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Europe's strengths and weaknesses in Information Society Technologies

A patent analysis

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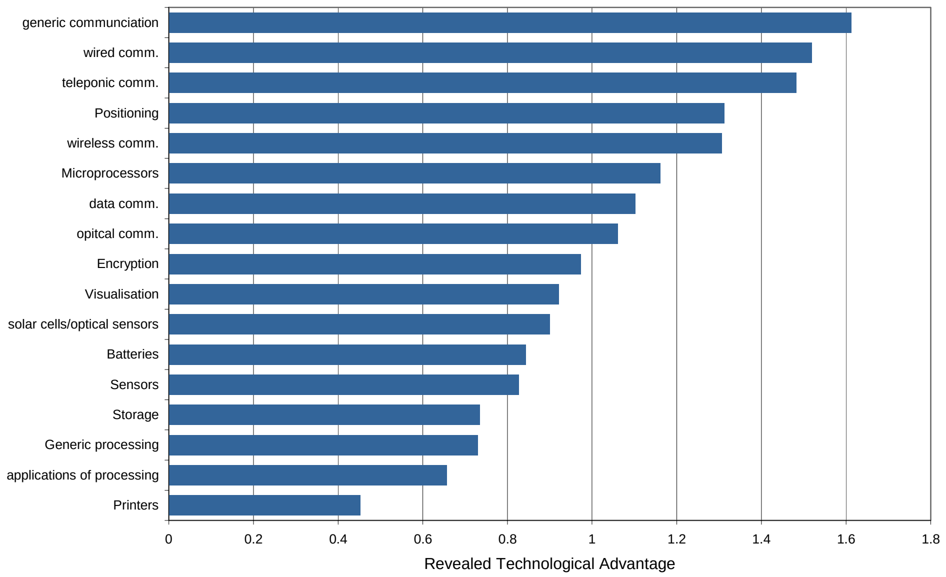
Executive Summary

The objective of the EU to become the "most competitive and dynamic knowledge-based economy in the world by 2010" (European Council 2000) is also a key element for developing a vision of the Information Society Technologies (IST) in Europe, and thus an important starting point for the work in FISTERA.

This study on "Europe's strengths and weaknesses in Information Society Technologies – a patent analysis" aims to gain insights into the position of Europe in the field of IST by analysing patent data at two different levels. Apart from comparing the situation of the EU to that of the US and Japan at an aggregate level, data on individual companies are used to study their relative position in different technological fields. As for the technological fields according to which the analysis is differentiated, compatibility has been sought with the technology categories used in other workpackages of FISTERA, based on a clustering of the corresponding categories of the International Patent Classification. In order to ensure a well-balanced picture of the patenting activities in IST worldwide and avoid the biases of the data from individual patent offices in Europe, the US and Japan, "triadic patents" are used as the main data source, i.e. patents that have been filed at **all** three patent offices of the Triade.

The aggregate picture reveals that Europe is still behind the US and Japan in terms of the share IST has on overall patent activity, but we can observe a process of catching up in the course of the 1990s. This was partly due to a favourable position in communication technologies, which is clearly an important European strength, as measured in terms of Europe's Revealed Technological Advantage (see below). But we also see a clear improvement of Europe's position against the US and Japan in other technologies where it is often said to be lagging behind, like for instance in processing.

Europe's Revealed Technological Advantage in various Information Society Technologies, 1996-1998



A value > 1 means a higher specialisation than the world and therefore a strength, a value < 1 means that Europe is less specialized in this technology

When looking deeper at the level of countries, it appears that Europe owes this favourable development in large parts to the small and medium-sized countries. On the contrary, the number of IST patent applications from German, French and UK firms grew slower than EU average.

The patent data at company level shows that the IST world is highly concentrated: We found that half of all patents applied for between 1976 and 2002 are owned by only 33 groups of companies. Europe's leading IST companies are all well-known: Philips, Nokia, Ericsson, Thomson, STMicroelectronics, Siemens, Infineon and Alcatel. Outstanding European enterprises with regard to R&D spending in their industries are Siemens, SAP, Nokia and Ericsson. These companies are constantly among Top 10 IST actors in all sectors examined. At the ranks from 10 to 100, however, European companies are clearly under-represented. The list of most relevant actors has not changed a lot over the past decades in many technologies, underlining the continuity in the competence base of major firms even in a highly dynamic area like IST.

Moreover, our results also point to the high degree of international interrelatedness in IST. Leading European companies invent between 30 and 70% of their IST patents outside of their home countries, i.e. although the patent may be applied for by the mother company, the actual inventor is based either in other European countries or in the US. On the other hand, the number of patent inventions by European actors is higher than the number of patent applications, which indicates a strong presence of R&D by US firms in Europe. One can estimate that there is a constant flow of knowledge from Europe to the US which accounts roughly for about 25% of all European patent applications.

The patent portfolios of individual companies like Philips, Thomson, Ericsson or Nokia tend to cover a very broad spectrum of technologies that goes well beyond the realm of their core products. This observation seems to contradict the well-known advice to concentrate on core competencies and rather reflects a strategy aiming to enable the companies to master unexpected emerging technological disruptions.

In general, patterns of specialisation show a high degree of continuity, both at the level of firms and at the aggregate level of countries or world regions. A significant change in the competence base seems to be process that can take decades, requiring adjustments well beyond the realm of research and extending, for instance, to education and training. From this perspective the catching up of Europe also outside its established areas of strength is quite remarkable.

These findings have some implications for technology policy in the field of IST: first, as national strengths and weaknesses in IST seem to change only slowly, it seems inevitable to pursue a long-term strategy to achieve a sustainable change in specialisation patterns. Processing has been mentioned as an example where a higher degree of specialisation could be achieved in the course of the 1990s, partly driven also by policy programmes at European level. With respect to the future specialisation patterns in the European Research Area, however, the long-term development of the competence base seems to matter more than technology programmes.

Second, as the competence profiles of all actors cover a quite broad range of technology fields in order to be able to cope with disruptions or take up unexpected new opportunities, it seems to be reasonable that IST technology policy also aims at striking a balance between the setting of targeted priorities on the one hand and the stimulation of more generic competencies on the other. This is also an experience from technological disruptions of the past in IST, when it was decisive in several cases to be well-positioned and prepared to take advantage of unexpected "windows of opportunities".

Third, in spite of the internationalisation of R&D in IST, the results have confirmed the important role played by very large players in IST. Europe-based firms are well represented in the world league of IST, what is missing, however, are the large and medium-sized players. In addition to the attention paid to ‘national/European champions’ or the ‘premier league’ in IST, RTD policy should thus also keep the second and third tier of IST firms and research organisations in focus.

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1 Introduction

1.1 Aim of the study

The objective of the EU to become the "most competitive and dynamic knowledge-based economy in the world by 2010" (European Council 2000), as brought forward by the Lisbon meeting of the European Council in 2000, is a key element for developing a vision of Information Society Technologies (IST) in Europe, and thus an important starting point for the work in FISTERA. FISTERA aims at analyzing gaps, opportunities and stepping stones on Europe's way to Lisbon for the domain of IST, but also looks beyond this time horizon in order to expanding the debate on future perspectives for IST..

The following report is part of a set of activities in workpackage 3 of FISTERA, which together aim at illuminating important facets of Europe's strengths and weaknesses in the field of IST. Work includes a co-nomination analysis of the European actor space in IST, an investigation of main drivers and challenges for Europe with regard to Human Resources in IST and an overview of the research priorities of Europe's leading public research centres in this field. This report uses patent data to capture an important dimension of techno-economic competitiveness.

Competitiveness as well as associated strengths and weaknesses tend to evolve slowly and cannot be adequately described by looking just at the last few years. This is why this report sets out to take a look at this phenomenon over a longer time period, starting with data from the early Nineties. Second, competitiveness is a multifaceted phenomenon, and the use of only one single data source may produce misleading results. The analysis will be based on patent data in first place, we will also provide an additional perspective with data on R&D expenditure.

We will ask the following and related questions:

- How has the performance of European firms in IST developed over time compared to US and Japanese firms? How has it developed at the level of member countries?
- In what technologies lay the main strengths or specialisations within IST, what are weaknesses?
- Who are the main European actors in various technologies? What is their position as compared to their Japanese and US competitors?

We will first draw the broad picture by comparing Europe's patterns of specialisation to those of the US and Japan, and then move to the level of specific technologies to analyse who the main players at the level of companies are. The selection of technologies is based on the categories developed by the FISTERA partner Telecom Italia Lab as part of its activities on technological trajectories (Saracco et al. 2004).

1.2 Competitiveness, productivity and specialisation

A key term of the EC's Lisbon strategy is competitiveness. However, in spite of the publicity of the claim, the meaning of competitiveness is far from being unambiguous and lively disputed among economists. A well-known contribution to this debate is Paul Krugman's claim that competitiveness is a "dangerous obsession" of policy makers;

“People who believe themselves to be sophisticated about the subject take it for granted that the economic problem facing any modern nation is essentially one of competing on world markets – that the United States and Japan are competitors in the same sense that Coca-Cola competes with Pepsi – and are unaware that anyone might seriously question that proposition.” (Krugman 1994 p. 4)

Krugman’s main point is that the concept of competitiveness, which may be helpful in explaining the growth of enterprises, is misleading if applied to countries, simply because most countries gain the largest share of their national income not in international trade, but in domestic activities. The sources of growth are domestic in most countries. Therefore, the ability to employ all available resources of a country in the most productive way is decisive for future wealth creation. Productivity, not competitiveness is the key.

Paul Krugman’s critique helps to understand what competitiveness means in the context of the Lisbon strategy. It seems obvious that it cannot be understood in the sense of winning market shares in foreign trade. Although small European countries like Austria or the Nordic countries depend heavily on exports, their most important trade partners are all members of the EU. In an European perspective, gains in market share of these countries would be a zero-sum game, at least in the short run. From this viewpoint, it becomes clear that competitiveness has to be understood in a wider sense. Fagerberg (1996) argues in this direction when he points out that competitiveness, when applied to a country, has a double meaning: it relates to the nation’s trade performance, but also in a broader sense, to the economic well-being of the citizens. By touching issues like employment and social inclusion, the Presidency conclusions of the Lisbon strategy clearly follow the latter meaning. Competitiveness in the sense of comparing the well-being of Europe’s citizens to those of countries outside of Europe is also the interpretation this paper will follow.

Information Technologies and the Knowledge Society are regarded to be key drivers of a higher well-being of European citizens by the Lisbon strategy. IST-producing industries and their exports have a noticeable influence on growth in some countries, like Finland or Sweden. However, economists expect the major contribution of IST for economic growth to arise from productivity gains in user industries (OECD 2003). The application of IST in all sectors of the economy may, by increasing labour productivity, raise Europe’s overall wealth. By increasing the extend to which IST is applied, European policy may help to maximise these benefits from IST. FISTERA contributes to this effort by drawing a picture of future uses of IST – future services in different ambients, as described Telecom Italia Labs in work package 2, and scenarios of future life pictured by PREST in work package 4.

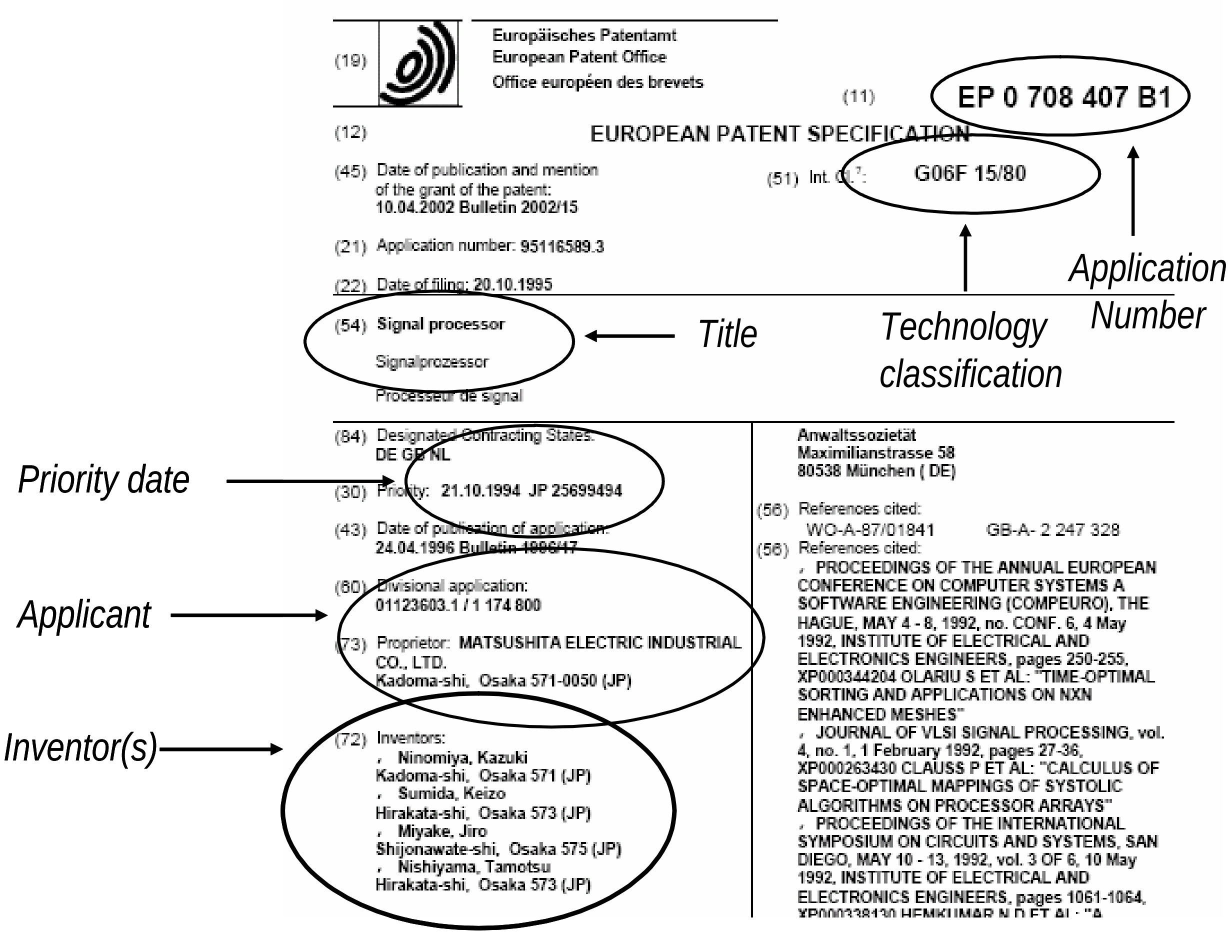
This report looks at the performance of enterprises, industries and countries in IST. Here, competitiveness is intimately related to the ability to create inventions and to turn them into market innovations. Key determinants of competitiveness include the resources mobilised to sustain it, the institutions active in supporting it, the existing demand conditions to develop it and the structure of inter-firm networks to strengthen it (Cantwell 2004). The players in this game are enterprises, who acquire technological knowledge from internal and external sources by own research and development activities, licensing, or co-operative agreements with universities or other firms.

