Europe's Position in Information Society Technologies

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Abstract. *Building on triadic patent data from the OECD, this chapter investigates Europe's position in key areas of IST (Information Science Technology) by comparing Europe's patterns of specialisation to those of Japan and the US. The data show that Europe has improved its position in IST considerably during the 1990s. Strengths in communication technologies could be defended. Moreover, Europe could also reduce relative weaknesses in a number of technologies like storage, visualisation and processing. This catching up process is quite remarkable in view of fierce international competition in these technologies. However, Europe is still behind the US in terms of its overall performance in IST patenting and in some key areas like processing technologies.*

Introduction

Europe has shown a mixed performance in Information Society Technologies (IST) over the past decades. Concerns are raised about Europe lagging behind the US and Japan in key areas of IST, many of which are regarded as having an important generic role to play for many other industrial and service sectors. Moreover, Information Society Technologies and the creation of a Knowledge Society are regarded as key drivers of wealth and employment creation in Europe along the lines of the Lisbon strategy. If Europe lags behind, so the argument goes, it will not only miss major industrial opportunities in the IST sector itself. Moreover, Europe will also deprive itself from a privileged position in using IST in a wide range of application areas, and become dependent on progress made elsewhere in the world. There are obviously exceptions from this highly generalised complaint. Mobile communications is often lauded as an important segment of IST where Europe as a whole has managed to establish a global lead by behind ahead in establishing a common standard, but even this leading position may be eroded in the course of time.

In order to give the current debates about Europe's performance in IST a quantitative base, this chapter aims to measure and quantify Europe's position in Information Society Technologies over the last 15 years. More specifically we ask the following questions:

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- How has the performance of European organisations in IST developed over time as compared to the US and Japan? How has IST developed at the level of member countries?
- In what technologies lay the main strengths or specialisations within IST, what are the major weaknesses?
- How is the international division of labour in the development of IST?

We will first draw a broad comparative picture by confronting Europe's patterns of specialisation with those of the US and Japan. Subsequently, we will discuss this picture in the light of the current move towards internationalisation of research and technology development.

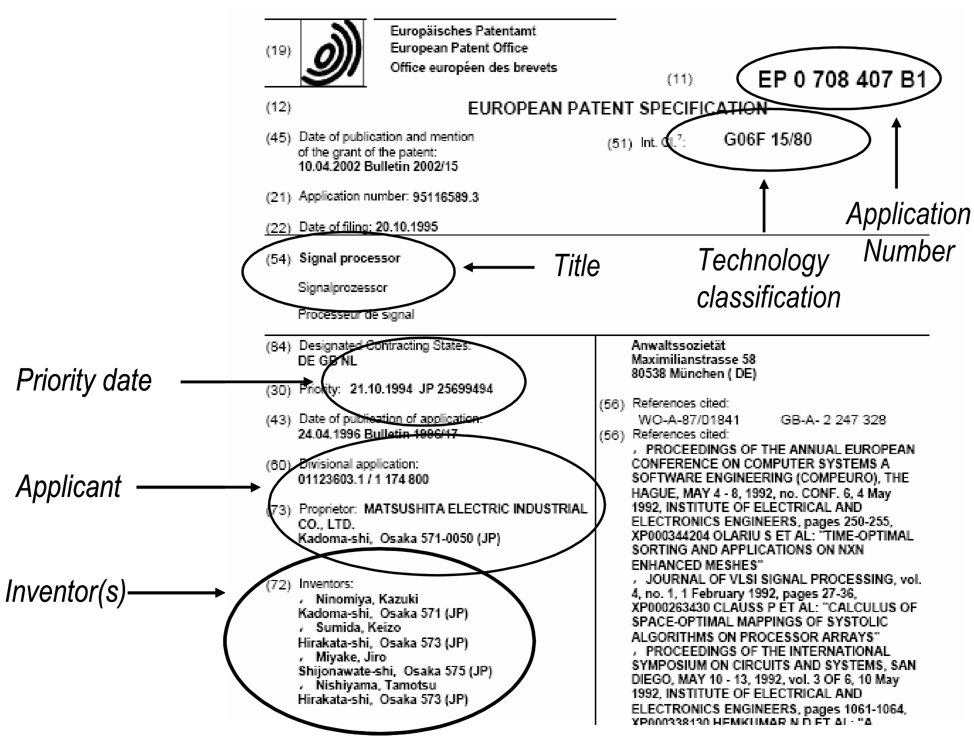
Patents as a Measure of Technological Specialisation

The central aim of the study is to measure the degree to which organisations (mostly firms and universities) possess technological knowledge. The specialisation of a firm or a country in a certain technology will be measured in terms of the share of that technology in its technology portfolio. A firm is highly specialized in a certain technology if this technology represents a large share of the firm's technology portfolio as compared to the average.

