JRC Scientific and Technical Reports

The 2009 Report on R&D in ICT in the European Union

Authors: Geomina Turlea, Sven Lindmark, Lucio Picci, Andrea de Panizza, Martin Ulbrich, Paul Desruelle, Marc Bogdanowicz, and David Broster

EUR 23832 EN - 2009

JRC
EUROPEAN COMISSION

Institute for Prospective Technological Studies

European Commission
Information Society and Media

Institute for
Prospective
Technological Studies

The 2009 Report on R&D in ICT in the European Union

Authors: Geomina Turlea, Sven Lindmark,
Lucio Picci, Andrea de Panizza, Martin Ulbrich,
Paul Desruelle, Marc Bogdanowicz,
and David Broster

2009

JRC
EUROPEAN COMISSION

EUR 23832 EN

The mission of the JRC-IPTS is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

European Commission
Joint Research Centre
Institute for Prospective Technological Studies

Contact information
Address: Edificio Expo. c/ Inca Garcilaso,3. E-41092 Seville (Spain)
E-mail: jrc-ipts-secretariat@ec.europa.eu
Tel.: +34 954488318
Fax: +34 954488300

http://ipts.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu

JRC 49951

EUR 23832 EN
ISBN 978-92-79-12433-4
ISSN 1018-5593
DOI 10.2791/10608

Luxembourg: Office for Official Publications of the European Communities

Acknowledgements

This report was produced by the Information Society Unit at the Institute for Prospective Technological Studies (IPTS),[1] for DG Information Society & Media. It is part of the project: "Prospective Insights on R&D in ICT" (PREDICT) which is jointly funded by DG Information Society & Media and JRC-IPTS.

The authors wish to thank the many external experts who have contributed to this report, and especially Alain Puissochet for his work on Public R&D expenditures and on the US and Asian data.

The authors would also like to acknowledge the following experts and colleagues for their longstanding support, valuable input and comments: Michel Vajou (MV Etudes et Conseil); Graham Vickery and Vladimir Lopez-Bassols (OECD); Raymond Wolfe and John Jankowski (NSF); Reni Petkova, Håkan Wilén and Albrecht Wirthman (EUROSTAT); Khalil Rouhana, Sofie Norager, Michael Arentoft and Alain Stekke (DG Information Society & Media); and Andries Brandsma, Hector Hernandez, Lesley Potters, and Alexander Tübke.

Finally, thorough checking and editing of the text by Patricia Farrer is gratefully acknowledged.

1 IPTS is one of the seven research institutes of the European Commission's Joint Research Centre (JRC)

Table of contents

List of figures

List of tables

Executive summary

1. Introduction

This report provides an analysis of EU R&D investments in the Information and Communication Technology industry sector. The research was carried out by the Information Society Unit at IPTS [2] in the context of PREDICT,[3] a research project co-financed by IPTS and the Information Society & Media Directorate General of the European Commission.

This PREDICT report is the first of a series which will be published annually. PREDICT builds on previous work by IPTS in the same field, in particular on the work presented in the JRC Reference Report, **Mapping R&D Investment by the European ICT Business Sector**,[4] co-published with DG Information Society & Media, which provided a first in-depth overview of available data on EU ICT industry R&D investments.

This report provides, for the first time, a comprehensive view on ICT R&D investments in the EU (2001-2005) by combining three complementary perspectives: national statistics, company data, and technology indicators. In addition to providing updated data on ICT industry R&D investment in a global perspective, the report provides the first -and to date only- estimate on public ICT R&D investment data (ICT GBAORD[5]) for the EU27. The report also provides information on economic trends in the ICT sector, investigates the input-output relationship for ICT R&D, and offers an analysis of EU ICT patents.[6]

This type of information is extremely important for policymakers since:

- The ICT sector is by far the largest R&D investor, R&D employer and R&D performer in the EU (as it is in the USA and Japan).
- Its is therefore a key sector in the pursuit of the Lisbon objectives, taking into consideration the role of the ICT industry and of ICT-enabled innovation in the economic growth of advanced economies.
- It is a pillar of the Information Society policy of the Commission, and the largest research budget of the Framework Programme.

2. Scope

For the first time, PREDICT provides the ability to monitor, assess and offer recommendations for EU ICT R&D policies on the basis of internationally-controlled data and observations. PREDICT has also pioneered the production of data and analyses on ICT R&D in the EU on a number of aspects:

- Time-series coverage for the period 2001 – 2005 (and 2006 for company data).
- A first comprehensive set of comparable series on private and public R&D data and indicators for the ICT sector.
- Sectoral coverage that offers disaggregated data and analysis for six ICT sub sectors: IT Components; IT Equipment; Telecom and Multimedia Equipment; Measurement Instruments; Telecom Services; Computer Services and Software.
- Output analysis (Patents).

2 The Institute for Prospective Technological Studies (IPTS) is one of the seven research institutes of the European Commission's Joint Research Centre (JRC)

3 PREDICT: Prospective Insights on R&D in ICT

4 http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1879, November 2008

5 GBAORD – Government Budget Appropriations or Outlays on R&D

6 PREDICT's methodology is described in the report annexes

Data sources and methodology

The data used by PREDICT, in terms of collecting, estimating, aggregating, comparing or processing follows the international standards set in particular by the **Frascati Manual (OECD, 2002)**. The integrated exploitation of various statistical surveys and tools characterises the work in PREDICT, as none of the available sources provide complete data series for the ICT industries. JRC IPTS has articulated official data from different repositories (national, EUROSTAT, OECD), filling a number of gaps, and correcting for incoherencies and for methodological differences, to allow international comparability. In this methodological effort, JRC IPTS cooperated with OECD and EUROSTAT. Where necessary and relevant, JRC IPTS has developed its own methods and has validated these by weighing them against the opinions and assessments of international experts. This cross-checking confirmed that the data produced were quite robust.