1.3 Patents as a measure of technological specialisation

As we assume that the positive effects of IST increase with the extend these technologies are employed, a central aim of the study is to measure the degree to which firms possess technological knowledge. We will call the share a certain technology on all technologies a country or firm possesses as ‘specialisation’. A firm is highly specialized in a certain technology if this technology holds a large share on its technology portfolio.

Specialisation will be measured by the number of patents a country or firm possesses. A patent is an intellectual property right issued to protect technological inventions. By granting these rights to inventors, the patent system enhances the approbability of inventions and therefore stimulates the creation of novelty. But the patent system is not only a legal institution. Patents are a valuable source for analyzing technological change and, therefore, a “Window on the Knowledge Economy” (Jaffe and Trajtenberg 2002). Figure 1 shows a patent file granted by the European Patent Office. A patent file first describes the invention that is protected by the patent by the title, an abstract and the technology classification. Moreover, a patent file shows the first application of this invention at a patent office (priority date), the owner or applicant of the patent and its inventors.

Figure 1: Patent file at the European Patent Office



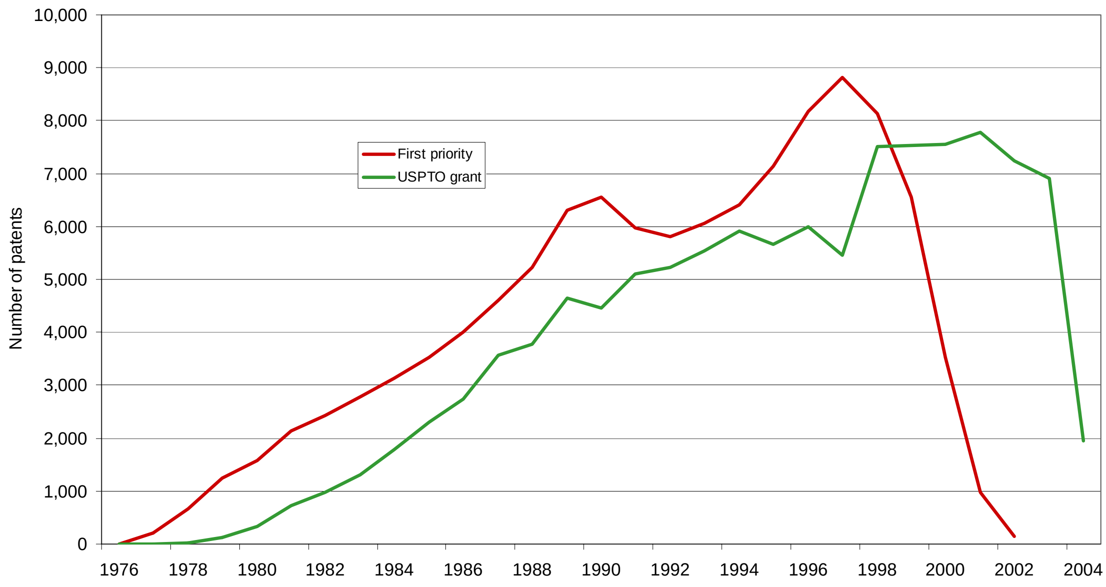
Source: European Patent Office

Patents have some features that make them useful for the analysis of technological change (see Griliches 1990; Jaffe and Trajtenberg 2002). First of all, patents directly represent technologies, not companies or proxies for technologies. There is a roughly proportional connection between patenting activity and research and development activities at the level of industries (Bound et al. 1984). Patents are the outcome of an innovation process and are, therefore, expected to be economically valuable in one way or another; either by using them, or by preventing their use by competitors. Otherwise the company would not apply for patent. Therefore, patents also reflect the competitive dimension of technological change.

A unified classification scheme (International Patent Classification, IPC), provided by the World Intellectual Property Organization (WIPO), makes it possible to follow developments over time and countries. Moreover, this classification is much more detailed than the classification scheme for publications (Science Citation Index) or industrial activities (NACE).

Patent documents usually have three different reference dates: priority date (first date of filing of a patent application, anywhere in the world, to protect an invention), application date and date of grant. Patent indicators are usually computed on the basis of the priority data, because this date is closest to the original invention. Patent offices usually issue only information of patents already granted; therefore, the number of patents counted by priority number decreases for the most recent years, because a large number of patent applications are still under examination. This time lag between priority date and final grant of the patent can add up to several years, as demonstrated in Chart 1which shows the annual number of patents according to priority date and date of grant at the USTPO. In the 1980s and 1990s the gap between filing and grant was on average about two years. The most recent priority dates in our analysis will be around 1999, which most often refers to patents granted in 2003 and 2004.

Chart 1: Annual number of patents according to priority date and date of grant at USPTO in IST, triadic patent applications, 1976-2004



Source: OECD, Triadic Patent Families Database, own calculations

Patent data as a measure of technological change, however, also have some important limitations. First, not all inventions are patentable. Although some patent offices, like the USPTO, have enlarged their patentability criteria, innovative activities in some important technological sectors of IST, like software or services, may still be underestimated by patents. Second, it is up to the inventor to apply for a patent or rely on other means of protection, like secrecy. We know that the propensity to patent varies considerably between sectors, even if the these sectors have a similar rate of innovative activities.

2 Data and definitions

2.1 The OECD Triadic Patent Families database

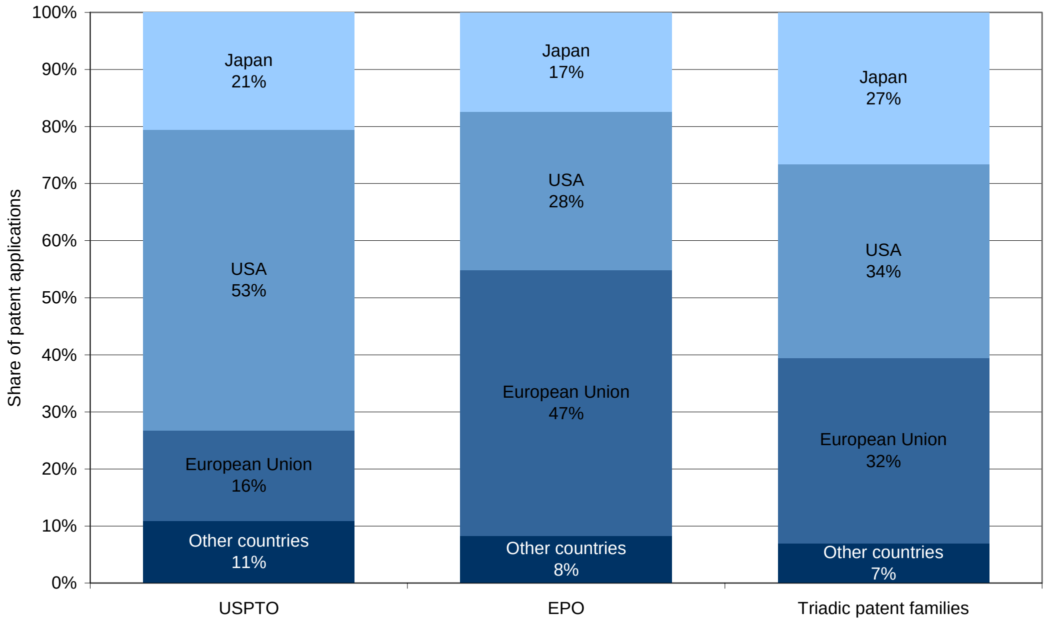
The most important decision regarding cross-country comparisons of patent data is the choice of the patent office. Enterprises, universities as well as private inventors tend to apply for a patent in their home country first. Patent protection may be later expanded to other countries if the invention becomes a success; but the first application will always be made in the home country. Therefore, the decision to use data of a single patent office will inevitably have an impact on the results received from the analysis. In 1998, for example, the share of European organisations of all patent applications in class H01l, semiconductors, was 35% at the European Patent Office, but only 6% at the US Patent and Trademark Office. On contrary, the US share of all semiconductor patents accounted for 28% at the EPO, but 42% at USPTO. We would get different results if we only looked at USTPO or EPO data.

To overcome this selection bias problem and allow balanced cross-country comparisons, the OECD has developed the concept of *Triadic patent families*: Patent families are set of patents (originating from the priority filing) taken in various countries (i.e. patent offices) to protect the same invention (Dernis and Khan 2004). Triadic patent families, therefore, are inventions for which a patent application has been filed at **all** three patent offices of the Triade, the US Patent and Trademark Office, the European Patent Office and the Japanese Patent Office (Dernis and Khan 2004).

Chart 2 illustrates the advantages of Triadic patent families over patent data from a single office: US applicants hold a share of 53% of all patent grants at the US Patent and Trademark Office in 1999, but only 28% of all patents applications at the EPO. In turn, we see a much higher propensity of European firms to apply at the EPO than at the USPTO. Therefore, an analysis of USPTO data would overestimate the position of US firms in IST, simply because the USPTO is the national patent office of these firms and the first choice to protect their inventions. The same is true for European firms at the EPO.

By using triadic patent families, we can overcome this bias. This is essential for any cross-country comparison like FISTERA. Chart 2 reports a roughly equal share of US and EU patents for triadic patent families. Moreover, Japanese inventions, which are underestimated at both the US and the EU patent office, now appear with a share of 27% of all worldwide patents.

Chart 2: Country shares of patents applied for at the EPO, patent grants by the USPTO and Triadic Patent Families, for priority year 1999



Source: Dernis and Kahn (2004)

2.2 Definition of the IST sector

Information Society Technologies are not a single group of technologies in the International Patent Classification (IPC)[1], but span over a number of groups. Therefore, the first task in studying IST patents is to define what is meant by IST. We had two starting points: first, the work of Telecom Italia Labs on Technologies and Technology Trajectories (Bianchi et al. 2003), second a classification of Information and Communication Technologies developed by the Fraunhofer ISI institute for the OECD (Schmoch 2004).

The major problem in finding a suitable classification of technologies in patent data is to reduce the hundreds of technology classes to some meaningful groups for further analysis. We decided to define these groups at the four-digit level of the IPC. Examples of such four-digit classes are G10L, speech analysis or synthesis; speech recognition, G11B (information storage based on relative movement between record carrier and transducer), or H01L (semiconductor devices). It is of course possible to dig much deeper into data to make very detailed analyses; H01L, for example, consists of numerous sub-groups to cover each aspect of semiconductors. The problem with a more detailed aggregation, however, is that many of these classes may then encompass only a very small number of patents.

The complete classification developed for this study is given in the Annex. It consists of 18 broad technology categories. Each of these technologies consists of at least one class of the International Patent Classification. We further split the two largest categories, processing, consist into sub-categories. Within communication, for example, we further distinguish between wireless and wired

1 http://www.wipo.int/classifications/fulltext/new_ipc/

communication, and between data and telephonic communication, and we introduced a class of generic communication technologies. These sub-classes follow the structure of the IPC; however, they also reveal some limits of the patent classification. One is that classifications sometimes cannot keep pace with technological change. The distinction between telephony and data communication on one hand, and wireless and wired communication reflects the historical trajectories of these technologies, and seems to be ill-suited for converging technologies like voice-over-IP.

Table 1 lists some of these technologies and their average number of patent applications during 1995-1998. Please note that due to the fact that some patents belong to more than one technological category the numbers of the classes add up to more than the total number of IST patent applications.

Table 1: Technology categories in IST, and average number of patent applications in these categories, world-wide and EU25, average 1995-1998

	Average number of new applications, 1995-1998, world	Average number of new applications, 1995-1998, EU 25
Processing	3,284	582
Communication	3,062	886
Storage	628	88
Visualisation	543	104
Sensors	487	88
Printer technologies	400	38
Batteries	355	63
Encryption	81	18
Positioning	17	5
Total IST patents	8,822	1,847

Source: OECD, Triadic Patent Families Database, own calculations

3 Empirical analysis at the level of countries

3.1 IST patents in the Triad

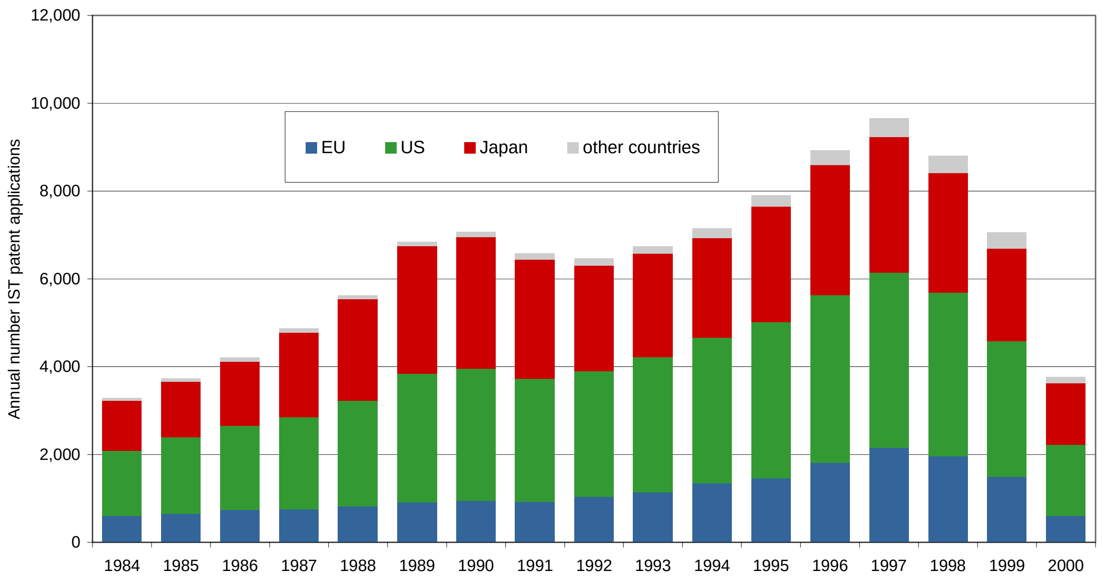
The increasing importance of Information Society technologies is reflected in the growing number of patent applications[2] in this field. The number of patents has more than doubled between 1984 and 1989. There was a decrease in the number of new patents at the beginning of the 1990s, but this slump has been more than compensated during the New Economy boom of the late 1990s. Lower

2 As this study concentrates on competitiveness, we will concentrate on patent statistics that has been compiled according to the ownership of patents, because this view is closely related to the idea of technology as an asset that contributes to the competitiveness of firms. As reference date, we will choose the priority date, which is closest to the invention.

numbers for the years 1998, 1999 and 2000 are due to the reference date of our study; as we count patents by the date of their first filing, and not by the date of granting, which may happen years after the first filing, patents filed in 1998, 1999 or 2000 may have received their grant in 2002, 2003 or are still under examination. The latest patents in the OECD patents dataset refer to 2002, but their number is still very small (about 800 IST patents, compared to 32,000 in 1999).