Specialisation is measured with patents. 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. Moreover, patents are also a valuable source for analyzing technological change and a "Window on the Knowledge Economy" (Jaffe and Trajtenberg 2002). Figure 1 shows the different types of information a patent file contains. It first describes the invention that is protected by the title, an abstract and a standardized 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.

Patents have some features that make them useful for the analysis of technological change (Griliches 1990; Jaffe and Trajtenberg 2002). First of all, patents directly represent technologies, not companies or other proxies for technologies. There is a roughly proportional connection between patenting activity and research and development activities at the level of industries (Bound, Cummins *et al.* 1984). Second, 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. Third, since patents described with a unified classification scheme (International Patent Classification, IPC[2]) provided by the World Intellectual Property Organization (WIPO), it is possible to follow developments over time and countries. This classification is much more detailed than the classification scheme for publications (Science Citation Index) or industrial activities (NACE).

[2] See http://www.wipo.int/classifications/fulltext/new_ipc/



Source: European Patent Office.

Figure 1. Patent file issued by the European Patent Office.

This study uses the priority date (first date of filing of a patent application, anywhere in the world), which is closest to the invention, as the reference date. The most recent priority dates in our analysis will be around 1999. However, this does not mean that they are outdated. Because of the time lags between application and grant, these patents usually refer to granting dates in 2003 and 2004.

As this study concentrates on competitiveness, we will concentrate on patent statistics which has been compiled according to the ownership of patents. This view is closely related to the idea of technology as an intangible asset owned by the enterprise that contributes to the firm's competitiveness.

Patent data as a measure of technological change have also 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 these sectors have a similar rate of innovative activities.

The OECD Triadic Patent Families Database

The most important decision regarding cross-country comparisons of patent data is the choice of the patent office where the patents are filed. 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. This leads to large differences between the patent offices. 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.

The decision to use data of a single patent office will inevitably have an impact on the results received from the analysis. This is particularly important for an analysis that aims at giving a balanced picture of the relative strengths and weaknesses of Europe, the US and Japan in IST research. In order to overcome this problem and make balanced cross-country comparisons possible, the OECD has developed the concept of *Triadic patent families*. A patent families is a 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). To correct for the biases originating from using data of one single patent office, we will use Triadic patent data for all cross-country comparisons.

Definition of the IST Sector

Information Society Technologies are not a single sub-group within the International Patent Classification (IPC)[3], 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, Dalla Mura et al. 2003), second a classification of Information and Communication Technologies developed by the Fraunhofer ISI institute for the OECD (Schmoch 2004).

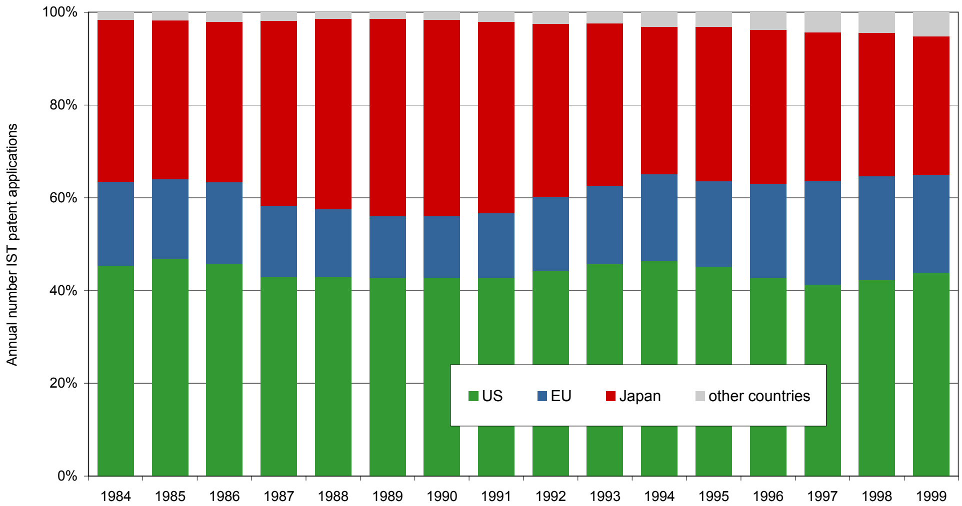
The major problem in finding a suitable classification of technologies in patent data is to reduce the hundreds of technology classes to some meaningful groups for further analysis. We decided to define these groups at the four-digit level of the IPC. Examples of such four-digit classes are G10L, speech analysis or synthesis, speech recognition, G11B (information storage based on relative movement between record carrier and transducer), or H01L (semiconductor