To address public R&D expenditures data (GBAORD), PREDICT used the socio-economic data following the nomenclature for the analysis and comparison of scientific programmes and budgets (NABS) classification (2007). The Frascati Manual clearly supports the identification of the ICT sector through the NABS groups, with the argument that despite issues of availability and international comparability of data for several countries, the classification by socio-economic objective may also be used to distinguish ICT-related R&D (OECD (2002) p.189). Initial work had been developed along theses lines by the GFII.[7] PREDICT further improved and deepened some of the methodological aspects, investigating the concrete way data were collected in each country, thus making major improvements both in terms of scope and quality. To fine tune estimations, the PREDICT team also performed extended expert consultations and interviews.[8]

The initial basis for assessing company data was the IPTS annual *EU Industrial R&D Investment Scoreboard*. The underlying information was integrated and reclassified to isolate the ICT sector. Demographic data (age) were added, to better capture dynamics. Also, some extra descriptive dimensions have been included (e.g. regions, countries, companies, R&D investment, R&D investment change, sales, R&D/Sales, composition of sectors). Finally, PREDICT has developed additional analytical insights to contrast scoreboard data with BERD data (especially concerning the US vs. EU R&D) and offers sub-sectoral analysis (R&D growth, etc.) on a more detailed level.

Complementary to the core ICT R&D analysis, PREDICT is also unique in analysing patent statistics using the information produced by all the national European patent offices and the European Patent Office (EPO). This is an original, now validated approach, which provides an indicator of the inventive capacity of the EU (ICT patents) with respect to ICT R&D investments.

7 GFII (2006), «Recherche et développement en sciences et technologies de l'information dans les grands pays industriels. Analyse statistique des investissements en R&D», Groupement Français de l'Industrie de l'Information, GFII Research Report, 2006. This report was produced on the request of the French *Ministère délégué à l'enseignement supérieur et à la recherche*. It is the only earlier attempt to estimate public national ICT R&D expenditure in the EU.

8 For a more detailed view on the methodology used for estimating R&D Public Expenditures, see Annex 6 at the end of this report

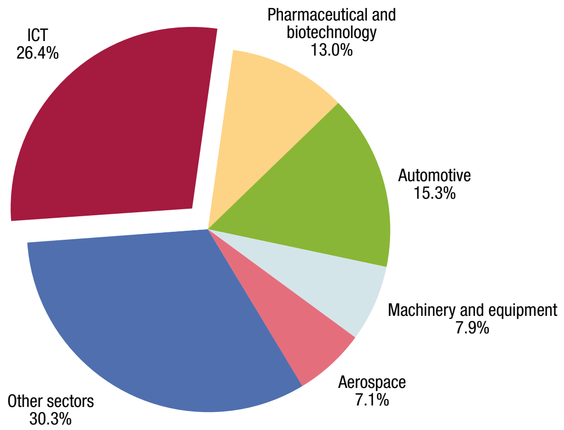
3. PREDICT results

The most important findings of this year's PREDICT report are briefly summarised in the sections below. A full treatment of the methodologies, concepts and data analysis can be found in the main body of this report.

3.1 The importance of the ICT sector

In the EU, the USA, and Japan, the ICT sector is **by far the largest R&D investing sector of the economy**. Although the EU ICT sector represents only about 3% of total employment in the EU and 4.9% of GDP, it accounts for **26% of overall business expenditure in R&D (BERD) and employs 32% of business sector researchers.**[9] The ICT sector has a much higher than average labour productivity (as measured by value added per person employed). It also leads other economic sectors in terms of R&D and provides them with productivity-enhancing technology, hence contributing directly and indirectly to increasing labour productivity and EU competitiveness. The ICT sector is therefore an R&D intensive economic engine, underpinning growth.