The number of IST patent applications has been growing steadily in the US, Japan and Europe since the 1980s, with the exception that Japan did not manage to perpetuate its high growth rates of the 1980s in the 1990s (Chart 3). As a result, Europe has overtaken Japan in the number of new IST patents per year and is still ahead. The slump we can see around 1992 can solely be attributed to Japan. Europe, in contrast, could increase the number of new patent applications in each year since 1984. As a result, Europe could raise its share of all patent applications in IST from 10% (1990) to 19% in 1998 at the cost of Japan and the US. If we assume a direct link between technological capabilities and competitive position, we may say that Europe has increased its competitiveness in the field of IST considerably during the last 15 years. All other countries, including Switzerland and South Korea, together apply for no more that 5% of all new patents.

Chart 3: Annual patent applications in Information Society Technologies, 1984-2000

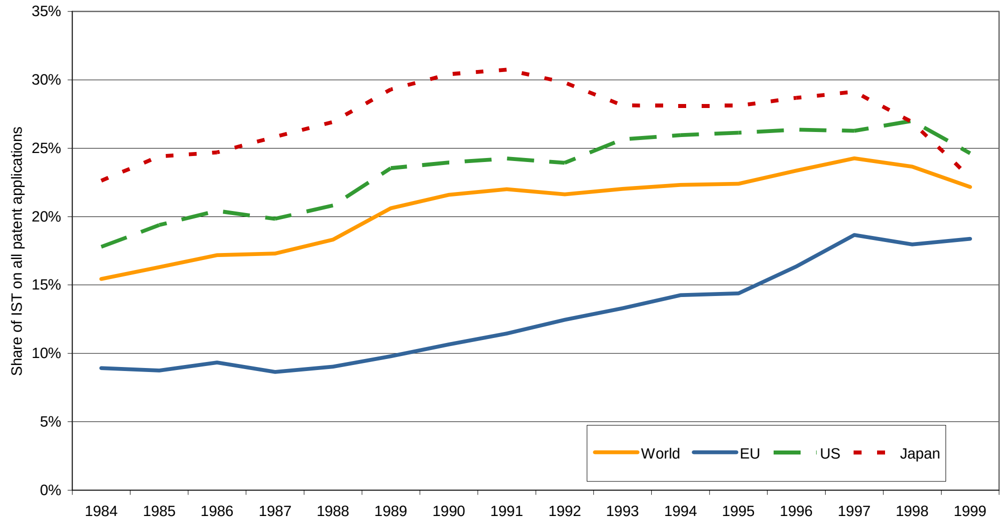


Source: OECD, Triadic Patent Families Database, own calculations

The huge increase in the number of IST patents has also changed the relative weight of IST compared to other technologies in patent applications; IST technologies got a higher share in the technological output of nearly all countries worldwide. As a result, nearly all countries are more specialized in IST at the end of the 1990's than ten or 15 years before (Chart 4). IST patents have raised their share of total patent activity from around 15% (1984) to 24% in 1996 worldwide. In Europe, IST patents account for 18% of all new European Triadic patents in 1998, compared to a share of about 10% in the Mid-1980s. The share of IST patents on all Japanese applications, in contrast, has stagnated from the early 1990s until the late 1990s. The downturn from 1998 on is certainly not a result of a decreasing interest on IST in the research community. These patents refer to grants in 2003 and 2004, and many patents from priority years 2000 are still under examination.

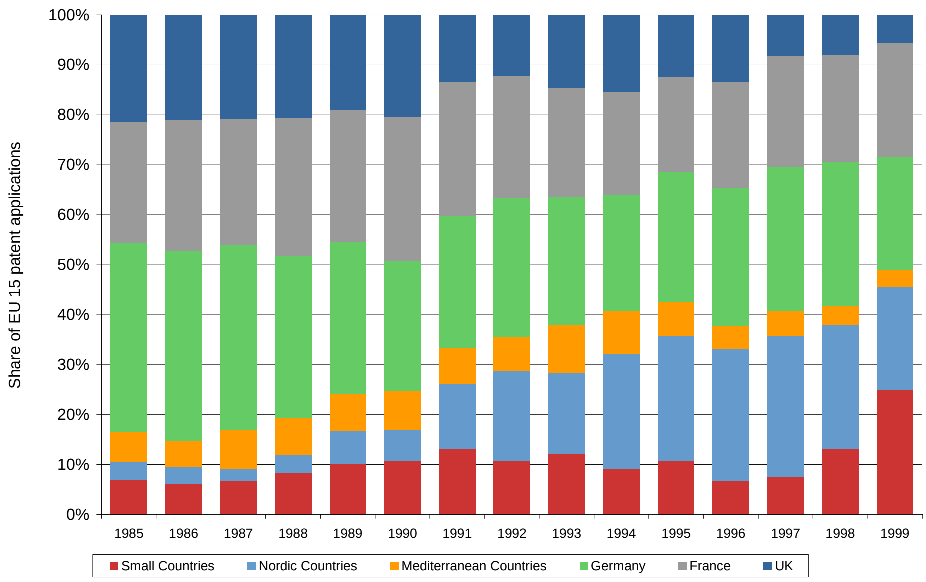
This is a remarkable development, both worldwide and in Europe, because we know from a number of studies that patterns of technological specialisation change only slowly and are very persistent over time. The two German states, for example, although separated for a long period, shared most of their technological specialisation over time: “40 years of division were not sufficient for a differentiated development of the basic specialisation patterns of research” (Grupp and Hinze 1995). The fact that it took such a short period for IST to increase its share on total patent activity considerably shows the remarkable advance of these technologies in their diffusion and may also point to their generic nature that allows applications in nearly every field of modern life.

Chart 4: Share of IST patents on all new patent applications worldwide and in the EU, US and Japan, 1984 - 1998



Source: OECD, Triadic Patent Families Database, own calculations

Chart 5: Share of the member states on all new patent applications in the EU15, 1985 - 1999



Source: OECD, Triadic Patent Families Database, own calculations

The increases of the 1990s, however, were not equally distributed over the member states. We find vast differences in the relative performance: Enterprises in large member countries, with the exception of Germany, increased their number of new IST patents per year considerably slower during the last 15 years than enterprises from small and medium countries (Chart 5). Patent applications in IST have stagnated or even declined in France, Great Britain or the Mediterranean countries (Italy, Spain, Portugal, and Greece).

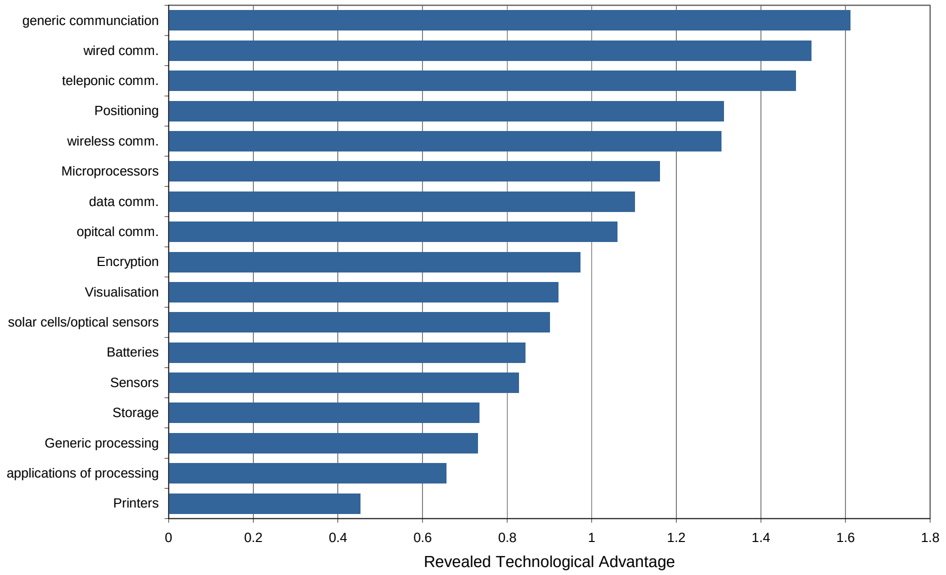
The Nordic and other small and medium countries like the Netherlands, Belgium or Austria, on the other hand, could increase their annual applications considerably. These countries are responsible for Europe's rising share on IST world patents in the 1990s. The share of the medium and small countries on Europe's patent activity increased from its share of 10% in the Mid-1980s to 45% at the end of the 1990s. However, as already noted, the last years should be taken with caution. In contrast, the share of the three large applicant countries UK, Germany and France decreased in the same period from over 80% to a share of 50%.

3.2 Europe's position in various technologies

What were the strengths that led to this catching-up? We will answer this question by calculating Revealed Technological Advantage values (RTA, see annex). The RTA measures Europe's specialisation in relative terms, by relating Europe's specialisation to that of the world. The result of this calculation is given in Chart 6. A value of 1 means that Europe's specialisation measured as the share of IST patent applications on all European patent application corresponds to the world's specialisation. A value of above 1, therefore, indicates a strength of Europe opposed to the world (which are basically the US and Japan), a value below 1 a weakness.

Daily experience already tells us that Europe has a strong position in the field of communication technologies is confirmed by our calculation: Europe's strengths lie in communication technology; processing technologies seem to be the major weakness. Moreover, fields like sensors, batteries, storage, or printing technologies are also weaker than on world average.

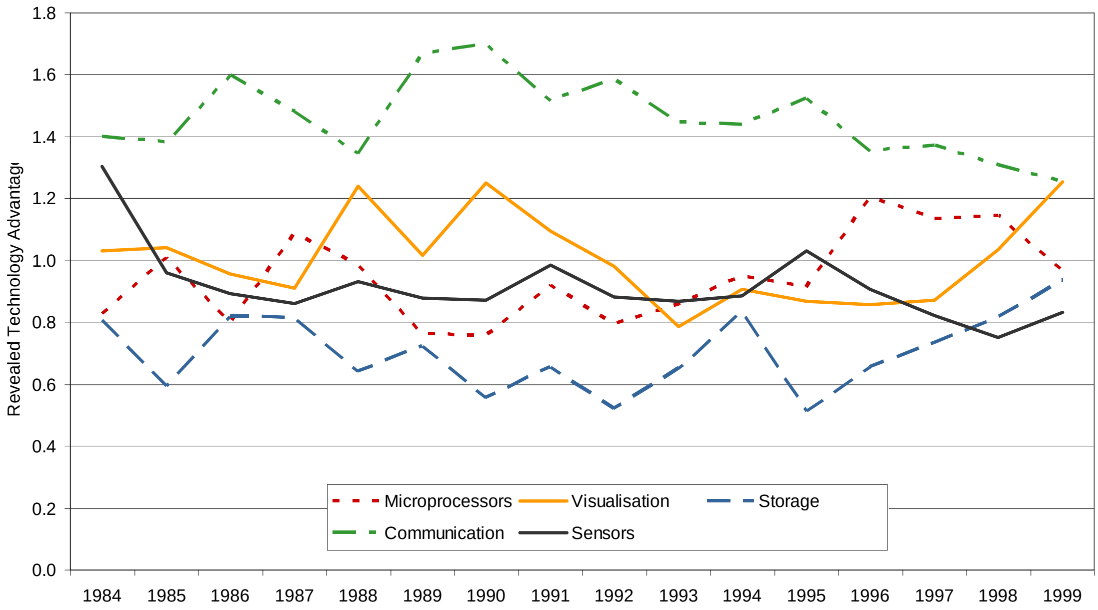
Chart 6: Europe's Revealed Technological Advantage (RTA) in various fields of IST, 1996-1998 average, priority date



Source: OECD, Triadic Patent Families Database, own calculations

Although there have been a number of breakthroughs and new technological paradigms in IST during the past 20 years, the development of specialisation patterns within the different technological trajectories have been remarkably stable, as can be seen in Chart 7. As the number of already granted patents with a priority date after 1998 decreases considerably because many patents are still under consideration, the results for the years after 1998 are less reliable than for previous years.

Chart 7: Revealed Technological Advantage (RTA) of Europe in five fields of IST, 1984-1999 priority dates



Source: OECD, Triadic Patent Families Database, own calculations

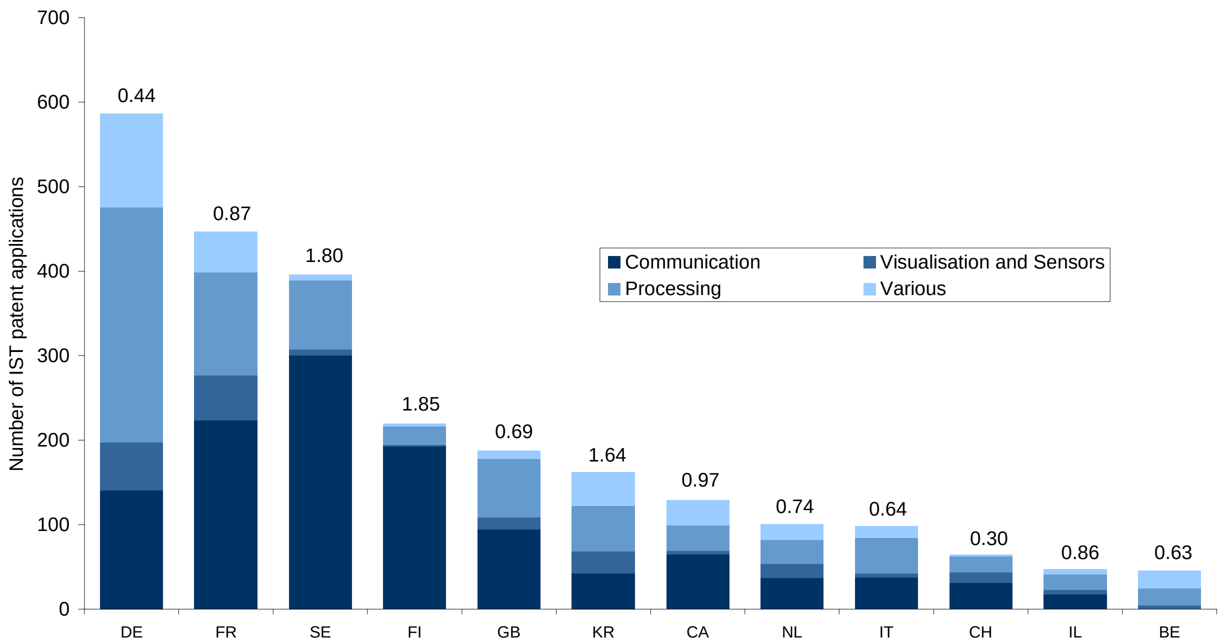
Europe has *always* been good in communication technologies, not just since the beginning of the 1990s. This advantage could be defended and even expandet to the area of mobile communication. Alike, Europe's weaknesses in storage and processing is a persistent phenomenon, which, in the case of microprocessors, has started to change in the last few years only. It would be interesting to examine the contribution of EU policies to this catching up process. In general terms, this observation confirms the argument that tomorrow's strengths will to a large extend build on today's specialisation patterns. This observation is probably one of the best justifications for studying patent data in the context of FISTERA.