[3] http://www.wipo.int/classifications/fulltext/new_ipc/

devices). It is of course possible to dig much deeper into data and 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 consists of 18 broad technology categories. Each of these technologies consists of at least one class of the International Patent Classification.

IST Patents in the Triad

The increasing importance of Information Society Technologies is reflected by the growing number of patent applications in this field. The number of patents has nearly doubled between 1984 (5,618) and 1999 (8,808). There was a decrease in the absolute 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. The number of IST patent applications has been growing steadily in the US, Japan and Europe since the 1980s. The US is well ahead of the other two economic blocks in terms of new patents in IST. More than 40% of all IST patents that come out each year are possessed by enterprises or universities from the US. Europe could increase the number of new patent applications in each year since 1984. Its share of all patent applications in IST rose from 10% (1990) to 21% in 1999 at the cost of Japan and the US. (Figure 2). All other countries, including Switzerland and Korea, together apply for no more that 5% of all new patents. 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.



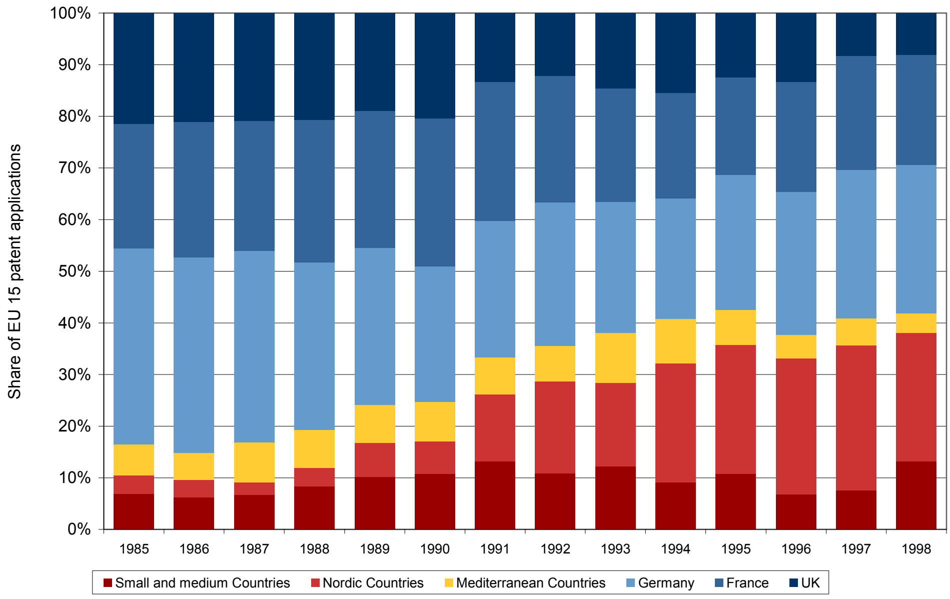
Source: OECD, Triadic Patent Families Database, own calculations.

Figure 2. Distribution of annual patent applications in Information Society Technologies, 1984-1999 (World = 100%).

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. IST patents have raised their share of total patent activity from around 15% (1984) to 22% in 1999 worldwide. In Europe, IST patents account for 18% of all new European Triadic patents in 1999, compared to a share of about 10% in the Mid-1980s.

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.

The increases of IST patent activity in the 1990s in Europe, however, were not equally distributed over the member states. We find vast differences in the relative performance. Organisations located in the large member countries (France, Germany and the UK) increased the number of new IST patents per year considerably slower during the last 15 years than enterprises from small and medium countries (Figure 3). Patent applications in IST have stagnated or even declined in France, Great Britain or the Mediterranean countries (Italy, Spain, Portugal, and Greece).



Source: OECD, Triadic Patent Families Database, own calculations.

Figure 3. Share of the member states on all new patent applications in the EU15, 1985 – 1998.