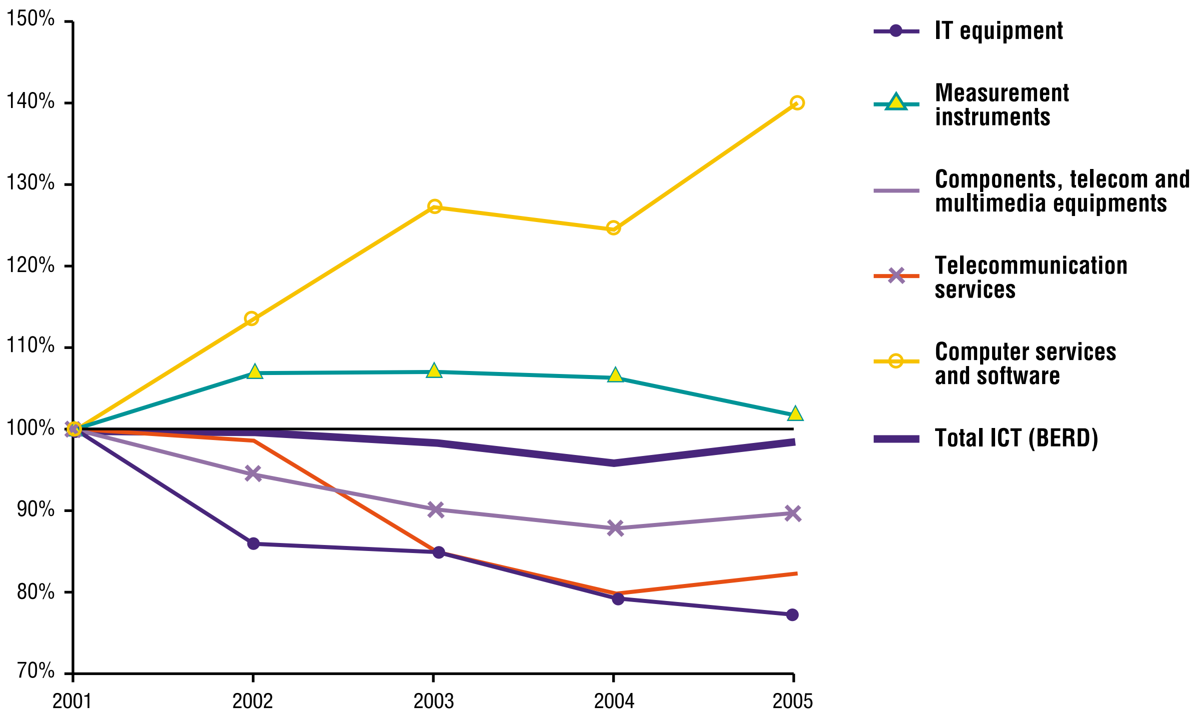
Figure 1: Share of ICT in EU total BERD, Year 2005



Source: EUROSTAT and IPTS calculations.

9 2005 figures, the latest available in December 2008

Figure 2: Real growth of ICT BERD in the EU27 (2001=100%)



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics

Moreover, total business expenditures in ICT R&D are even larger than the ICT sectoral figures show, since **additional ICT R&D is carried out in non-ICT** designated sectors (for example, the automotive sector). The size of this ICT R&D expenditure was estimated by OECD as up to one-third of that carried out in the ICT sector in a sample of countries.[10]

Further evidence of the importance of the sector includes the fact that there has been a 10% growth in ICT researchers during the period 2001-2005. Additionally, an 18% share of all EU public and private expenditures in R&D (GERD), and a 21% share of all EU patents are in ICT.

The total EU ICT BERD (see Figure 2) shows only a very slight decline following the burst of the dot-com bubble, with an equally slight upwards tendency in 2005. In fact, it is fair to say that, during 2001-2005, EU ICT BERD remained stable, at about 6% of the ICT industries aggregate value added. The two ICT sub-sectors that experienced growth after the dot-com crisis are *computer services and software*, and *measurement instruments*, which are also those where the ICT R&D gap between the EU and the US is most pronounced.[11]

10 Czech Republic, Denmark, Norway, Finland, Japan. Australia, with over 60% of ICT R&D performed outside the ICT sectors, remains an exceptional case, largely due to in-house ICT R&D of large Australian banks (OECD, 2008 b)

11 **Topical footnote:** In comparison, the present crisis of 2008-2009, has occurred at a time when computers, mobile telephones, multimedia equipment and telecom services are increasingly subject to commoditisation. However, it should not be forgotten that the ICT industry is an enabling one, hence the R&D and innovation related to its deployment and application are expected to continue. Within the industry, R&D will probably concentrate on improving the technology behind the main building blocks of ICT applications: broadband, semiconductors, storage capacities, power, and of course software.

3.2 The ICT R&D investment gap (vis-à-vis the EU's main competitors)

The EU's main competitors (such as the USA, Japan, or Korea) are investing significantly more in ICT R&D (when comparing ICT R&D over GDP ratios). **The equivalent figures for the USA are twice as big as those of the EU.** With roughly equivalent GDP for the US and the EU, a two-to-one ratio between the US and EU is observed in terms of (a) total ICT R&D expenditure (ICT GERD), (b) business ICT R&D expenditure (ICT BERD) and (c) public ICT R&D expenditure (ICT GBAORD), as illustrated in Figure 3.

In terms of total R&D investment (in all sectors), the gap between the EU and the US is €73 billion, of which almost half (€33 billion) is accounted for by the ICT sector.

In relative terms, when comparing ICT BERD to GDP ratios, one third of the business R&D expenditure gap with the USA is due to the smaller size of the EU ICT sector, while two thirds are due to the lower R&D intensity of the EU ICT sector as a whole (measured as ICT BERD/ICT value added). Factors contributing to the lower R&D intensity include sectoral composition and overall size of companies. These observations should be interpreted with a degree of caution. They do not necessarily mean that the gap in R&D intensity is due to individual EU ICT companies spending less on R&D than their American counterparts. On the contrary, a recent JRC-IPTS report shows that company R&D intensity is similar for comparable EU and US firms in the different ICT sub-sectors.[12] Analyses at ICT sub-sector and company levels are provided in Chapters 5 and 6 of this report.

The EU total R&D investment is also well below that set in the Lisbon agenda and, in particular, the 3% Barcelona Target as illustrated in Figure 4.