Which countries are responsible for Europe's strengths and weaknesses? Chart 8 answers this question by showing the absolute number IST patent applications in 1997 for some European and non-European countries that applied for more than 40 Triadic IST patents in 1997 and a split-up of the absolute sum into main technology categories. Moreover, we also included the RTA value as a measure of the specialisation of a country relative to the world's specialisation in these technologies. RTA measures how specialised is a country in a certain compared to the world.

Not surprisingly, Finland and Sweden, often regarded as the leading IST countries in Europe, are also found among the nations with the highest specialisation in IST in the world. Their RTA is even higher than that of South Korea. But the two Nordic countries also succeed in absolute terms, by having the third and fourth highest number of IST patents in the EU. Finland and Sweden owe their rank to a high degree to communication technologies. Without communication technologies, Finland would probably rank at the level of Italy or Switzerland in the number of new patents. Moreover, we may also assume that a considerable part of the non-communication patents are somehow related to the communication field, e.g. processing technologies applied in data switching, It is a well-known result of innovation studies that the technological competences of firms, measured by patent applications, are often broader than the range of technologies that become manifest in their products (Patel and Pavitt 1997).

It is also worth to notice that beside Finland and Sweden, there is no other country with a RTA above 1 in Europe. This means that all other European countries, except Finland and Sweden, are less specialised in IST compared the world. Europe as a whole had an RTA of 0.75 in 1997. Even Germany, which applies for the largest number of IST patents in Europe, has a quite low value of 0.44, which shows that the country is more specialised in other technologies than IST.

Chart 8: Number of IST patent applications in various fields and share of IST patents on all national applications and RTA value, 1997



Source: OECD, Triadic Patent Families Database, own calculations

Communication technologies are clearly the field where Europe excels Japan in the US. This specialisation also explains the catching up of Europe in the 1990s which is the result of two different trends:

- First, communication technologies are increasing their market share on all IST patents; this share rose from 24% (1984) to 35% (1998), and

- Europe has been highly specialised in these emerging technologies and could enlarge it competitive advantage. Nearly each second European patent in the field of IST applied for in 1997 comes from this field, compared to a share of 32% (US) and 28% (Japan).

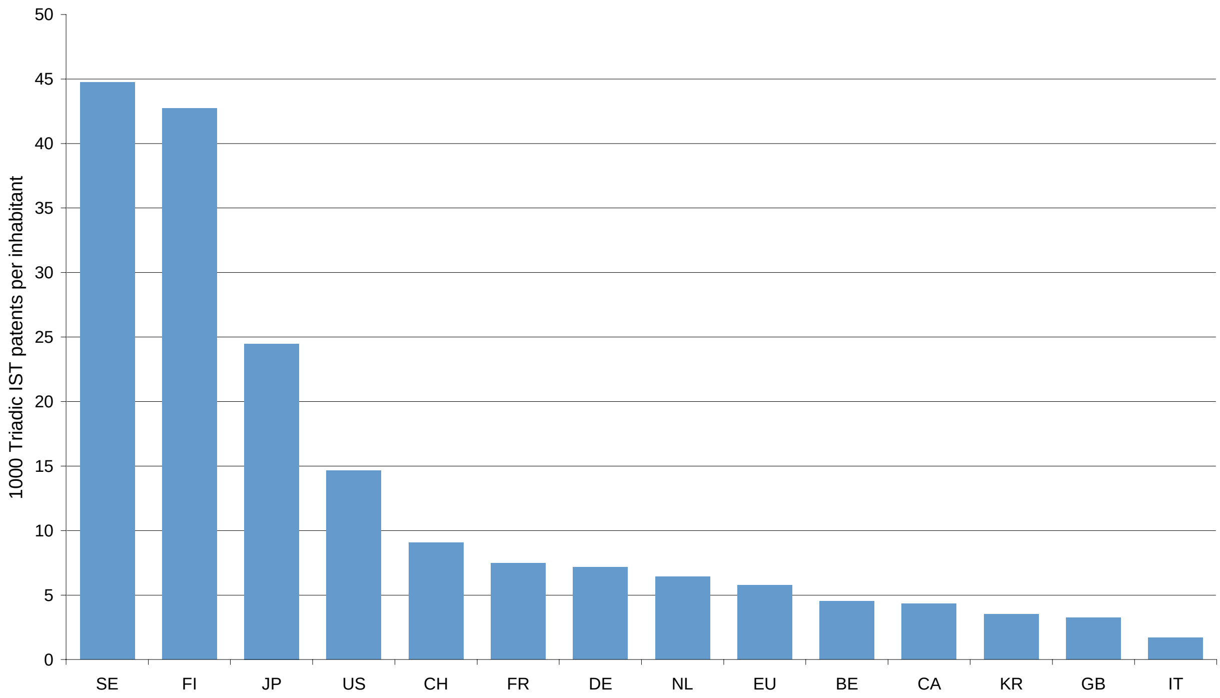
This clearly shows the benefits a country can earn that specializes early on a growing technology area. However, there is also a downside to specialisation that is known as “lock-in” in the literature.

There is ample evidence that patterns of specialisation in a technology are stabilised by institutional, organisational political and other interdependencies. They are thus difficult to overcome although the technologies (and related industries) are already approaching the end of their life cycle. It is of course the wish of every policy maker to support change toward a promising technology/industry. However, the anticipation of future markets from today's perspective remains difficult and uncertain . Foresight and technology road mapping as applied in FISTERA may help to reduce uncertainties, structure future options and create shared visions.

Simply speaking, Europe could gain market shares in IST patenting because European firms were engaged in the right technologies at the right time. But this is not the whole story; Europe's enterprises not only managed to reach a competitive advantage in some technologies, they could also secure and expand their competitive edge. We will come back to this in chapter 4**.**

We can also relate the number of IST patents to the size of the country, as measured by total population or Gross Domestic Product. In this perspective, the high specialisation of Finland and Sweden becomes even more evident. Moreover, it becomes one more time clear that Europe, despite the catching-up in the 1990s, is still behind the US and Japan. Differences between France and Germany are much smaller in this perspective.

Chart 9: Number of IST patent applications related to the countries' population, 1997



Source: OECD, Triadic Patent Families Database, own calculations

Finally, a short remark on the position of the New EU member countries in Middle and Eastern Europe: we found only very few Triadic IST patents possessed by organisations or persons from Hungary, Poland, the Czech or Slovak Republic, Slovenia, Estonia or the Baltic States. These countries only applied for about 50 IST patents since 1990. More patents are found if we look at the number of IST patents *invented* in the New Member countries (NMC): about 100 have been invented by NMC residents since 1990, more half of them are applied by firms from the 'old' EU 15, the US or

Japan. Given their scientific and engineering potential in Information Society Technologies, the NMCs will certainly become very interesting locations for doing research for IST companies. Inzelt (2003) reports for Hungary that enterprises like Nokia, Samsung, or Flextronics have already used a governmental funding scheme to set up research laboratories for large R&D investments in Hungary; the IST sector is second among the sectors who took part in the scheme and there are a lot of other firms who either set up or significantly upgraded R&D facilities without governmental support. For far, however, the fruits of R&D activities have not yet shown up in patent statistics.

3.3 Internationalisation of European R&D in IST

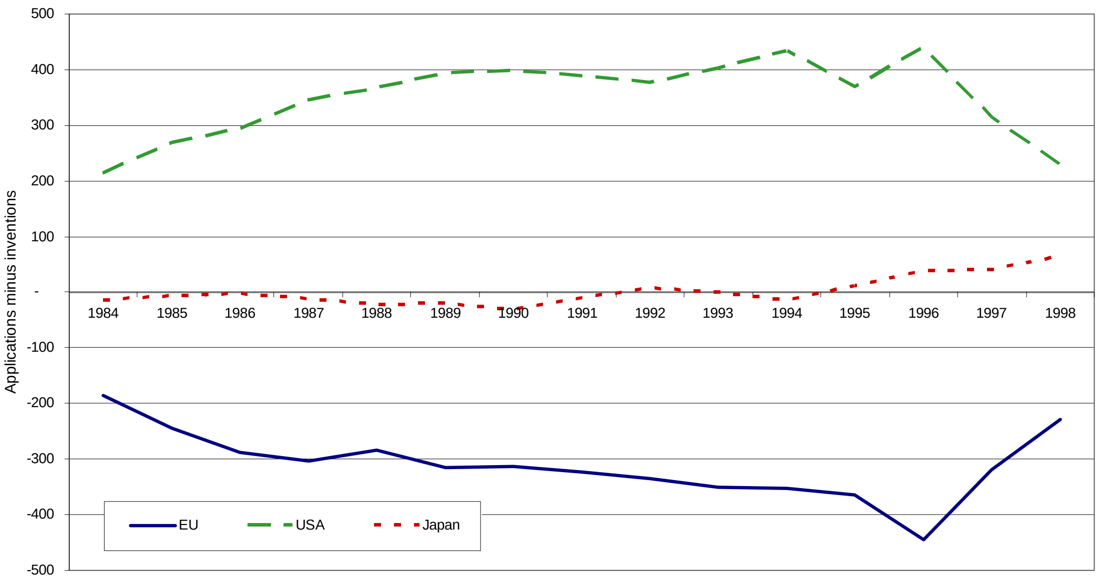
An important trend regarding competitiveness in the field of IST is the internationalisation of research and development. Today, the sources of competitive advantage of enterprises do not lie in their home countries alone, but are spread over a number of locations in different countries. Some areas have become focal points of innovation in a certain field of technology. The most prominent example of such a cluster or high-tech agglomeration in IST is Silicon Valley. Multinational enterprises try to gain access to this localized knowledge by decentralizing their R&D and establishing affiliate research labs in these clusters. Another reason for the internationalisation or R&D activities is the need to support local marketing and production by R&D in the target markets. FISTERA has already recognized the importance of this issue in the context of Human Resources in IST (Mahroum et al. 2004). We will now briefly sketch Europe's position in the internationalisation of IST by patent data following the approach suggested by Guellec and van Pottelsberghe de la Potterie (2001).

Gullec and van Pottelsberghe de la Potterie trace the internationalisation of R&D with patents by comparing the applicant's and the inventor's country of origin. A patent document holds information about the patent inventor(s) (who is always a person) as well as the patent applicant (a person or a firm, see figure 1). In most cases, applicant and inventor are both residents of the same country. In the case R&D is carried out at an affiliate lab outside the home country, they are different, because patents of multinational enterprises are usually applied for by the head office in the home country. If, for example, a patent is has been invented by the Czech affiliate of a German company, we will find a Czech inventor and a German applicant. By calculating the difference between patents applied for and patents invented by persons or firms located in a certain country, we can see if a country is a host country for foreign R&D or if this country has multinational enterprises very active in developing knowledge abroad.

Chart 10 shows the results of this calculation for Triadic IST patents. The chart indicates if one of the regions has a surplus of applications over inventions (positive value) or a surplus of inventions over applications (negative value). It turns out that the number of patents *applied for* by US residents in IST considerably excels the number of patents *invented by* US residents. This surplus is persistent and observable throughout the entire period. On the contrary, a surplus of inventions over applications is revealed for Europe. Japan exhibits slightly more patent applications than patent inventions. In the absence of any other major technology regions in IST in the world (see chart 3) it is clear that the US surplus of patent applications over inventions is the mirror image of Europe's surplus of inventions over applications. The United states, in other words, apply about 300 to 400 IST patents per year that have been invented in Europe. These patents have been most likely invented at affiliate companies of US enterprises in Europe and applied for in the home country. This gap has been stable throughout the 1990s. For the years after 1998 we see it diminishing; however, as illustrated in Chart 3, the total number of patents for these years decreases too, and the closing of the gap may also be a result of the delays between priority and grant of the patents. In the United States, in contrast, the number of patents applied for exceeds the number of patents invented. Due to the fact that Japan's balance is even, there is a constant flow of knowledge from Europe to the US which accounts roughly 25 % of all European patent applications.

We can learn two things from Chart 10: First of all, the chart shows the interrelatedness of Europe and the US in IST research. In this perspective, the image of Europe and the US as two economic powers struggling with each other for predominance in the field of IST is misleading given the magnitude of interdependence. On balance, there is a *net* flow from Europe to the US, but one should be aware that the knowledge flow in the opposite direction, from the US to Europe, is also important. All leading IST companies in Europe have strong ties to US research; Nokia, for example, develops 8% of their patents in the US, Infineon, Ericsson and Thomson 21% and STMicroelectronics even 30% (see Chart 11). Giarratana and Torrisi (2001) show that Europe's largest IST enterprises have considerably more alliances with partners outside of Europe than inside of Europe. These agreements significantly increase the technological competences of European firms.