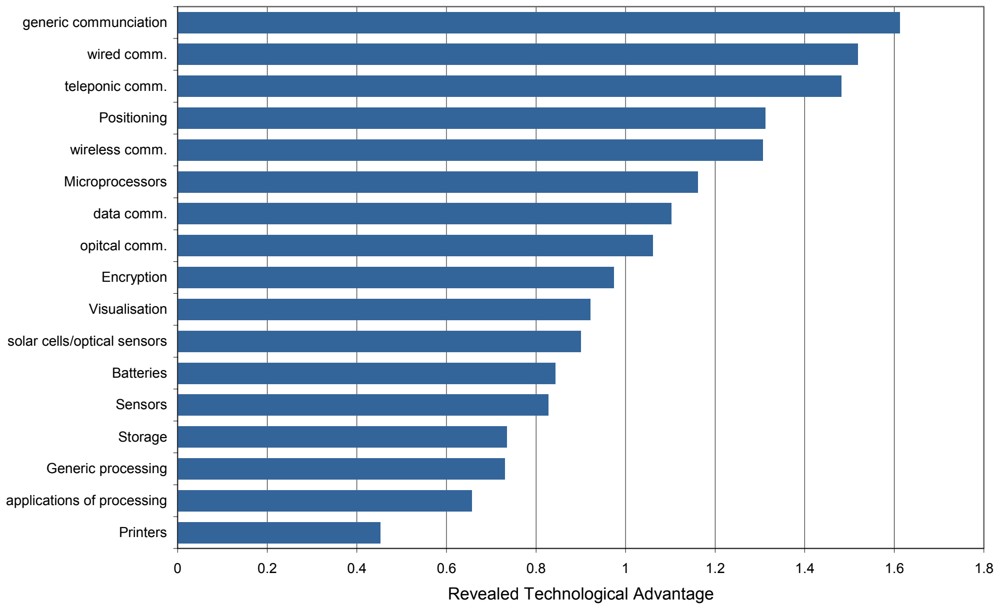
The Nordic states and other small and medium countries like the Netherlands, Belgium, Ireland or Austria, on the other hand, could increase their annual applications considerably. These small countries – and not the large member states of the EU - are responsible for Europe's rising share on IST world patents in the 1990s. The share of the medium and small countries on Europe's patent activity increased from 10% in the Mid-1980s to 45% at the end of the 1990s. 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%.

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, 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 than half of them have been applied for by firms from the 'old' EU 15, the US or Japan.

Patent data show that the NMC are lagging in terms of technological capabilities for developing new IST. However, there are reasons to expect more from the future. One reason is that these countries have a well-educated workforce in sciences and engineering. Moreover, the NMCs offer good conditions for investment by major IST companies. We have seen a huge inflow of foreign direct investment in these countries. Inzelt (2003) reports for Hungary that enterprises like Nokia, Samsung, or Flextronics have already set up for large R&D investments in Hungary; the IST sector is second among the sectors who took part in a governmental scheme to promote new industrial R&D labs.

Europe's Position in Various Technologies

What were the strengths that led to this catching-up process of Europe? We will answer this question by calculating Revealed Technological Advantage values (RTA). The RTA is a wide-used measure for technological specialisation and relates the share of a certain technology on all patent applications of a country to the share this technology has worldwide. It is the fraction of the share of technology x in country y and the share of technology worldwide. 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 average level of specialisation. A value of above 1, therefore, indicates a strength of Europe opposed to the world (which basically consists of the Triade), a value below 1 a weakness. The result of this calculation is given in Figure 4. Not surprisingly, Europe's strengths lie in communication technologies: RTA values in generic communication technologies (relates to techniques that are used in all fields of communication), wired communication, telephonic communication and wireless communication are all well beyond 1. Processing technologies, in contrast, seem to be the major weakness of Europe. Moreover, fields like sensors, batteries, storage, or printing technologies are also weaker than on world average.