12 See the JRC-IPTS Reference Report "Mapping R&D Investment by the European ICT Business Sector" (Lindmark et al. 2008)

Figure 3: Breakdown of ICT GERD for the EU27 and the USA (billion €), 2005

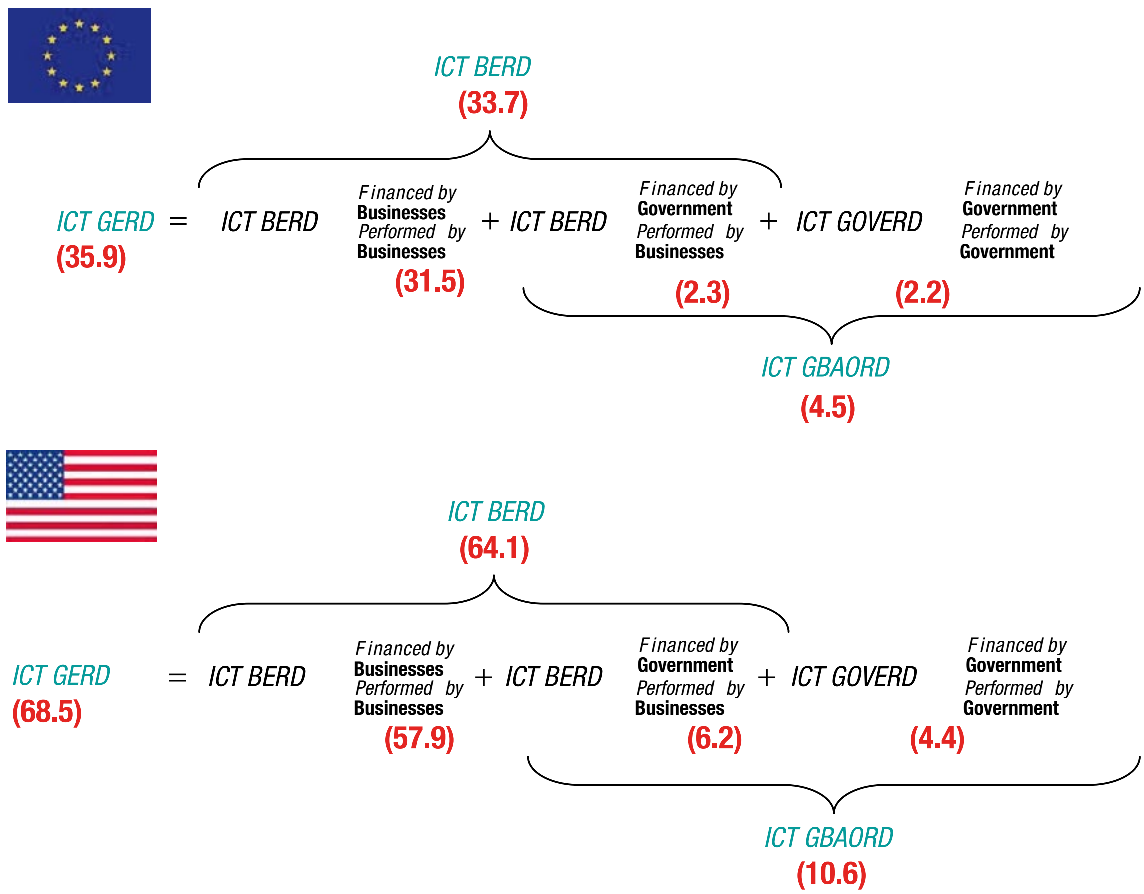
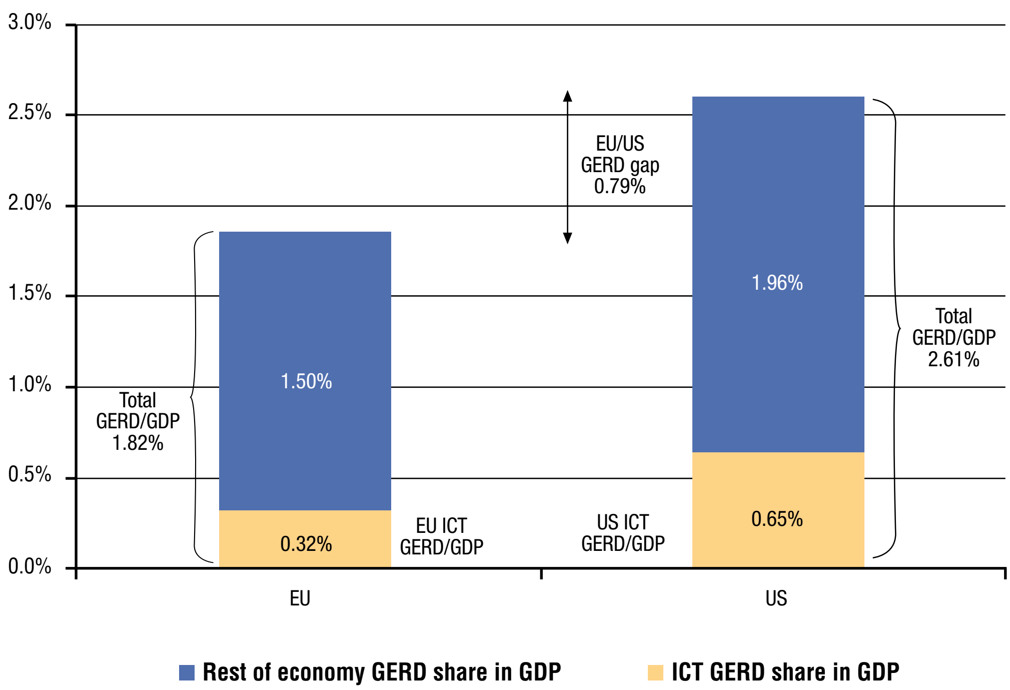
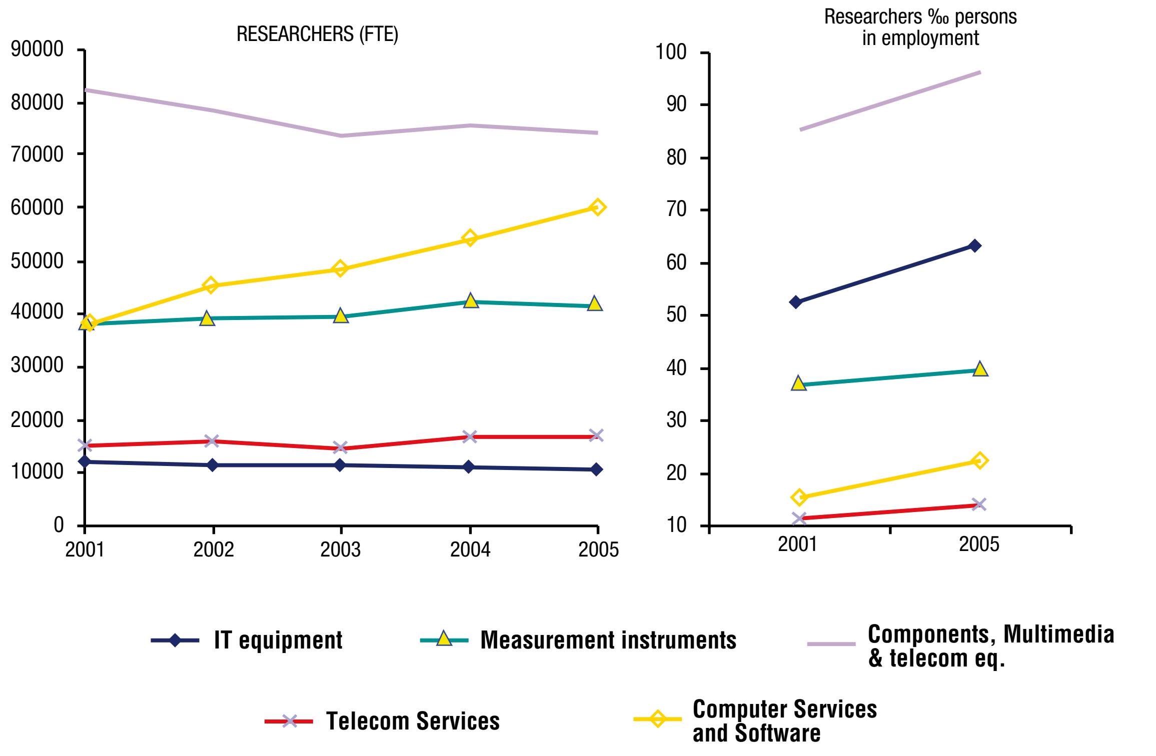