Chart 10: Difference between the number of Triadic IST patents applied and invented by the US, Europe and Japan, 1984 - 1998



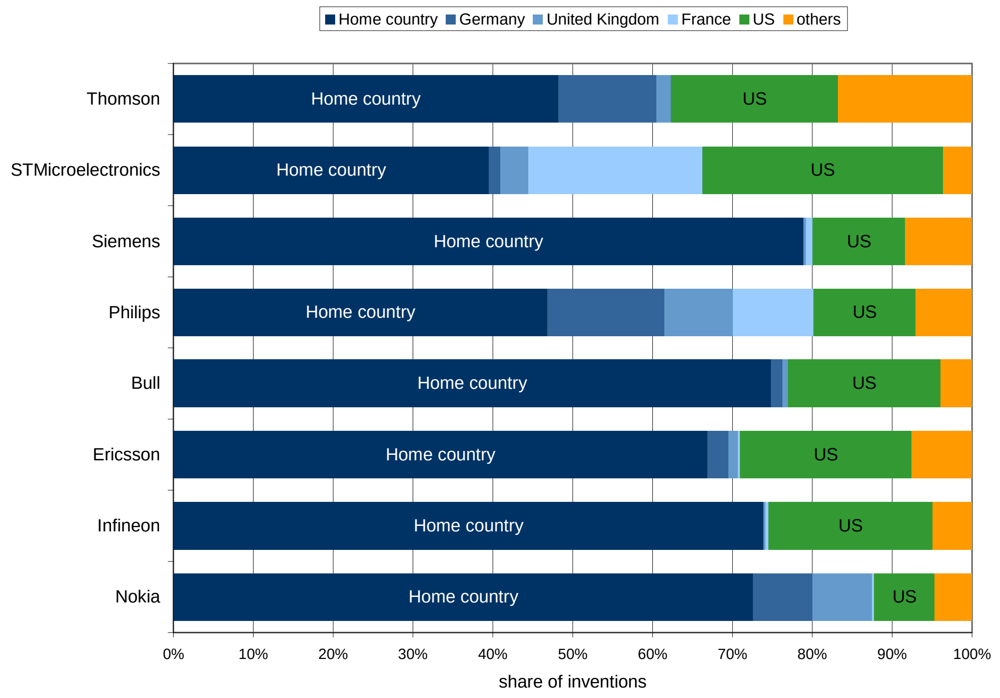
Source: OECD, Triadic Patent Families Database, own calculations

Second, the fact that US enterprises choose Europe as a location for R&D is clearly a sign of Europe's attractiveness for scientific research. According to the data, the degree of foreign engagement is not related to technology involved. We find a surplus of inventions in nearly all technologies, even in fields where Europe is less specialized than the US. However, one may also ask why US, and not European firms commercialize these research results, a topic already discussed in 1995 as the 'European paradox': "Compared with the scientific performance of its principal competitors, that of the EU is excellent, but over the last fifteen years its technological and commercial performance in high-technology sectors such as electronics and information technologies has deteriorated" (European Commission 1995). In this view, we may also interpret the surplus of the US as a sign for the disability of Europe to transfer scientific excellence into innovation.

At the level of countries, the most important host country for research activities of foreign-owend firms is the UK. Moreover, we find large differences between the number of applications and inventions in Germany, the Netherlands, Belgium and Austria. These countries can therefore be seen as important target countries for research-oriented FDI. Austria, for example, has become an important R&D location for German IST firms like Siemens and Infineon; today, considerably more patents are invented than applied for by Austrian residents (Dachs and Schibany 2004). Finland and Sweden, on the other side, are 'net importers' of IST knowledge, as counted by patents. As a result, the number of IST patents *invented* in Finland is considerably lower than the number of patents *applied for* by Finnish enterprises. Finnish firms, most noticeably Nokia, have internationalized their

R&D since the Middle of the 1980s, with the result that a growing share of patents owned by these companies is partly or wholly invented outside of Finland.

Chart 11: Location of inventors of Europe's leading IST enterprises (triadic patent families) 1976-2000



Source: OECD, Triadic Patent Families Database, own calculations

4 Empirical analysis at the actor level

4.1 R&D expenditure in IST at the firm level

We now turn to the level of actors, which, in the case of patenting, are mostly companies. Similar to countries, the innovative efforts of enterprises can be measured at the output and at the input side. Our analysis will again largely rely on patent data to cover the output side of innovation; however, for the largest players in IST we can also present data on R&D expenditure. Taken together, these two data sources give a more comprehensive picture. We can use this data to contrast, enhance and deepen our analysis of the main actors as presented by patent data. Moreover, R&D expenditure has an advantage over patents that it also includes data on the software sector, which is only poorly covered by patent data. As a disadvantage, R&D spending data is only available for the whole company, and not for single technology fields.

Data on R&D expenditure at the firm level is usually provided by the companies' annual financial reports and collected by providers of financial databases or by newspapers in the form of annual firm rankings (like the Fortune 500). One of the best known publishers of such rankings is Technology Review, a monthly journal affiliated to the Massachusetts Institute of Technology (MIT). Another very detailed study which uses R&D expenditure data which has published very recently is the '2004 EU

Industrial R&D Investment Scoreboard' by the European Commission (2004). The Scoreborad provides R&D expenditure data of the top 500 companies with registered offices in the EU, as well as the top 500 companies with registered offices outside the EU. Like all other rankings, data is collected from company reports and published company accounts.

Technology Review (2003), on contrast, takes a more narrow approach and restricts itself to annual research and development spending of the world's top 150 technology companies. The scorecard figures are derived from annual reports and U.S. Securities and Exchange Commission filings for fiscal years ending between June 1, 2002, and May 31, 2003. Therefore, most recent filings could be designated either fiscal year 2002 or fiscal year 2003. Each company has been assigned to one of 11 technology sectors on the basis of its primary business. This means that conglomerates are not split up according to the range of products provided, but assigned as a whole to their dominant technology sector. The ranking includes five sectors which are of interest for FISTERA: computer hardware, computer software, electrical/electronics, semiconductors and telecommunication.

We will first look at a ranking of the absolute size of R&D budgets which are given by tables 2 and 3. The company with the largest R&D budget is Siemens, followed by IBM and Matsushita. However, it has to be noted that these figures relate to R&D spending of *all* sectors of these companies; a split-up in single fields of technology is not available from this source[3].

Microsoft, a software company, follows on 4th place. This is surprising, given that Software development is less research-intensive on average. Beside Siemens, there is only one other European IST enterprise, Ericsson, in the Top 10, and three others, Philips, Nokia, and Alcatel are following at the places between 10 and 20.

Table 2: R&D spending of the largest companies in IST, fiscal year 2002-2003

			R&D Spending		
Rank	**Company**	**Country**	**Latest Year (Mio. $)**	**% Change From Prev. Year**	**$ per employee**
1	SIEMENS	Germany	6,173	-14.2	14,491
2	IBM	USA	4,754	2.9	15,050
3	MATSUSHITA ELECTRIC	Japan	4,599	-2.6	15,951
4	MICROSOFT	USA	4,307	-1.6	85,287
5	HEWLETT-PACKARD	USA	4,105	53.7	29,113
6	INTEL	USA	4,054	1.5	51,512
7	MOTOROLA	USA	3,766	-13.6	38,825
8	SONY	Japan	3,698	2.3	22,957
9	CISCO SYSTEMS	USA	3,513	-26.5	97,583

3 A number of companies provide a brakedown of their R&D expenditure on tiehr webpages; Siemens, for example, reports that more than 55% of their R&D expenditure is related to information and communications and automation and control technologies., see http://www.siemens.com/index.jsp?sdc_p=pFEcfi1182518lmn1182521o1182521s7t4u20z2&sdc_sid=3163612394&

10	ERICSSON TELEFON	Sweden	3,399	-37.1	52,596

*Data are for fiscal years ending between June 1, 2002, and May 31, 2003; Source: Technology Review

A different way to rank R&D spending of enterprises is to relate them to the size of the company measured by total staff. We did this in the last column of Table 2 and 3. With the exception of Microsoft, which is also a big player in absolute terms, the large IST conglomerates like IBM, Siemens or Philips show only low intensities. The most highly ranked European enterprise according to R&D spending per employee is Nokia on the 22nd place with an annual total expenditure of 62,567 $ per employee.

Table 3: R&D spending of the largest companies in IST (cont.), fiscal year 2002-2003

			R&D Spending		
Rank	**Company**	**Country**	**Latest Year (Mio. $)**	**% Change From Prev. Year**	**$ per employee**
11	NIPPON TELEGRAPH & TELEPHONE	Japan	3,305	1.3	15,937
12	PHILIPS ELECTRONICS	Netherlands	3,241	-7.8	19,054
13	NOKIA	Finland	3,238	2.2	62,567
14	HITACHI	Japan	3,148	-9.2	9,821
15	TOSHIBA	Japan	2,767	1.6	16,689
16	NEC	Japan	2,472	-11.2	16,957
17	FUJITSU	Japan	2,385	-18.3	15,186
18	ALCATEL	France	2,361	-22.4	31,096
19	LUCENT TECHNOLOGIES	USA	2,310	-34.4	49,149
20	NORTEL NETWORKS	Canada	2,281	-35.0	61,713

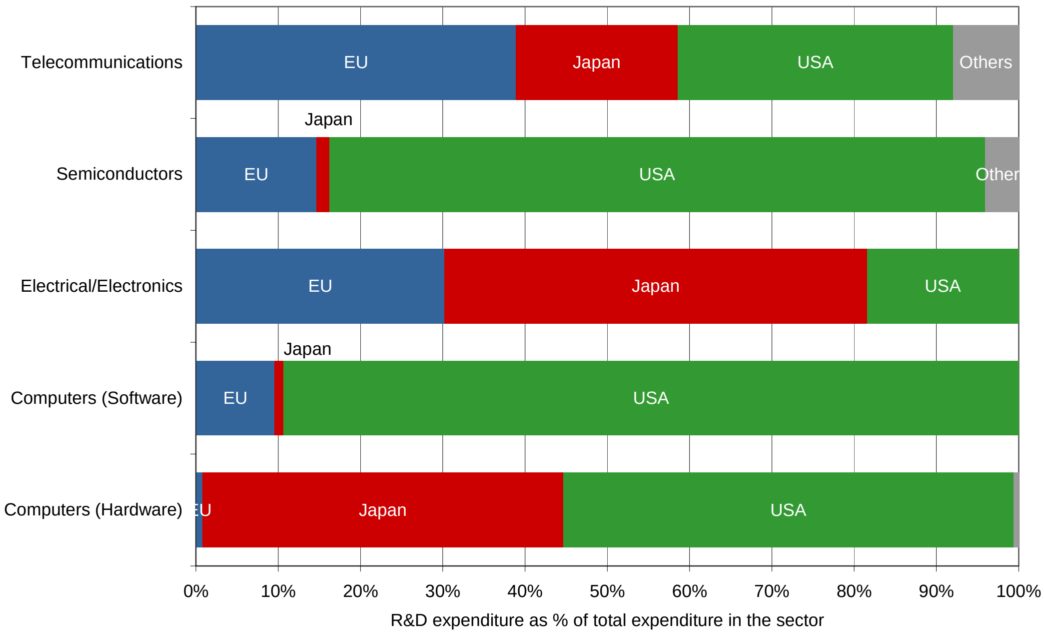
Data are for fiscal years ending between June 1, 2002, and May 31, 2003; Source: Technology Review

The lagging behind of European enterprises in the general ranking with respect to R&D intensity is mainly a result of the sectoral composition in IST, and not a sign of weakness. European enterprises are more often found in telecommunications than in semiconductors. Semiconductors, however, show a higher R&D intensity than telecommunications. Compared to their sectoral peers, they exhibit a R&D intensity equal or slightly below sectoral average.

Finally, we look at the level of sectors. The importance of European actors varies considerably at this level. In a Triadic perspective, Europe’s share on total R&D spending varies between 40% in tele-communications and 1% in computer hardware (Chart 12). A ranking of enterprises per sector is given in the annex.

Europe’s position at the sectoral level is weakest in *Computer Hardware*, where only one enterprise, OCE[4], managed to enter into the Top 20. A similar situation is in *Computer Software*, with the exception of SAP as the only, but well-positioned player among the enterprises with the highest R&D spending. Things look better in Electronics with Siemens as the ranking leader and five other enterprises in the Top 20. European enterprises are also surprisingly strong in *semiconductors*, which is usually regarded as a domain of US enterprises. *Telecommunications* is the well-known strength of Europe, and enterprises like Ericsson, Nokia or Alcatel are among the Top 10 in this field. But Europe’s R&D strengths in telecommunications lie not only in telecom hardware, but also in services, as shown by the Scoreboard of the European Commission (2004) which has a separate section for this sector. NTT is the telecom service operator with the highest R&D budget in the world, the next three are Deutsche Telecom, France Telecom and British Telecom.

Chart 12: R&D expenditures according to Technology Review R&D Scorecard, 2003



Source: Technology Review

“True” European world champions in the IST world, to sum up, are Siemens, which has one of the highest IST R&D budgets of all enterprises in the ranking (even if the company is also engaged in other fields), Philips, SAP, which competes with Oracle for the 2nd place in Software (but is out of reach of the first place, which is held by Microsoft), and the Nordic telecommunications companies Ericsson and Nokia. However, it has to be noted that the sectoral classification may be too rough in some cases, like for large conglomerates like IBM, Siemens, or Philips, which are active in a number of fields.

4.2 Actors in information society technologies

We now turn to the level of actors. Patents have the advantage of delivering direct information on actors, as they protect their property rights. This allows us to answer important questions regarding actors in Information Society Technologies, such as:

4 OCE, however, is not a pure Computer Hardware Comany but also a producer of photocopy machines.

- Who are the main actors in various technologies? Do they change over time?

- How is the “actor space”, the total population of active organisations in our data, structured? Is it dominated by a number of enterprises, or is there a change over time

- How is the position of European firms compared to their US and Japanese competitors?

We will first have a look at the main actors. We calculated the 25 largest applicants of patents in IST for the period before 1980, 1980-89, 1990-94, 1995-1999 and for all patents in the database with the priority year 2000 and later (see annex). The first surprising fact, given the pace of technological change in IST, is the relatively low number of companies in the table. Altogether, the Top 25 for all five periods consists of only 52 enterprises, which means that each enterprise is on average 2.5 times in the Top 25. Some of these enterprises are related to each other like Siemens/Infineon, Thomson-CSF/Thales, Thomson/SGS Thomson/STMicroelectronics or AT&T Bell Labs/Lucent; this reduces the number of central actors even further. Ten enterprises are among the Top 25 in all five periods: IBM, Fujitsu, Matsushita, Hitachi, Xerox, Philips, AT&T Bell Labs/Lucent, Siemens/Infineon, Tokyo Shibaura/Toshiba and Thomson/SGS Thomson/STMicroelectronics.

