlined :

a) in terms of geographic distribution, at EU-15 level (between countries), the concentration of foreign-linked technological activities is stable ; the intra-country concentration decreases somewhat ; in total, at EU-445 level, the trend is a slow decrease of concentration, like for scientific and technological activities in general. The situation for country to country is quite variable. At EU-15 and EU-445 levels, the geographic dynamics of foreign-linked technological activities is not significantly different than that of technological activities in general.

b) the situation is quite different when considering the dynamics in terms of the distribution among the groups of regions, there is a strong divergence process at play :

- the most developed regions, having the highest density of foreign-linked technological activities, are also those with the highest rate of increase of such activities,
- less developed regions, are, at a large majority, having a slower than average development of foreign technological linkages.

c) the profiles characterized by international linkages - both European and extra-European - are those spreading the most among regions.

d) the regions with profile 'extra-European', tend to have a particularly good record in technological activities growth.

5. Characterization of the Framework Programme activities of the EU regions

Finally, the activities of the EU regions in terms of participation to the FP are analyzed, relating these activities to their scientific and technological activities, in order to address through another entry point, the question of cohesion among EU regions.

More specifically, the top 20 EU regions in number of participations in the Framework Programme, and the top 28 less developed and most participating EU regions in the Framework Programme, are identified.

But one cannot understand the technological activities at regional level without considering explicitely of the firms - and particularly the multinational firms (MNFs) - of which they are a result. Technological activities are part of two dynamics simulaneously, and after having examined the geographic dimension, we now turn towards the institutional dimension - that is the firm's logic and strategy.

••• part 2 - Technology strategies of large European Firms

This part has been concerned with using publicly available data on R&D expenditures and on US patenting to analyse the technological competitiveness and strategies of large European companies. This section summarizes the main findings of the project and discusses their policy implications.

1. European Technological Competitiveness

There are a number of European companies that rank amongst the world leaders in a number of industries and technologies. In general, areas of EU strength are characterized by a greater numerical presence of European-based firms, e.g. in Chemicals, Pharmaceuticals, Food, and Aerospace. On the other hand, in areas of weakness there are very few European companies compared to those based in Japan and the US: Electronics, Vehicles, Machinery and Metals.

In terms of measurement, there appears to be very little consistency amongst ‘within-industry’ company rankings based on different measures constructed from R&D and

patent information. One reason could be the lack of a ‘time-series’ dimension in the data on R&D expenditures.

2. The role of Large Firms

Large firms are a major source of national technological activities especially in the so-called ‘high-tech’ areas of Chemicals-Pharmaceuticals and Electronics.

Foreign large firms (i.e. those based in Japan and the US) are important contributors to EU technology especially in Chemicals-Pharmaceuticals and Electronics. On the other hand in Japan and the US, the contribution of foreign firms is much smaller.

3. Internationalization of technology

Whether as individual countries or collectively, European technological activities are more internationalized than those of their Japanese and American counterparts. However, in spite of some increases since the early 1980’s technology development remains the least internationalized of all corporate activities. The main patterns of internationalization can be summarized as follows :

Firms are active outside their home countries in those areas of technology where there have been big increases in R&D expenditures and where they have formed strategic alliances (National Science Board, 1996): pharmaceuticals, computers, telecommunications, and materials. However quite a sizeable part of their foreign activities, regardless of product group and nationality, are concerned with improvements in process technology and machinery.

In terms of locations there is a high level of concentration of foreign technological activities in just 3 countries: the most important foreign location is the US followed by Germany and the UK. In the mid-1990's, Japan is still unimportant as a host country.

In a large majority (more than three quarters) of cases, firms tend to locate their technology abroad in their core areas where they are strong at home. In a small minority of cases (10%), firms go abroad in their areas of weakness at home to exploit the technological advantage of the host country.

The largest increases, especially for chemical and pharmaceutical companies, have been in technical fields where there are complementary strengths between the domestic activity of a company and the host country.

In relation to the motives for foreign technological activities, our results suggest that adapting products and processes and materials to suit foreign markets and providing technical support to off-shore manufacturing plants remains a major factor. They are also consistent with the notion that firms are increasingly engaging in small scale activities to monitor and scan new technological developments in centres of excellence in foreign countries within their areas of existing strength. However we

find very little evidence to suggest that firms routinely go abroad to compensate for their weakness at home.