Figure 4: The Barcelona target: Total GERD and ICT GERD as % of GDP, for the EU27 and the USA, 2005.



Source: EUROSTAT and IPTS calculations.

Figure 5: EU27 ICT sector researchers and R&D employment intensity by industry, 2001-2005



Source: IPTS estimates based on Eurostat, OECD and national sources.

3.3 R&D expenditures in the ICT services and manufacturing sub-sectors

In the period 2001 to 2005, ICT manufacturing, and also telecom services, experienced decreasing BERD (in real terms) and stagnating or decreasing numbers of researchers. The reduction since 2001 in the number of researchers in ICT manufacturing, particularly in the Components, Multimedia and Telecom Equipment sub-sector, was however counterbalanced by an increase of researchers in ICT services, particularly in the Computer Services and Software sub-sector. **The Computer Services and Software ICT sub-sector is, moreover, the only EU ICT sub-sector with a clear sustained trend showing increasing BERD** (+40% from 2001 to 2005) **and increasing employment of researchers** (+60% during the same period).

3.4 Top ICT investing companies and business demographics

PREDICT offers a detailed analysis of top R&D investing companies in the ICT sector, comparing companies or groups registered in the EU to those registered in the rest of the world. This analysis reinforces the nature of the differences between the EU and US ICT industrial landscapes. In particular, relatively young (less than 15 years old) US companies show strong R&D investment growth, while they already have high absolute levels of R&D investment. In comparison, the EU has fewer large ICT companies with high R&D investments, and they are usually older than their US counterparts. Hence the dynamics and growth characteristics exhibited in the US are less present in the EU. In particular, even though Computer Services and Software is currently the most dynamic ICT sub-sector in the EU in terms of R&D investment, US firms largely predominate in this sub-sector on a global level.

3.5 Public funding of ICT R&D

This year's PREDICT report provides a first set of estimated data on public funding of R&D based on Government Budget Appropriations or Outlays for R&D by Socio-economic Objectives (GBAORD), as computed and published by OECD (Science, Technology and Patents Statistics Database) and Eurostat (R&D Statistics Database), and following the recommendations of the Frascati Manual (OECD, 2002).