The years before 1980 are characterized by the technological dominance of IBM; IBM developed a quarter of all patents invented in IST, never again was a single enterprise so dominant. The small size of the actor space these days can be seen in two details: the Top 25 hold a share of 67% of all patents which was never reached again. Moreover, a number of companies that today are not associated with IST like Du Pont or Hoechst entered the Top 25

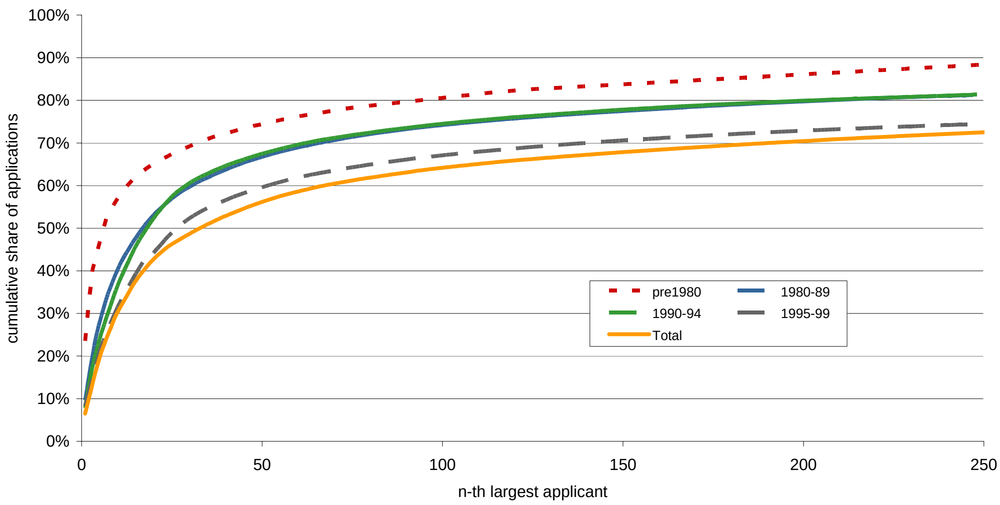
IBM could hold its position as technology leader for the two following periods, but the challenge by other companies is becoming to grow with the beginning of the PC era in the 1980s as IBM’s share is shrinking. Important players that entered the field are Sharp, Sony, Hewlett-Packard or AMD. Other important entrants in the early 1990s are Ericsson and Nokia. The rise of telecommunications in the 1990s has broadened the actor space considerably, as can be seen in the decrease of the cumulative share of the Top 25.

In the late 1990s the IST world is becoming increasingly ‘European’ which is, as already shown, a result of increasing importance of communication technologies as well of the active and at least partly politically driven processes of “catching up” in the 1990s. In the period 1995-1999, Philips took over the top position of the ranking. Moreover, seven out of the Top 25 were European companies. At the ranks 10 to 100, however, European enterprises are much less frequently listed than their US and Japanese competitors. For the period 1995-1999, only three enterprises at the ranks 20 to 50 and six enterprises at the ranks 50 to 100 are European. European companies are well-represented in the ‘premier league’ of IST; what is missing, however, are European enterprises in the first and second league.

The evolution of the IST industry over the last 30 years as illustrated by the Top 25 enterprises can also be measured and described by the distribution of the cumulative share of a number of applicants on all patents. Investigations of the size distribution of patent applications have constantly revealed two propensities: high concentration, which means that a small number of enterprises possess big share of all patents, and a ‘fat tail’ distribution, which indicates a very large number of small applicants. We can also observe these two characteristics in IST patents (Chart 13):

- First, patenting is highly concentrated: a very small part of the population accounts for the majority of the patents. Chart 13 exhibits the ‘screwness’ of the distribution: half of *all* patents applied for between 1976 and 2002 are owned by only 33 companies. The 1,000 largest patent owners cover already 83% of all inventions ever patented in IST. We can cover the vast majority of all patents in IST by looking at the 1,000 largest applicants. However, there are many more applicants than these. This high concentration reflects the advantages of large companies for technology development: Large companies have the financial power for long-term research activities that constantly yield new technologies over a long period, and the market power to turn new scientific discoveries into products. Some research projects may require a certain minimum scale to be carried our effectively. The more diversified a company, the higher is the chance to find an application for new scientific knowledge. However, we see that the screwness diminishes with time. Moreover, the remarkable stability of composition of the group of leading IST enterprises exhibits a high ability to cope with technological change and react and adapt to technological disruptions.

Chart 13: Cumulative distribution of the applicants' shares of total IST patenting, 1965-2002 priory date



Reading aid: Distribution of total applicants: the largest applicant accounts for 6% of all patent, the second largest together with the largest accounts for 10%, the 33 largest applicants together account for 50% etc.

Source: OECD, Triadic Patent Families Database, own calculations

- As a second characteristics of the actor space in many technologies, the kind of distribution shown in Chart 13 exhibits a 'fat tail', which means that there is a very large number of applicants with only very few patents. 80% of all patents in IST are applied by only 630 organisations; if we want to increase the coverage to 90% of all patents, we would have to include 3,190 applicants, 95% relates to 8,100 different applicants. A certain part of these small applicants can be attributed to firms which went bankrupt, were taken over by other companies or simply by typing errors in the patent files. However, even if we clear these cases, a very large number of small applicants remain. Their number reflects the importance of individual inventors and entrepreneurs in a certain technology and the chances of entering this field of technology. If the knowledge base in a sector has strong cumulative characteristics and requires a certain minimum scale of research activity, the number of small applicants may be lower. Given the number of new technological trajectories which have emerged in the last 30 years (the PC, Client-Server environments, the Internet …), cumulativeness in IST seems to be rather low: therefore, the high number of small applicants is not surprising.

4.3 Actors in semiconductors and processing technologies

Semiconductors are, beside communication, the key technology within IST. Most obvious is the presence of semiconductors in processing, where it is the key technology for manufacturing of microprocessors. Progress in this field, as described by Telecom Italia's WP 2.1 report (Saracco et al. 2004), is continuing towards miniaturisation, increasing processing speed and a ever decreasing price-performance ratio. Embedded Systems, System on a Chip, MEMS are approaches to go beyond these trajectories and enlarge the functionalities of microprocessors with radio frequency etc. Moreover, developments in semiconductor technology have driven major technological advances in other fields as well: flat screen technologies like LCD (Liquid Crystal Display) or OLED (Organic Light Emitting Display) have already or are expected to replace older display technologies like CRT (Cathode Ray Tube). Semiconductor technologies are also the key to some storage (DRAM) or energy technologies (solar cells) or concepts like Ubiquitous Computing and Wearables which require miniaturized, energy-saving processing power.

How well are European enterprises positioned in this important field of Information Society Technologies? Triadic patent data exhibit a surprisingly high share of European applicants in processing, as already indicated by an increase in the RTA during the 1990s in Chart 7. At the level of actors, we find three European enterprises in the Top 10 since 1990 with Siemens/Infineon leading the ranking (Table 4). One large player we know from the figures on R&D expenditure is missing: Intel did not enter into the Top 10. Intel of course patents a lot in semiconductor technologies and processing: however, Intel seemed to have applied for patents predominantly in the US during the 1990s, and not in Europe and Japan. According to a ranking of the most active companies at the US Patent and Trademarks Office (USPTO) compiled by MIT's Technology Review (2004), Intel was the second-largest player in semiconductors by patents *granted* in 2003, only excelled by Micron Technology. The case of Intel shows most strikingly the limitations of the measurement of innovative activity and competitiveness with patent data. A balanced approach using Triadic patent data is less effective if the most important player decides to concentrate its patenting activities on the US, i.e. on the dominant market in the world only. A similar result would come out if the analysis of Europe's strengths in communication technologies would only be based on patent data by the European patent office.

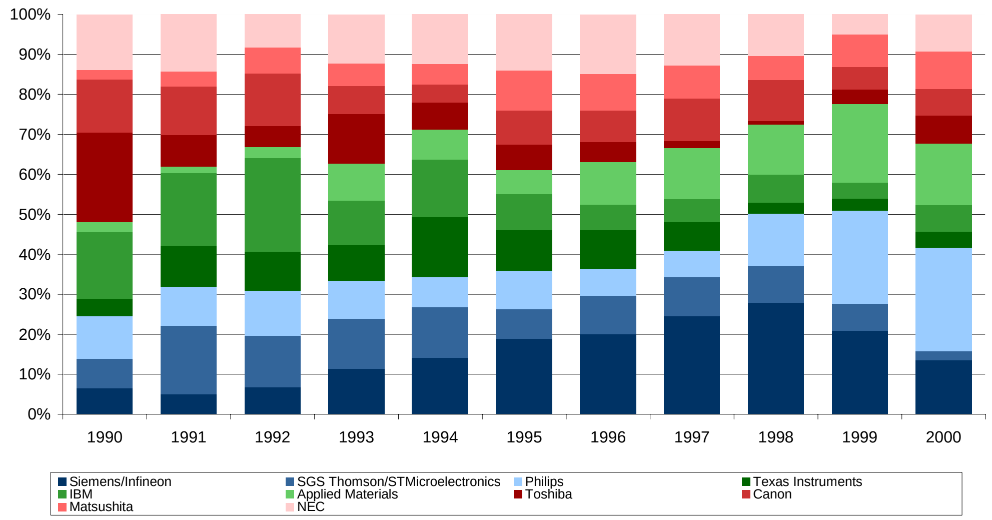
Table 4: Top 10 applicants in Semiconductors, triadic patent applications, 1990-2002 priority date

Company	No. of patents 1990-2002
Siemens/Infineon	686
NEC	506
Philips	495
IBM	471
SGS Thomson/STMicroelectronics	432
Canon	400
Applied Materials	390
Texas Instruments	348
Toshiba	318
Matsushita	306

Source: OECD, Triadic Patent Families Database, own calculations

In a global perspective as provided by Triadic patent data, the three European companies could considerably enlarge their share from 1990 to 2000 at the cost of Japanese and, to a smaller degree, US companies (Chart 14). Especially Siemens and Infineon increased the number of patents. The good performance of the large European players, however, is somehow misleading because beyond the Top 10 Europe is only weakly represented. We find only four other European organisations in the Top 50. Two of them are public research organisations: Commissariat a l'Energie Atomique (CEA) – presumably the LETI research lab - and Interuniversity Microelectronics Center (IMEC). Their research activities have been analyzed in a separate FISTERA report (Dachs and Zahradnik 2004) Their presence shows that it is possible for public research labs to operate successfully in a field that is dominated by R&D of large corporations.

Chart 14: Patenting in Semiconductors: Share of the Top 10 applicants, 1990-2000 priority date, triadic patent applications



Source: OECD, Triadic Patent Families Database, own calculations

A look at other fields of processing is less promising. Again, Philips is well-positioned, but only one other European company could enter the Top 10. Siemens/Infineon is at the 12th place. The presence of US enterprises in this field, however, is impressing. Again, there may be some major US competitors missing which exhibited high R&D spending.

Table 5: Top 10 applicants in Processing excluding semiconductors, triadic patent applications, 1990-2002 priority date

Company	No. of patents 1990-2002
IBM	1,966
Philips	991
Sun Microsystems	826
NEC	777
Hewlett-Packard	542
Sony	541

Matsushita	539
Canon	526
Fujitsu	508
SGS Thomson/STMicroelectronics	385

Source: OECD, Triadic Patent Families Database, own calculations

The level of concentration in semiconductors and processing, measured by the share of the Top 10 on all patent applications is comparable to that in IST in general and in other fields of IST. The 10 largest companies hold a share of 39% of all patents applied for in semiconductors and 36% of all patents applied for in processing in the 1990s. A share of 80% is reached with 134 organisations in semiconductors and 297 organisations in processing which means that concentration rises slower in processing and the number of actors may be higher in this field. However, as shown above, small actors did not succeed to gain considerable influence in terms of patent applications either.

4.4 Actors in communication technologies

Europe's position in the field of communication technologies is strong, as indicated in Chart 7. Europe was lucky to be "at the right place at the right time" in the 1990s, being specialized in a rising field. Europe's strength however sees to have diminished in recent years although Europe's leading firms still account for about 40% of the R&D spending of the world's largest companies in this field Chart 12).

Not surprisingly, we find the same enterprises from the ranking of R&D spending in tele-communication again in the Top 10 places of patent activity. Most companies are hardware manufacturers, but we also find telecom operators, like NT&T (14th place), British Telecommunications (21st place) or France Telecom (33rd place). Four European enterprises are in the Top 10, Siemens follows at the 16th place.

Table 6: Top 10 applicants in communication technologies, triadic patent applications, 1990-2002 priority date

Company	No. of patents 1990-2002
NEC	337
Bell Labs/Lucent Technologies	281
Ericsson	270
Alcatel	240
Matsushita	193
Nokia	185
Philips	143
Motorola	129
Sony	126

Qualcomm	122

Source: OECD, Triadic Patent Families Database, own calculations

We also analyzed two sub-fields of communication technologies, mobile communication and data communication. Mobile communication refers to various types of technologies and transfer media like near-field transmission systems, radio transmission systems, infrared, and aerials, data communication includes data switching networks etc.

Table 7: Top 10 applicants in mobile and data communication, triadic patent applications, 1990-2002 priority date

Mobile Communication		Data Communication	
Company	**No. of patents 1990-2002**	**Company**	**No. of patents 1990-2002**
NEC	337	Bell Labs/Lucent Technologies	292
Bell Labs/Lucent Technologies	281	IBM	288
Ericsson	270	Ericsson	245
Alcatel	240	NEC	241
Matsushita	193	Philips	228
Nokia	185	Alcatel	165
Philips	143	Fujitsu	147
Motorola	129	Sony	134
Sony	126	Matsushita	132
Qualcomm	122	Nokia	128

Source: OECD, Triadic Patent Families Database, own calculations

European companies are among the leading players in both fields, but not at the top, as can be seen in Table 7. It is interesting to see that European companies are also strong in data communication, as a number of US or Asian enterprises like Cisco are engaged in this field. Data communication technologies, however, are closely related to other forms of communication and share a large number of generic functions like switching, error correction. Therefore, enterprises that succeed in one field may also have competencies in neighbourhood technologies.

4.5 Actors in storage technologies

Finally, we want to have a look at storage technologies, which encompass a number of technologies from silicon storage (ROM, DRAM), to recording by magnetisation or demagnetisation and recording or reproducing by optical means. The topic touches also on neighbouring fields like consumer electronics which in the field of recording - cannot be distinguished from data storage. Therefore, it is not surprising to find some well-known producers of entertainment equipment next to semiconductor manufacturers in the ranking. Sony is the most innovative enterprises in this field, measured by the number of patents between 1990 and 2002. European enterprises are again well-positioned in the ranking; however, only three other European enterprises (Infineon, Siemens[5], Thomson[6]) could enter the Top 20.

Table 8: Top 10 applicants in mobile and data communication, triadic patent applications, 1990-2002 priority date

Company	No. of patents 1990-2002
Sony	522
Matsushita	367
NEC	352
Philips	341
IBM	330
Fujitsu	301
Toshiba	281
Sharp	206
SGS Thomson/STMicroelectronics	290
Pioneer Electronic Corp.	170

Source: OECD, Triadic Patent Families Database, own calculations

If we divide storage technologies into 'moving' storage (hard disks, optical storage) and static storage (DRAM, ROM), we find two separated groups of actors; on one hand manufacturers of semiconductors like NEC, Toshiba, ST Microelectronics or Infineon and, on the other hand, enterprises like Sony, Matsushita, Philips, or Pioneer Electronic from the 'moving' storage sector. IBM is the only enterprise that bridges both technologies.