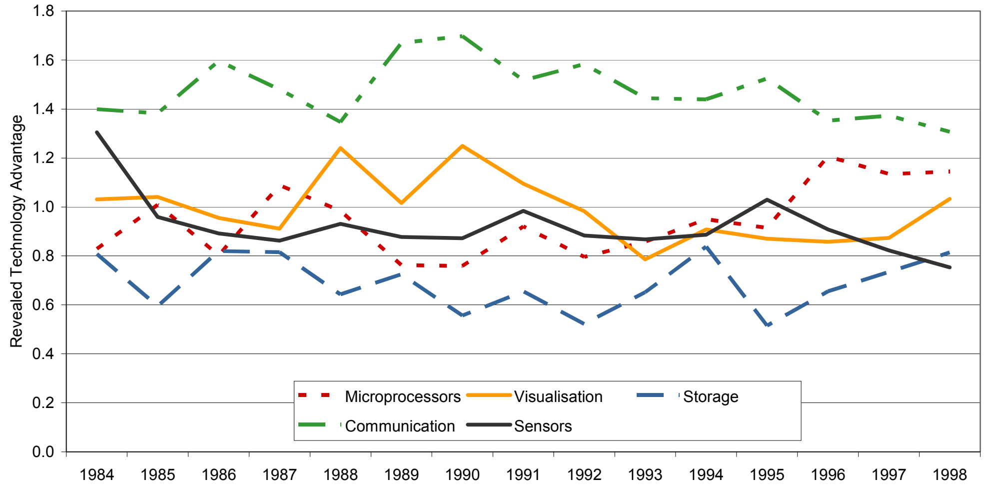


Source: OECD, Triadic Patent Families Database, own calculations.

Figure 4. Europe's Revealed Technological Advantage (RTA) in various fields of IST, 1996-1998 average, priority date.

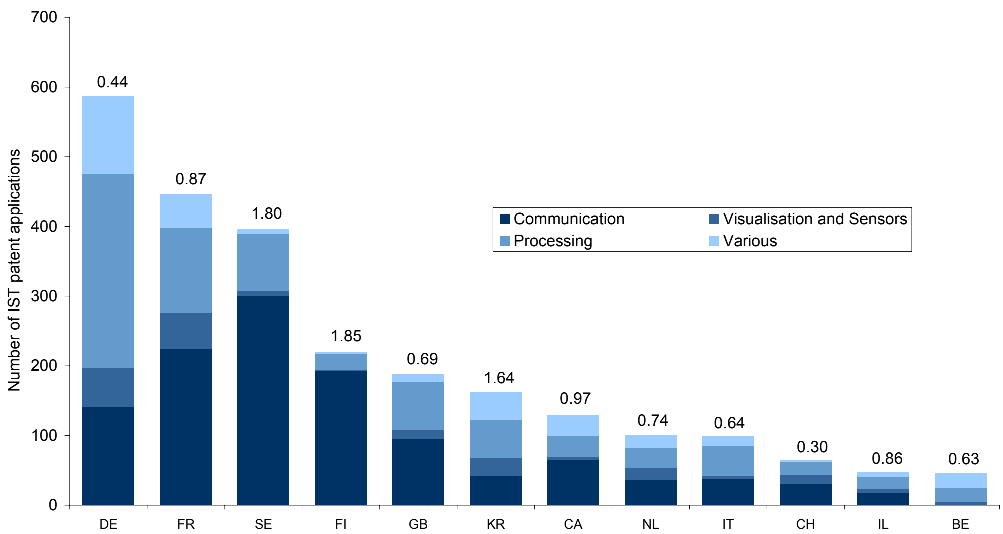
This competitive advantage of Europe is by far not a result of the 1990s, but has a long history, as can be seen in Figure 5. Europe has *always* been good in communication technologies, not just since the beginning of the 1990s. The EU members largely managed to hold its competitive advantage in communication technologies despite the emergence of new competitors in the Triad and other countries like Taiwan or Korea. Moreover, this advantage could be defended and even expanded to the area of mobile communication. Alike, Europe's weakness 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.

Which countries are responsible for Europe's strengths and weaknesses? Figure 6 answers this question by showing the absolute number IST patent applications for some European and non-European countries and a split-up of the absolute sum into main technology categories. We also included the RTA value as a measure of the specialisation of a country relative to the world's specialisation in these technologies.



Source: OECD, Triadic Patent Families Database, own calculations.

Figure 5. Revealed Technological Advantage (RTA) of Europe in five fields of IST, 1984-1999 priority dates.



Source: OECD, Triadic Patent Families Database, own calculations.

Figure 6. Number of IST patent applications in various fields and share of IST patents on all national applications and RTA value, 1997.

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 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. The high specialisation of Finland and Sweden becomes even more evident if we relate the number of IST patents to the size of the country. 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 a comparison of the number of new patents. Moreover, we may also assume that a considerable part of the non-communication patents of these countries are 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 average. Europe as a whole had an RTA of 0.75 in 1997. Especially 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.