It must be underlined that this estimate excludes indirect forms of R&D support by the government, for example, the remission of taxes for industrial R&D, loans, and public funding to venture capital instruments. This estimate also excludes funding provided by the local governments and therefore may overlook some potentially important channels of public support. This is, in particular, valid for the US, for which regional or state funding is not taken into account in the GBAORD figures. The R&D procurements are a subset of the R&D totals reported in GBAORD.

Inconsistencies might appear at different levels when looking into different data sources. There might be significant data classification issues between the GBAORD data used and other data sources reporting on R&D procurements. Inconsistencies might appear as well between the data collected at performer level (GERD/BERD) and data collected a source level (GBAORD), mainly due to the fact that not all funds budgeted are actually obligated. In spite of these caveats, GBAORD data provided by OECD and EUROSTAT remain the main reference point for the public support of research.

PREDICT has estimated the part of GBAORD directed to ICT industries using a range of methods and references, mostly based on expert interviews. This year's results should therefore be taken to indicate an order of magnitude, rather than providing a precise measurement. The work on deepening this research and refining results is ongoing.

PREDICT present results indicate that EU Governments apparently **fund only a relatively small share of ICT R&D.** In 2005, EU governments' support to ICT R&D, estimated through Government Budget Appropriations or Outlays on R&D (GBAORD), was €4.5 billion, or 12.5% of ICT GERD. This is well below the US figure of €10.6 billion that represent 15.5% of US ICT GERD (itself twice as large as the EU ICT GERD). As illustrated in Figure 3, the difference in public funding between the EU and the US results from differences both in terms of government funding for ICT R&D performed in public institutions (ICT GOVERD, €2.2 billion EU vs. €4.4 billion US), and in terms of government funding for R&D performed by the business sector (€2.3 billion EU, vs. €6.2 billion US) - a share of ICT BERD. In particular, the business expenditure in R&D financed by governments is almost three times higher in the US than in the EU.

4. Further investigations

The next PREDICT report will include data for the period 2001-2007, based entirely on comprehensive EUROSTAT data resulting from the implementation of the new data collection Regulation.[13]

Future lines of investigation include:

- Business demographics EU/US linked to differential R&D investment, company growth rates and globalisation capacities.
- ICT R&D and production off-shoring and implications for R&D/VA (intensity) determination.
- ICT R&D undertaken outside the ICT business sector.
- Modelling of ICT sectors based on general equilibrium approach.

13 With implementation of the Regulation 753/2004, transmission by the EU Member States to EUROSTAT of BERD broken down by industry is obligatory since reference year 2003 (except when they used derogations).

1 Introduction

This report provides an analysis of the state of Information and Communication Technologies (ICT) Research and Development activities in the European Union.

It was produced by the Information Society Unit of the Institute for Prospective Technological Studies (IPTS)[14] under PREDICT,[15] a research project analysing Research and Development (R&D) in ICT in Europe. PREDICT is being run by the IPTS for the Directorate General Information Society & Media of the European Commission. The project follows up on previous work in the same field.[16] This report is the first of a series of PREDICT annual reports.

Each annual report will consist of two parts: the first will provide an analysis of available data as part of a regular reporting on ICT R&D that is provided yearly, and the second will focus on a particular topic. This year's report focuses on output of R&D in ICT.

Part I starts with a short overview of the ICT sector in general and presents general trends in the EU ICT R&D landscape (Chapter 2). It then analyses R&D in the ICT sector overall, first by putting the available data on the EU27 in an international perspective, looking in particular at Japan and the USA as benchmarks (Chapter 3). Analyses by ICT sub-sector and by Member State follow in Chapters 4 and 5 respectively. Chapters 2 to 5 are based on data from the national accounts systems and on statistics on business and government R&D expenditure, business R&D employment, value-added, turnover and trade. Chapter 6 provides a complementary analysis at company level, using data from the EU Industrial R&D Investment Scoreboard, which tracks R&D spending by the biggest European and non-European R&D spenders.

Part II of the report includes a thematic analysis on R&D output in ICT and provides a detailed investigation of ICT R&D output based on the analysis of patent data. Chapter 7 is an introduction to analysis of R&D performance and presents a conceptual framework for the analysis and assessment of innovative activities. Chapter 8 provides an overview of ICT patenting in the European Union and a comparison of ICT patenting performance by Member State. Finally, Chapter 9 provides the conclusions of the report. Several methodological annexes can be found at the end of the report.

14 The Institute for Prospective Technological Studies (IPTS) is one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC).
15 PREDICT: Prospective Insights on R&D in ICT
16 See the JRC Reference Report "Mapping European Investment in ICT R&D" published in November 2008. It is available at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1879

PART 1: General Analysis of ICT R&D in the European Union

2 The ICT sector and ICT R&D in the EU economy

This chapter presents a brief overview of the ICT sector and underlines its importance in terms of R&D in comparison to other sectors of the EU economy.

The ICT sector, as defined in this report, includes all firms whose principal activity is in NACE classes 30 (IT Equipment), 32 (Components, Telecom and Multimedia Equipment), 33 (Measurement Instruments), 642 (Telecom Services) and 72 (Computer Services and Software).