4.6 Actors in some emerging technologies

In this section, we will take a look at some example technologies that are still in the phase of emergence and for which patent data could be interpreted as weak signals of growing levels of activity, and this in spite of the time lag that is characteristic of patent data. Telecom Italia Lab's work has identified some emerging technological trajectories that have not yet reached the stage of commercialisation and diffusion in enterprises and households. From this list, we will have a look at the examples of speech recognition, the utilisation of quantum effects in IST (quantum computing and quantum encryption), optical computing, or holographic imaging.

5 here, we did not unify the data for Siemens and Infineon because Siemens proceeded patenting in this technology after the Infinion became an independent company.

6 These are the entertainment product activities of Thomson

Man-machine interaction by natural speech is an often announced feature of software which, however, has not yet reached its full functionality or even a wide diffusion. We find the first patent applications in this technology in 1978. However, patent activity in this technology was only moderate in the 1980s and early 1990s and increased considerably from the 1993 on. So far, about 900 patents have been applied for in this technology area.

The company with the largest stock of patents is Philips, followed by Lucent and NEC. If we go down the ranking, we find that the actor space in this technology consists of three types of companies; first, large diversified technology conglomerates like Philips, NEC and IBM which are already well-known from other technologies; second, enterprises from the telecom sector like Nokia BT or Qualcomm, which indicates that the actors in mobile communication pay a lot of attention to this technology. The third group active in speech recognition are enterprises from the avionics/defence sector. Examples are Sextant Avionique, a part or the French Thales Group, or Rockwell.

Table 9: Top 10 applicants in mobile and speech recognition, triadic patent applications, 1990-2002 priority date

Company	No. of patents 1980-2002
Philips	55
Bell Labs/Lucent Technologies	44
NEC	43
Matsushita	34
Sony	32
Canon	23
IBM	21
British Telecommunications	20
Nokia	20
Qualcomm Inc.	20

Source: OECD, Triadic Patent Families Database, own calculations

A comparable case is *holographic imaging*. There are only a few early patents from the 1970s and early 1980s, and patenting in holographic imaging did reach a first peak in the late 1980, but it followed a lower number of applications in the following years. Hughes Aircraft (acquired by General Electric in the 1990s) seems to have worked intensively on holograms in this time, because the vast majority of patents from these years can be attributed to this company. Altogether, Hughes Aircraft is the largest patenting company in holographic imaging form the 1980 until recently. Hughes' last priority dates from 1994.

In the second half of the 1990s we can see a lower level of patenting activity. It seems that Hughes gave up research in this area. Others followed, like printing companies (Dai Nippon Printing, Toppan Printing), but also some well-known, large multi-technology enterprises like Fujitsu, IBM, Sony, Thomson, etc. Holographic imaging is a good example for the fact that the technology portfolios of large enterprises are much more diversified than the product portfolios (Patel and Pavitt 1997). Beside the companies already mentioned, we also find patents in holographic imaging by Matsushita, Canon, NCR, NEC, Siemens, Sharp, Xerox, Ericsson, and Sun Microsystems. A similar strategy – being present, but not at an intensive level – seem to follow large chemical companies in holographic imaging like Du Pont, Merck and Ciba-Geigy. Research in holographic imaging by these companies seems to have the purpose of watching and absorbing knowledge rather than pushing scientific progress.

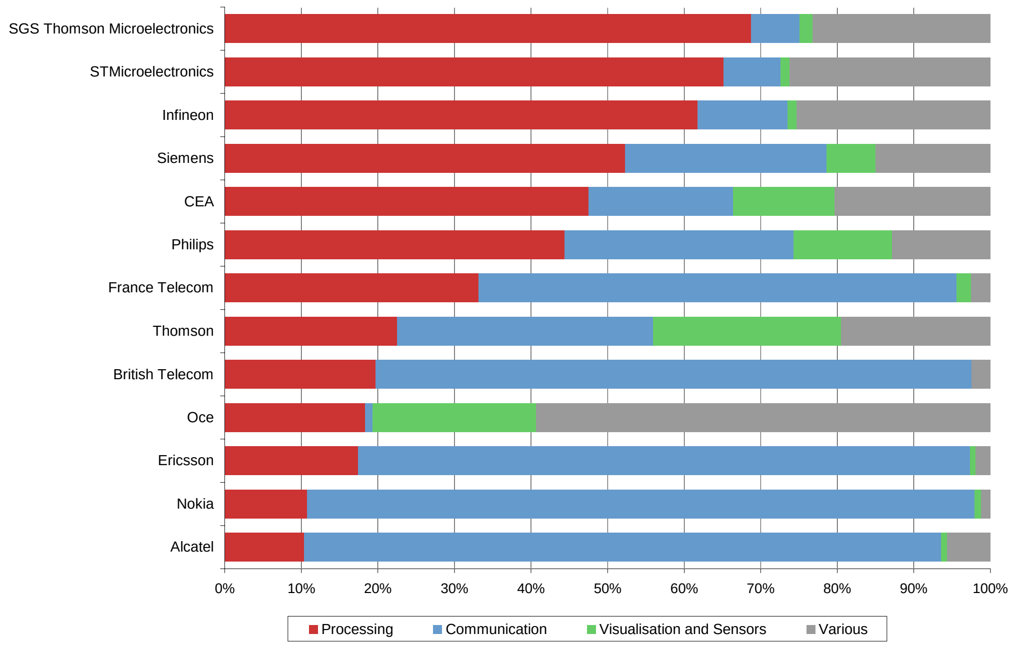
The International Patent classification knows a separate class for optical computing devices where at least one computing function is performed by optical means (G06E), however, only 49 Triadic patent applications have been made so far, which indicates that this technological trajectory is still in the very beginning. Moreover, the figures indicate that research on *optical computing* devices had its peak in the late 1980s/early 1990s (1989: eight applications; 1990: six applications) and interest in this topic seemed to weaken in recent years. The main players in this small field are beside the well-known IST conglomerates, aircraft manufacturers like Hughes Aircraft, Gumman Aerospace, or Boeing.

The utilisation of *quantum effects* seem to play a certain role in semiconductors or devices for the emission of wave energy like masers, in computing, however, we found only two patents that refers to the use of quantum effects in computing, the applicants are Hitachi (they applied for a patent on a "quantum computer") and Sun Microsystems in co-operation with the US Army. Quantum cryptography is found six times in patent files; active in this field are British Telecommunications, the Scripps Research Institute, Swisscom and France Telecom.

4.7 Core competencies of Europe's leading IST companies

Finally, we try to explore what the core competencies of some of Europe's leading IST companies are. Multi-technology conglomerates like Philips, Siemens or Thomson have showed up in more than one ranking presented in the preceding chapters. Even enterprises that seem to concentrate on some 'core' products maintain a comparatively broad technological portfolio. Ericsson and Nokia are engaged in some of the emerging technologies described in chapter 4.6. Here, we may ask what the 'true' core competencies of these companies are. We try to answer this question by breaking down the patenting activities of Europe's leading IST enterprises into technological fields (Chart 15).

Chart 15: Share of various technological fields on the total patenting of Europe's leading IST companies, 1990-2002, Triadic patent applications



Source: OECD, Triadic Patent Families Database, own calculations

It turns out that even dedicated telecommunication enterprises like Nokia and Ericsson have competencies in fields other than communication technologies, like processing. Vice versa, also ST Microelectronics or Infineon hold patents in communication technologies. The portfolios of conglomerates like Philips, Thomson or Siemens consist of a number of different fields with no 'core' in the sense of one predominant technology. There may be two reasons for this behaviour which looks like contradiction to advice for concentration: first, there is a considerably interdependence between various technologies and products that may require a broad portfolio; as a manufacturer of switches, Ericsson needs also considerable processing competencies. At a lower level, the convergence between technologies like data and speech communication may favour a broader portfolio. A second argument in favour of a lower specialisation in the field of IST is that new emerging technological opportunities and disruptions as described by FISTERA's WP 2. Large enterprises constantly monitor technological developments even in fields they are currently not active in but which may become future business opportunities. These technologies may have a very small share on today's patent portfolios, but this may change in the future. Good examples are the emerging technologies described in 4.6

Summary and Conclusions

This study has presented evidence on the strengths and weaknesses of Europe in IST at the country and the company level. We analyzed patent and R&D spending data. The main findings are:

- Europe is still behind the US and Japan in terms of the share of IST in overall patent activity, but Europe has gained momentum in the 1990s. Catching up was to a significant extent due to a favourable position in one growing technology area, i.e. communication, but. Europe's specialisation in processing technologies has also increased considerably. This success could even be interpreted as being at least partly due to the active role EU policy has taken in these areas a few years before. Specialisation in visualisation, storage, sensors, and other technologies, however, is still low.

- At the level of countries, we find that the catching up of Europe was mainly due to the small and medium-sized countries in the European Union. The number of IST patents in France and the UK grew slower than in the Nordic countries, the Netherlands or Belgium. Germany is still the largest single applicant country.

- The development of new IST is highly 'globalized'; leading European companies invent between 30 and 70% of their IST patents outside of their home countries, a considerable share in the US. On the other hand, the number of patent inventions by Europeans is higher than the number of patent applications, which indicates a strong presence of R&D by US firms in Europe. One can estimate that there is a constant flow of knowledge from Europe to the US which accounts roughly for about 25% of all European patent applications.

- Concentration is high in IST; on a worldwide scale, a relatively small number of large players dominate the IST world in terms of the number of patent applications. Half of all patents applied for between 1976 and 2002 are owned by only 33 groups of companies. Over the last 30 years, the composition of this group has been remarkably stable.

- Europe's leading IST companies are all well-known: Philips, Nokia, Ericsson, Thomson, STMicroelectronics, Siemens, Infineon and Alcatel. Outstanding European enterprises with regard to R&D spending in their industries are Siemens, SAP, Nokia and Ericsson. These companies constantly are among Top 10 IST actors in all sectors examined. What is missing, however, are European companies at the ranks from 10 to 100.

- The relevant actors do not change for decades in many technologies; this fact indicates a high ability of the players to adapt to technological change. Contrary to the well-known advice to concentrate on core competencies, companies like Philips, Thomson, Ericsson or Nokia have very broad patent portfolios outside of their core products which enable them to master emerging technological disruptions.

These findings have some implications for technology policy in the field of IST:

- Strengths and weaknesses in IST are changing only slowly; therefore, it seems inevitably to pursue a long-term strategy. An example for such a successful strategy is processing, where the successes of initiatives at the European level from the beginning of the 1990s seem to have lead to a higher specialisation at the end of the decade. This is an example that technology policy can be effective in the field of IST.

- The competence profiles of all actors cover a very broad range of technology field in order to be able to cope with disruptions or take up unexpected new opportunities; it seems to be reasonable that IST technology policy also aims at striking a balance between the setting of targeted priorities on the one hand and the stimulation of more generic competencies on the other. However, given the technological disruptions of the past in IST, it seems reasonable in some cases to take advantage of “windows of opportunities”.

- In spite of the internationalisation of R&D in IST, the results have confirmed the important role played by very large players in IST. Europe-based firms are well represented in the world league of IST, what is missing, however, are the large and medium-sized players. RTD policies should not only consider the ‘premier league’ in IST, but also the second and third tier of IST firms and research organisations.

- Although we did not look at spillovers, is seems obvious that a large national player is important for the establishment of central competencies in a country. But how to make such central players? By far most of these companies have been created by private rather than public initiative.

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Annex

Revealed Comparative Advantage (RTA)

Revealed Technological Advantage can be written down as:

$$\frac{\dfrac{\sum p_{aIST}}{\sum p_a}}{\dfrac{\sum p_{IST}}{\sum p}}$$

which is the number of IST patents of a countries as a fraction of the total number of patents of the country, divided by the fraction of the worldwide IST patents and the total number of patents in the world.

Information Society Technologies in the International Patent Classification

Processing

Group	IPC Code	Title
Generic Processing	H03M	coding, decoding or code conversion, in general
	H03K	pulse technique
	G06F	electric digital data processing
	G06M	counting mechanisms; counting of objects not otherwise provided for
Micro-processors	H01l21	processes or apparatus adapted for the manufacture or treatment of semiconductor or solid state devices or of parts thereof
	H01l23	details of semiconductor or other solid state devices
	H01l25	assemblies consisting of a plurality of individual semiconductor or other solid state devices
	H01l27	devices consisting of a plurality of semiconductor or other solid-state components formed in or on a common substrate
	H01l29	semiconductor devices adapted for rectifying, amplifying, oscillating, or switching, or capacitors or resistors with at least one potential-jump barrier or surface barrier

applications of processing	G06T	image data processing or generation, in general
	G10L	speech analysis or synthesis; speech recognition
	g06f17/20	digital computing or data processing equipment for handling natural language data

‚alternative' computing	G06C	digital computers in which all the computation is effected mechanically
	G06D	digital fluid-pressure computing devices
	G06E	optical computing devices
	G06G	analogue computers
	G06J	hybrid computing arrangements
	G06N	computer systems based on specific computational models

Communication technologies

Group	IPC Code	Title
Generic communication technologies	h04b1	details of transmission systems, not covered by a single one of groups
	h04b13-end	transmission systems characterised by the medium used for transmission, not provided for in groups
	h04j	multiplex communication
	h04q	selecting
	h03c	modulation
	h03b	generation of oscillations, directly or by frequency-changing, by circuits employing active elements which operate in a non-switching manner; generation of noise by such circuits
	h03d	demodulation or transference of modulation from one carrier to another
	h04l5	arrangements for synchronising receiver with transmitter
Wired communication	h04b3	line transmission systems
	h01b	communication cables or conductors
	h04b5	near-field transmission systems, e.g. inductive loop type
	h04b7	radio transmission systems, i.e. using radiation field

	h04b10	transmission systems employing beams of corpuscular radiation, or electromagnetic waves other than radio waves, e.g. light, infra-red
	h04b11	transmission systems employing ultrasonic, sonic or infrasonic waves
	h04l27	modulated-carrier systems
	h01q	aerials

Optical communication	g02b6	light guides; structural details of arrangements comprising light guides and other optical elements, e.g. couplings
	h01s	lasers, maser
	G02f1	devices or arrangements for the control, e.g. modulation, of light beams
	g02f2	devices or arrangements for demodulating light, transferring the modulation or changing the frequency of light
	g02f3	optical logic elements
	g02f7	optical analogue/digital converters
	h04j14	optical multiplex systems

Data communication	h04l1	arrangements for detecting or preventing errors in the information received
	h04l5	arrangements affording multiple use of the transmission path
	h04l12	data switching networks
	h04l17	apparatus or local circuits for transmitting or receiving codes wherein each character is represented by the same number of equal-length code elements
	h04l25	baseband systems
	h04l27	modulated-carrier systems
	h04l29	arrangements, apparatus, circuits or systems, not covered by a single one of groups