Communication technologies are clearly the field where Europe excels Japan and 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 have increased their market share on all IST worldwide 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).

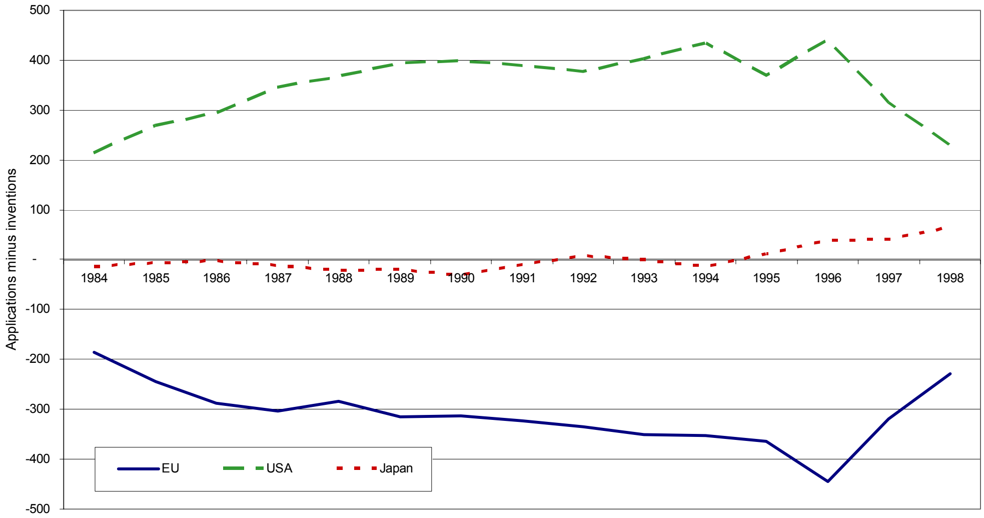
Simply speaking, Europe could gain market shares in IST patenting because European organisations were engaged in the right technologies at the right time. But this is not the whole story; Europe's enterprises not only managed to reach a competitive advantage in some technologies, they could also secure and expand their competitive edge. This clearly shows the benefits a country can earn from an early specialisation in 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. These factors 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.

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. Regions like Silicon Valley, or the Boston and Cambridge area have become focal points of innovation in a certain field of technology. We will now briefly sketch Europe's position in the internationalisation of IST by patent data.

Gullec and van Pottelsberghe de la Potterie (2001) 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) (always a person) as well as the patent applicant (a person or an organisation, 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 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 organisations located in a certain country, we can see if a country is a host country for foreign R&D or if organisations from this country (multinational enterprises) are very active in developing knowledge abroad.

Figure 7 shows the results of this calculation for Triadic IST patents. The chart indicates if one region 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 Figure 4) 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 apply about 300 to 400 IST patents per year that have been invented in Europe. This gap has been stable throughout the 1990s. 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 to 25 % of all European patent applications.



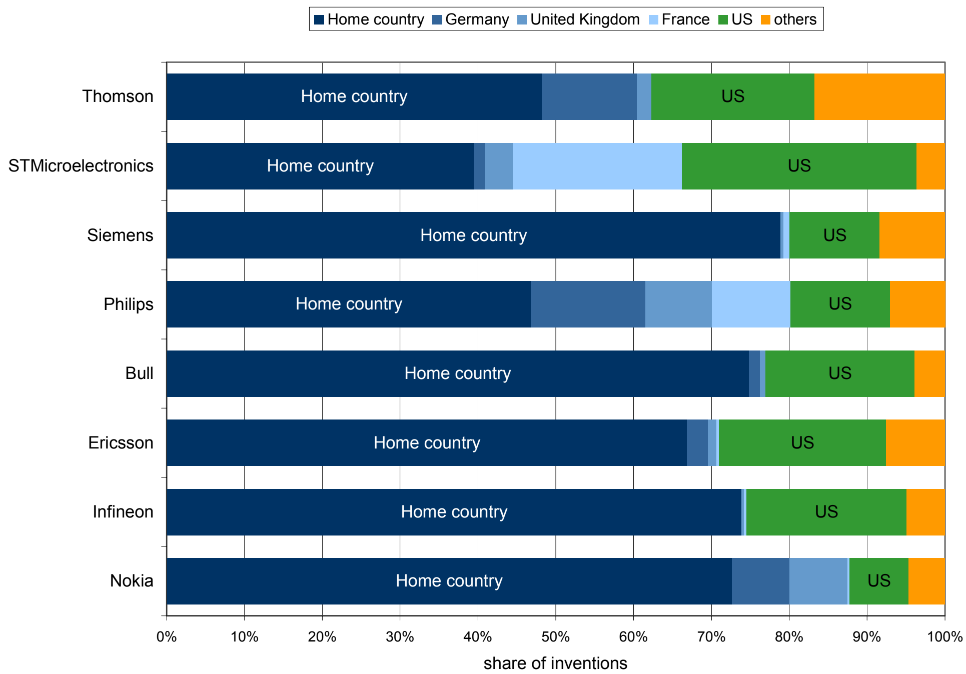
Source: OECD, Triadic Patent Families Database, own calculations.