The ICT sector is easily the leading sector in the EU economy in both labour productivity (almost twice the whole economy average) and R&D expenditure, although its weight in the EU economy is lower than the weight of other sectors. The ICT sector is therefore the sector contributing most to the development of the EU knowledge economy.[17]

2.1 Overview of employment and value added in the EU ICT sector

In 2005, there were about 680,000 enterprises in the EU27 whose main activity was in ICT manufacturing and service industries, with 5.9 million people employed and a value added approaching 500 billion €,[18] corresponding to a little less than 3% of total employment and to 4.9% of GDP. With respect to the EU27 non financial business economy,[19] these figures amount to 3.5% of enterprises, 4.6% of employment and 9.0% of value added. In recent years, the ICT sector has slightly reduced its share in employment and increased its share in value added.

Employment in ICT services grew more than the average for non financial services, while in ICT manufacturing it declined at a faster rate than overall manufacturing employment. ICT services now account for nearly 70% of total ICT employment (10 percentage points more than at the end of the 1990s), with Computer Services and Software alone reaching almost 50%.

ICT manufacturing employment shrank from about 2.25 million to less than 2 million between 2000 and 2005, and value added at current prices stagnated; employment decreased in IT Equipment and in Components, Telecom and Multimedia Equipment, whilst growing in Measurement Instruments. Among service activities, meanwhile, employment grew from 2.2 to 2.7 million in Computer Services and Software and fell from 1.2 to 1.1 million in Telecom Services, while value

17 Figures presented in this report are IPTS estimates based on official sources and refer to the EU27, although some data include periods in which the EU had only 15 and then 25 member states.

18 See Annex 4 - Methodology for value added data, and Annex 5 - Methodology for R&D employment data.

19 The non-financial business economy excludes agriculture, public administration and other non-market services, as well as the financial services sector. It includes NACE sections C to I and K.

added increased, especially in the latter industry Figure 2-1). A similar tendency can be observed in the USA, where employment shrank by about 30% in ICT manufacturing, and expanded in ICT services, although at a slower pace than in the EU.

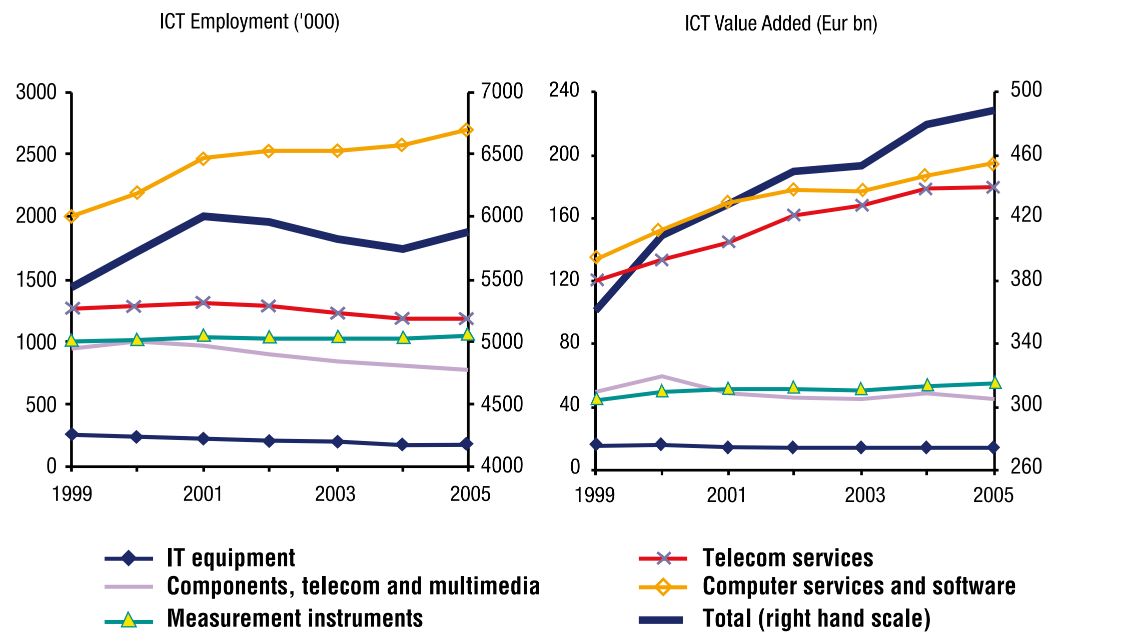
Methodological note

All figures characterising the ICT sector presented in Chapters 2 to 5 only refer to those ICT industries included in the NACE classes listed above (30, 32, 33, 642 and 72). They do not therefore cover ICT-related activities embedded into other sectors of the economy, such as those taking place in IT departments of firms not belonging to the ICT sector.

ICT enterprises have a much higher than average labour productivity (as measured by value added per person employed), both in manufacturing (58,000 € in 2005, against 47,000 € for overall manufacturing) and in service industries (80,000 € in Computer Services and Software and 160,000 € in Telecom Services, against less than 40,000 € for the aggregate of non financial business services). With respect to the 1999-2000 levels, ICT sector labour productivity grew faster than the non-financial business economy average thanks to services, especially telecommunications. In ICT manufacturing, on the other hand, productivity growth was sluggish and even negative in IT Equipment. However, it is worth noting that this drop in IT Equipment is due entirely to the effect of quickly falling unit prices, while physical output was still growing.