Two key features related to the launching of major innovations may help explain why large firms involved in producing for a world market may keep a large part of their technology production close to the home base : the involvement of inputs of knowledge and information that are essentially 'person-embodied', and a high degree of uncertainty surrounding outputs. Both of these are best handled through intense and frequent personal communications and rapid decision making, i.e. through geographic concentration. Thus it may be most efficient for firms to concentrate the core of their technological activities in the home base with international 'listening posts' and small foreign laboratories for adaptive R&D.

The major point here is that the knowledge assets existing in the territories constitute the building blocks of the development of the technology strategies of the large firms : the firms can be viewed as knowledge networks relating the territories in which they are active. The question then is to characterize in an empirical and quantitative way such network of relations, particularly those linking the firms knowledge assets (centered on the RD laboratories) and the territories knowledge assets (centered on public research facilities).

••• part 3 - The global science base of information and communication technologies : strategic analysis of scientific publication activity in the EU, USA and Japan

This part presents a large-scale application of a systemic method for quantifying empirical information on ICT research activity to aid comparative studies of these science bases. Numerical data on publicly documented scientific knowledge outputs as embodied in research papers provides useful ‘bibliometric’ indicators of the absolute and relative size of ICT research output, and of geographical and institutional patterns of scientific cooperation within those science bases.
The bibliometric analyses were conducted on some 55,000 research articles published in international scientific and technical journals in the period 1992-1996. The quantitative measures describe and compare various structural characteristics of research output and scientific collaboration, featuring the countries of the trade (i.e. EU, USA and Japan).

ICT is of vital economic importance to the European Union and its national knowledge-based economies, as indicated by numerous policy studies and discussions concerning competitiveness and job creation. An important measure of an EU nation’s or region’s ability to catch-up, or respond to ICT-related trends and demands, are the relative strengths and weaknesses of their knowledge base. In particular the science base comprising of industrial research and the related publicly funded scientific activities. In order to be able to effectively describe and monitor ICT-related scientific activity, it is important to be able to provide reliable statistics of this science base at the level of countries, regions, institutional sectors and large institutions within the framework the global ICT science base.

This report presents a large-scale application of a systemic method for quantifying empirical information on ICT research activity to aid comparative studies of these science bases. Numerical data on publicly documented scientific knowledge outputs as embodied in research papers provides useful 'bibliometric' indicators of the absolute and relative size of ICT research output, and of geographical and institutional patterns of scientific cooperation within those science bases.

This exploratory case study was based on the *CWTS ICT Database*, a specially developed customized database. It provides a worldwide coverage of research papers published in high-quality international scientific and technical journals. The bibliometric analyses were conducted on some 55,000 research articles published in international scientific and technical journals in the period 1992-1996. The quantitative measures describe and compare various structural characteristics of research output and scientific collaboration, featuring the countries of the trade Triad (i.e. EU, USA and Japan), and broken down by :

- major ICT research domain : Computers and Data Processing versus Telecommunications;
- institutional sector : universities and other public research institutions versus enterprises and private R&D labs;
- aggregate level : countries versus major research performing institutions.

This large international bibliographic database and its related bibliometric indicators together provide an analytical framework and appropriate proxy measures to describe and monitor relative strengths and weaknesses of the science bases in this large and multidisciplinary area. The findings show that ICT-related research papers originate from a wide variety of institutions within the Triad, and that private firms account for a substantial part of that research output. Moreover, we find several significant differences between countries, institutional sectors, and institutions within the ICT science base of the Triad countries.

Key results concerning the EU science base are :

• The EU private sector produces a much lower share of research papers as compared to the private sector in the USA or Japan (EU data: Computers and Data Processing - 11.1%; Telecommunications - 34.1%),

• EU nations are less focused on domestic research collaboration as compared to the USA or Japan (EU data: Computers and Data Processing - 39.6%; Telecommunications - 37.3%). However, a significant share of the EU collaborative links involve other EU Member States (EU data : Computers and Data Processing - 28.6%; Telecommunications - 33.4%),

• The EU shows a relatively low share of :
  - inter-firm collaborative papers (EU data : Computers and Data Processing - 5.8%; Telecommunications - 29.2%),
  - public/private collaborative papers in Computers and Data Processing (EU data : 10.7%), but a comparatively high share in Telecommunications (EU data: 25.8%),