Figure 7. Difference between the number of Triadic IST patents applied and invented by the US, Europe and Japan, 1984 – 1998.

For the years after 1998 we see the gap diminishing; however, 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.

Europe and the US are highly interrelated in IST research. On balance, there is a *net* flow of patent inventions from Europe to the US, but one should be aware of flows in the opposite direction. 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 Figure 8). Giarratana and Torrisi (2001) show that Europe's largest IST enterprises maintain considerably more alliances with partners outside of Europe than with partners inside of Europe. These agreements significantly increase the technological competences of European firms. Therefore, 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.

Moreover, 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.



Source: OECD, Triadic Patent Families Database, own calculations

Figure 8. Location of inventors of Europe's leading IST enterprises (triadic patent families) 1976-2000.

Conclusions

This chapter has measured Europe's competitive position in Information Society Technologies with patent data. The aggregate picture shows that Europe has improved its position in IST considerably during the 1990s. The main reason for this development was that patent applications in communication technologies, an area that has always been an area of strength of European enterprises, grew above average in the 1990s. In other words, Europe could increase its share in IST patenting because European firms were engaged in the right technologies at the right moment in time. Moreover, Europe could also reduce relative weaknesses in a number of technologies like storage, visualisation and processing. This catching up process is quite remarkable in view of fierce international competition in these technologies. However, in spite of these positive developments, Europe is still behind the US in terms of its overall performance in IST patenting, but it is slowly catching up.

When analysing patent data at the level of countries we see that the favourable development of the 1990s was largely due to the contributions of some small and medium-sized countries in Europe, most notably the Nordic countries. The share of the small and medium-sized countries on Europe's patent applications increased from 10% in the Mid 1980s to about 40% at the end of the 1990s.

The dynamism in patenting performance in IST that we can observe for Europe as a whole is thus even stronger at the level of some countries. In spite of this apparent dynamism, the patterns of specialisation within IST have nevertheless remained rather stable. The persistence of specialisation is particularly obvious for communication technologies, where Europe has been strong for many decades, but it can also be observed for other areas like microprocessors.

The interpretation of these data is not as straightforward as it appears to be at first sight. In fact, IST research is not conducted independently in different monolithic world regions. There are strong interdependencies between the US, Europe and Japan, that reflect an important trend towards the internationalisation of R&D in IST. This affects also the picture of Europe's comparative performance in IST research. When taking into account the locations of inventors and applicants of patents respectively, we find that Europe has a significant surplus in inventions over applications. The contrary is the case for the US. The US organisations apply about 300 to 400 IST patents per year that have been invented in Europe. Leading European IST enterprises, on the other hand, develop 10-20% of their IST patents in the US.

These findings show that in order to benefit from the strong dynamism in a technological area like IST it is important to be engaged in the right technologies at the right time. Cultivating certain areas of specialisation is thus important for playing a major role in the increasingly internationalised world of IST research. However, trying to maintain or develop areas of specialisation is a difficult task. It involves the risk of lock-in, and our limited ability to anticipate techno-economic developments entails the risk of misallocation of resources. Two strategic conclusions for policy can nevertheless be drawn. First of all, rather than pursuing short-term strategies of following recurring "fashions" in IST research, it seems more appropriate to put greater weight on established strengths and areas of specialisation. Secondly, in order to maintain the ability to move early on into new emerging fields of IST and position oneself in an advanced position, it is necessary to invest in a reasonably broad portfolio of areas of IST research. As one cannot predict the future, such a diversified portfolio has the potential to comprise at least some promising growth areas in which a country or a company can benefit from its early investments.

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