Telephonic communcation	h04m	telephonic communication

Visualisation

IPC Code	Title
G03H	holographic processes or apparatus
G05B	control or regulating systems in general; functional elements of such systems; monitoring or testing arrangements for such systems or elements
G08C	transmission systems for measured values, control or similar signals
G09G	arrangements or circuits for control of indicating devices using static means to present variable information
H01J: Subclasses 11,13,15,17,19,21,23,25,27,29,31,33,40,41,43,45	cathode ray tube
h01l27	devices consisting of a plurality of semiconductor or other solid-state components formed in or on a common substrate
h01l51	electroluminescent light sources
h05b33	solid state devices a... using organic materials as the active part
H05H	plasma technique

Positioning

IPC Code	Title
G01S1	beacons or beacon systems transmitting signals having a characteristic or characteristics capable of being detected by non-directional receivers and defining directions, positions, or position lines fixed relatively to the beacon transmitters; receivers co-operating therewith
G01S3	direction-finders for determining the direction from which infrasonic, sonic, ultrasonic, or electromagnetic waves, or particle emission, not having a directional significance, are being received

Sensors

IPC Code	Title
G05B	control or regulating systems in general; functional elements of such systems; monitoring or testing arrangements for such systems or elements
G05D	systems for controlling or regulating non-electric variables
G08C	transmission systems for measured values, control or similar signals
h04n1	scanning, transmission or reproduction of documents or the like, e.g. facsimile transmission; details thereof

Batteries

IPC Code	Title
H 01 M	processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
H01M6	primary cells; manufacture thereof [2]
H01M8	fuel cells; manufacture thereof
H01M31	semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation
H01M41	piezo-electric elements in general; electrostrictive elements in general; magnetostrictive elements in general; processes or apparatus peculiar to the manufacture or treatment thereof or of parts thereof

Haptic interfaces

IPC Code	Title
A61B5/00	measuring for diagnostic purposes

Solar Cells

IPC Code	Title
H01M31	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation

Printing

IPC Code	Title
G03G	electrography; electrophotography; magnetography

Top 25 enterprises in IST

Top 25 enterprises in IST: Period before 1980

Rank	Company	Cumulative Share of all patent applications
1	IBM	24%
2	Fujitsu	33%
3	Siemens	40%
4	AT&T Bell Laboratories	44%
5	Thomson	47%
6	Philips	50%
7	Xerox	53%
8	Hitachi	54%
9	Tokyo Shibaura Denki Kabushiki Kaisha	56%
10	General Electric	57%
11	NCR Corp.	58%
12	Eastman Kodak	59%
13	Motorola	60%
14	Nippon Electric Co. Ltd.	61%
15	Matsushita	62%
16	Alcatel	63%
17	Westinghouse Electric Corp.	63%
18	Du Pont	64%
19	Burroughs Corp.	65%
20	Commissariat a l'Energie Atomique - CEA	65%
21	Hoechst AG	66%
22	Hughes Aircraft Company	66%
23	Cselt SpA	67%
24	Agfa	67%
25	Lucas Industries	67%

Reading instruction: the 10 largest patent applicants in IST account for 57% of all patents in the period.

Top 25 enterprises in IST: Period 1980 - 1989

Rank	Company	Cumulative Share of all patent applications
1	IBM	10%
2	Toshiba	15%
3	Philips	20%
4	Fujitsu	25%
5	Hitachi	28%
6	NEC	31%
7	Siemens	34%
8	AT&T Bell Laboratories	36%
9	Canon	38%
10	Thomson	40%
11	Sony	42%
12	Matsushita	44%
13	Sharp	45%
14	Xerox	46%
15	Motorola	48%
16	Mitsubishi	49%
17	Eastman Kodak	50%
18	Fanuc Ltd.	51%
19	Digital Equipment Corp.	52%
20	Hughes Aircraft Company	53%
21	Advanced Micro Devices	54%
22	Hewlett-Packard	55%
23	Mita Industrial Co. Ltd.	56%
24	Texas Instruments	56%
25	Sumitomo	57%

Top 25 enterprises in IST: Period 1990 - 1994

Rank	Enterprise	Cumulative Share of all patent applications
1	IBM	8%
2	Canon	13%
3	NEC	17%
4	Philips	21%
5	AT&T Bell Laboratories	24%
6	Thomson	27%
7	Toshiba	29%
8	Sony	32%
9	Fujitsu	34%
10	Xerox	36%
11	Matsushita	39%
12	Motorola	40%
13	Sharp	42%
14	AT&T	44%
15	Siemens	46%
16	Mitsubishi	47%
17	Hewlett-Packard	49%
18	Eastman Kodak	50%
19	Alcatel	51%
20	Hitachi	52%
21	Texas Instruments	54%
22	Nokia	55%
23	Advanced Micro Devices	56%
24	Ericsson	57%
25	Sumitomo	57%

Top 25 enterprises in IST: Period 1995 -1999

Rank	Enterprise	Cumulative Share of all patent applications
1	Philips	4%
2	NEC	8%
3	Canon	12%
4	Matsushita	15%
5	Lucent Technologies	18%
6	Ericsson	21%
7	Sony	24%
8	IBM	26%
9	Siemens	28%
10	Sun Microsystems	30%
11	Nokia	31%
12	Alcatel	33%
13	Hewlett-Packard	35%
14	Fujitsu	36%
15	Sharp	38%
16	Xerox	39%
17	Toshiba	41%
18	Motorola	42%
19	STMicroelectronics	43%
20	Mitsubishi	43%
21	Samsung	44%
22	Infineon	45%
23	Texas Instruments	46%
24	Hitachi	47%
25	Qualcomm Inc.	48%

Top 25 enterprises in IST: Period 2000 +

Rank	Enterprise	Cumulative Share of all patent applications
1	Philips	5%
2	Canon	9%
3	Matsushita	12%
4	Hewlett-Packard	15%
5	Sony	18%
6	Fujitsu	20%
7	Eastman Kodak	23%
8	NEC	25%
9	Lucent Technologies	27%
10	Xerox	29%
11	Ricoh Co. Ltd.	31%
12	Toshiba	34%
13	Infineon	36%
14	Texas Instruments	37%
15	Sharp	39%
16	Sumitomo	40%
17	Samsung	42%
18	Hitachi	43%
19	Agilent Technologies	44%
20	Alcatel	45%
21	Sanyo Electric Co. Ltd.	46%
22	STMicroelectronics	47%
23	Mitsubishi	48%
24	IBM	50%
25	Advanced Micro Devices	51%

R&D spending at the firm level

Source: Technology Review

R&D Spending in Computer Hardware

			R&D Spending			
Rank	Company	Country	Last Year Mio. $	% Change From Prev. Year	as % of Revenue	$ per employee
1	IBM	USA	4,754	2.9	5.9	15,050
2	HEWLETT-PACKARD	USA	4,105	53.7	7.3	29,113
3	TOSHIBA	Japan	2,767	1.6	5.9	16,689
4	NEC	Japan	2,472	-11.2	6.3	16,957
5	FUJITSU	Japan	2,385	-18.3	6.2	15,186
6	CANON	Japan	1,950	6.9	7.9	19,941
7	SUN MICROSYSTEMS	USA	1,835	-12.3	14.7	46,574
8	MITSUBISHI ELECTRIC	Japan	1,498	-12.3	4.9	13,585
9	XEROX	USA	917	-8.0	5.8	13,525
10	EMC/MA	USA	781	-15.9	14.4	44,911
11	RICOH	Japan	697	3.4	4.8	9,347
12	APPLE COMPUTER	USA	447	1.4	7.8	36,517
13	MAXTOR	USA	401	-24.5	10.6	32,213
14	DELL	USA	319	-0.6	0.9	8,159
15	UNISYS	USA	273	-17.6	4.9	7,508
16	LEXMARK	USA	248	0.7	5.7	20,542
17	NCR	USA	232	-36.1	4.2	7,708
18	OCE	NL	226	6.6	6.7	10,040
19	STORAGE TECHNOLOGY	USA	215	-12.1	10.5	30,283
20	MINOLTA	Japan	203	-16.1	4.6	10,319

R&D Spending in Software

			R&D Spending			
Rank	Company	Country	Last Year Mio. $	% Change From Prev. Year	as % of Revenue	$ per employee
1	MICROSOFT	USA	4,307	-1.6	15.2	85,287
2	ORACLE	USA	1,180	9.7	12.5	29,028
3	SAP	GER	965	1.2	12.3	33,957
4	COMPUTER ASSOCIATES	USA	664	-2.1	21.3	41,500
5	BMC SOFTWARE	USA	502	4.7	37.8	73,153
6	AUTOMATIC DATA PROCESSING	USA	475	-7.7	4.9	11,871
7	AVAYA	USA	459	-19.2	9.3	24,415
8	ELECTRONIC ARTS	USA	401	3.4	16.2	100,248
9	CADENCE DESIGN SYSTEMS	USA	373	15.9	28.9	72,091
10	SIEBEL SYSTEMS	USA	366	84.4	22.4	61,978
11	PEOPLESOFT	USA	353	16.0	18.1	42,526
12	SYNOPSYS	USA	313	65.0	34.6	73,635
13	VERITAS SOFTWARE	USA	273	12.9	18.1	48,378
14	ADOBE SYSTEMS	USA	252	12.4	21.6	75,382
15	DASSAULT SYSTEMS	France	233	5.0	28.4	58,742
16	INTUIT	USA	206	-0.8	15.1	31,642
17	SYMANTEC	USA	202	23.2	14.4	46,970
18	MENTOR GRAPHICS	USA	193	40.0	32.4	55,122
19	I2 TECHNOLOGIES	USA	173	-42.9	19.1	66,563
20	AUTODESK	USA	173	0.7	21.0	49,453

R&D Spending in Electrical/Electronics

			R&D Spending			
Rank	Company	Country	Last Year Mio. $	% Change From Prev. Year	as % of Revenue	$ per employee
1	SIEMENS	GER	6,173	-14.2	6.9	14,491
2	MATSUSHITA ELECTRIC INDL	Japan	4,599	-2.6	7.4	15,951
3	MOTOROLA	USA	3,766	-13.6	14.1	38,825
4	SONY	Japan	3,698	2.3	5.9	22,957
5	PHILIPS ELECTRONICS	NL	3,241	-7.8	9.6	19,054
6	HITACHI	Japan	3,148	-9.2	4.6	9,821
7	AGILENT TECHNOLOGIES	USA	1,169	-13.3	19.5	32,472
8	SHARP	Japan	1,120	6.5	6.7	24,016
9	SANYO ELECTRIC	Japan	1,008	12.9	5.3	12,762
10	EMERSON ELECTRIC	USA	530	-10.8	3.8	4,753
11	MARCONI	UK	520	-47.9	16.3	24,786
12	SCHNEIDER ELECTRIC	France	501	-7.8	5.2	6,703
13	MATSUSHITA ELECTRIC WORKS	Japan	461	-1.2	4.7	9,590
14	QUALCOMM	USA	452	8.9	14.9	55,763
15	TOKYO ELECTRON	Japan	418	-6.9	10.9	41,612
16	SUMITOMO ELECTRIC INDS	Japan	406	0.4	3.3	5,126
17	THOMSON	France	397	1.6	3.7	6,059
18	KYOCERA	Japan	395	17.0	4.4	7,983
19	PIONEER	Japan	379	16.2	6.4	10,931
20	INVENSYS	UK	353	-16.2	4.4	5,575

R&D Spending in Semiconductors

			R&D Spending			
Rank	**Company**	**Country**	**Last Year Mio. $**	**% Change From Prev. Year**	**as % of Revenue**	**$ per employee**
1	INTEL	USA	4,054	1.5	15.1	51,512
2	TEXAS INSTRUMENTS	USA	1,619	1.3	19.3	46,807
3	INFINEON	German	1,124	-10.8	20.4	37,260
4	APPLIED MATERIALS	USA	1,060	-12.3	20.9	65,949
5	STMICROELECTRONIC	NL	1,022	4.5	16.3	23,674
6	ADVANCED MICRO DEVICES	USA	816	25.4	30.3	67,192
7	MICRON TECHNOLOGY	USA	561	14.7	21.7	30,016
8	LSI LOGIC	USA	519	-23.5	28.5	98,196
9	NATIONAL SEMICONDUCTOR	USA	436	-1.4	26.1	44,520
10	ANALOG DEVICES	USA	424	-10.6	24.8	49,287
11	CONEXANT SYSTEMS	USA	324	-33.0	53.8	131,630
12	ASML HOLDING NV	NL	317	-26.9	15.2	53,016
13	CYPRESS SEMICONDUCTOR	USA	290	-0.2	37.4	70,733
14	KLA-TENCOR	USA	287	-19.4	17.6	50,422
15	MAXIM INTEGRATED	USA	276	-1.7	26.9	45,417
16	ROHM	Japan	266	48.4	9.1	15,773
17	NVIDIA	USA	260	69.1	13.9	172,036
18	ATMEL	USA	253	-5.6	21.2	33,532
19	NOVELLUS SYSTEMS	USA	230	-15.5	27.5	71,238
20	XILINX	USA	222	8.5	19.2	85,046

R&D Spending in Telecommunications

			R&D Spending			
Rank	**Company**	**Country**	**Last Year Mio. $**	**% Change From Prev. Year**	**as % of Revenue**	**$ per employee**
1	CISCO SYSTEMS	USA	3,513	-26.5	18.6	97,583
2	ERICSSON TELEFON	Sweden	3,399	-37.1	20.1	52,596
3	NIPPON TELEGRAPH &	Japan	3,305	1.3	3.6	15,937
4	NOKIA	Finland	3,238	2.2	10.2	62,567
5	ALCATEL	France	2,361	-22.4	13.5	31,096
6	LUCENT TECHNOLOGIES	USA	2,310	-34.4	18.7	49,149
7	NORTEL NETWORKS	Canada	2,281	-35.0	20.4	61,713
8	MATSUSHITA	Japan	1,258	9.9	19.2	75,382
9	NTT DOCOMO	Japan	1,054	25.8	2.6	50,670
10	BROADCOM	USA	714	-18.7	65.9	284,756
11	AGERE SYSTEMS	USA	693	-27.1	31.8	64,766
12	ALSTOM	France	660	8.1	2.9	6,017
13	FRANCE TELECOM	France	611	1.6	1.2	2,545
14	BT GROUP	UK	605	5.0	2.0	5,777
15	CORNING	USA	483	-23.5	15.3	20,819
16	TELLABS	USA	341	-19.9	25.9	70,547
17	JDS UNIPHASE	USA	280	-61.0	25.5	30,373
18	VODAFONE GROUP	UK	261	382.4	0.5	3,916
19	CIENA	USA	255	-14.8	70.7	120,534
20	AT&T	USA	254	-21.8	0.7	3,577

Verteiler

01 – 05	Erste Zeile
06 – 10	Beiratsmitglieder
11	Belegsexemplar