• Major public research institutions within the EU are :

- less inclined to co-author research papers with other units within the same main institution as compared to their counterparts in the US (EU data: Computers and Data Processing - 19.4%; Telecommunications - 8.7%),

- more inclined to co-author research papers with US firms than vice versa (EU data : Computers and Data Processing - 4.6%; Telecommunications - 6.9%),

- more inclined to co-author research papers with other PRIs outside the Triad (EU data : Computers and Data Processing - 10.9%; Telecommunications - 5.1%),

• Large R&D intensive firms whose home base is located within the EU show a smaller share of research papers originating from R&D units located in their home country as compared to large US and Japanese companies (EU data : Computers and Data Processing - 74.6%; Telecommunications - 83.6%),

• Selected large EU multinationals have :

- a propensity for collaborative links with : (i) public research institutions in domestic research base, and (ii) other firms in the EU base,

- foreign R&D-performing affiliates or subsidiaries, which are predominantly involved in scientific collaboration with research partners in the public research sector of the host country.

Conclusions and policy implications

••• One major set of results of the research is :

- the overall correlation between S&T activities and socio-economic development at national, but also, at regional level, even though particular cases show there are no mechanistic determinations,

- the very slow inter-regional convergence among EU regions in terms of S&T activities in spite of all the efforts made, which show the cohesion issue is to stay for some time in the political and the policy agendas,

- the need to take into account both national inter-country and regional intra-country dimensions in order to address properly the questions of convergence, since part of the problem lies in the national territorial dynamics.

This has major policy implications in the sense that it suggests to relate much more the EC S&T cohesion policies - Structural funds but also, to a certain extend the Framework programme - with the member-countries national territorial dimension of their S&T policies. This may be a very good case for better integration of EC and national policies - which would be all the more timely that there are possibilities of a reinforcement of divergence forces as the EMU is launched, along with continuing liberalization and de-regulation.

••• Another important set of results is the specific role of the EU MNFs regarding the linkages of the less favored regions of the EU with the more developped regions : the less developped regions in the EU tend to have technological linkages - through EU multinational firms - oriented towards the more developped EU regions.

Thus the process is one in which companies :

- learn from leading edge research in a particular location and use this knowledge to enhance the bulk of their technological capabilities which are located at home,

- play an important role both in terms of stimulating competition amongst domestic firms and in terms of 'knowledge spillovers' or learning benefits to local suppliers and customers, particularly in less developped regions where these firms may have subsidiaries.

A first policy implication of this second set of results is the need to have policies that enable domestic firms to learn and assimilate knowledge and techniques that have been created and developed elsewhere in the EU or in the world. The exact nature of such policies is a matter of debate and discussion but a crucial element has to be investments in the public infrastructure for training, R & D and related activities both at the EU and the national level.

A second policy implication is to think about S&T developments in less developped EU regions not only in terms of SMEs, but also in terms of linkages to the center via EU MNFs. This would then imply - in turn - to view EU MNFs as actors of the linkage between developped and less developped regions of the EU, and concetualize cohesion policies accordingly.

••• But such broad assessments must be completed and adjusted when analyzing the specificities of sectors, for example the ICT sector. The major result is here that the EU ICT science base is more internationalized than the US and Japanese science base, but that EU firms play a less prominent role in the EU science base in terms of level of research activities and collaboration as compared to the activities of US and Japanese companies in their home countries.
Furthermore, the EU science base of Telecommunications R&D is more developed and focused on intra-EU cooperation than the science base underlying R&D activities in Computers and Data Processing.

In terms of policy implications these results raise concerns on ICT both public and industrial research strategies : lack of interactions within and among institutions in the EU and insufficient industrial role can hardly go un-noticed in such a strategic area, where Europe is striving to keep its competitiveness. These result are - unfortunately - coherent with the macro analysis showing a continuing loss of technological and industrial positions to the US and Japan. Our research show that it is not the overall S&T activity level in ICT which is at stake, but strategies and linkage patterns within and among EU public and industrial organizations.

A larger implication is that some features of a 'EU innovation system' (EUIS) are emerging, which deserves an understanding and a monitoring through the recognition of this phenomenon as such. The steps from a pluri-national to a somewhat integrated EUIS are certainly not a 'natural' process, but can only result from political will embodied in policies shared not only by the governments, but also by all the actors concerned, including industry and public research institutions.