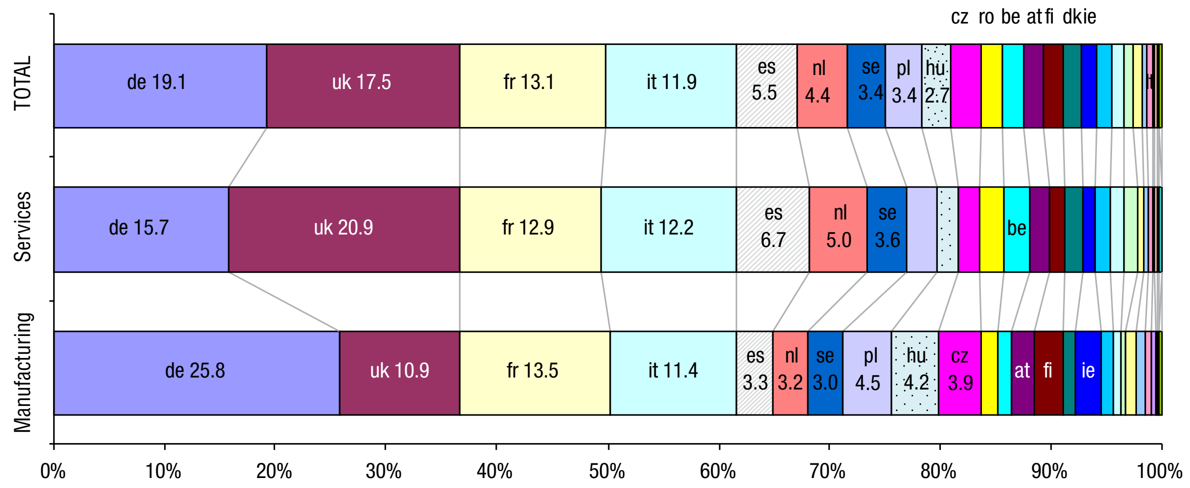
The five largest EU economies (DE, UK, FR, IT, and ES) accounted for 2/3 of total employment in both ICT manufacturing and services in 2005 (see Figure 2-2). In manufacturing, this share went down to 65% in 2005 from 70% in 2000, as France and the UK were most affected by the employment fall in IT equipment. The UK also lost the most employment in Components, Multimedia and Telecom Equipment, and lost more than one third of its employment base in ICT manufacturing, falling behind France and Italy (in the UK, there was a decrease of 130,000 people out of a total decrease in the EU of 200,000 people). Hungary and the Czech Republic, on the other hand, recorded increases of respectively 27% and 16%.

Figure 2-1: Employment and value added in the EU 27 ICT sector 1999-2005. 1 000 people and billions of €



Source: IPTS estimates based on Eurostat

Figure 2-2: Country shares in the EU27 ICT sector employment, Manufacturing, Services and Total, 2005



Source: IPTS estimates based on Eurostat SBS data

When it comes to ICT services, the UK is the leading country in employment both for Telecom Services and for Computer Services and Software, with an overall share of 21%. In Telecom Services, nearly all countries but Germany lost employment with respect to the year 2000. Employment grew everywhere in Computer Services and Software.

Overall, the relevance of ICT for total employment in the non-financial business economy varies widely among the EU27 countries, from less than 3% in Portugal, Greece, Spain, Latvia, Poland, Cyprus and Romania, to more than 7% in Sweden, and near to 9% in Finland and Ireland.

2.2 R&D expenditure in the ICT sector

In the EU in 2005, gross expenditure in ICT R&D (GERD) was €35.9 billion, which represents 18% of the total R&D expenditure of €201.5 billion. The bulk of GERD consists of business expenditure in R&D (BERD).[20] In 2005, the ICT sector BERD totalled €33.7 billion, or 94% of GERD. The remaining 6%, i.e. €2.2 billion, consist of government-funded R&D executed outside of the private sector.[21] Within the ICT sector, two thirds of BERD are accounted for by manufacturing and one third by services industries.

The €33.7 billion of ICT BERD represent a share of 26.4% of total BERD in the EU economy, which was €127.7 billion in 2005.[22] This share not only makes ICT the number one sector in BERD, but actually means that the ICT sector alone is nearly as important for R&D as the two next sectors combined, pharmaceuticals and biotechnology, and automotive. The next sectors, aerospace and machinery and equipment, are far behind, each one representing less than a third of the ICT sector BERD share.

In addition, since R&D expenditure in other economic sectors often concerns ICT as well, – i.e. in "embedded systems," it is safe to say that the R&D in the technological field of ICT is significantly above the R&D in the ICT sector

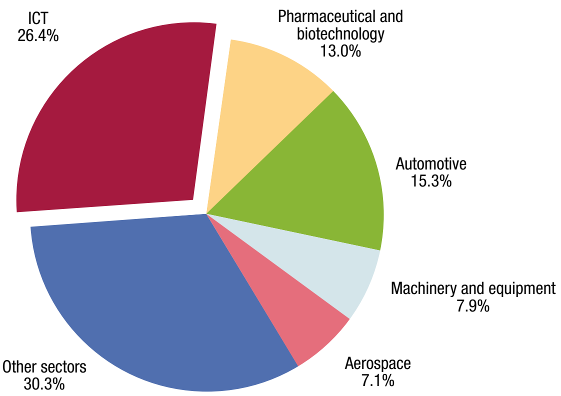
20 Data on BERD used this report are based on figures published by EUROSTAT and OECD as from the 6 December 2008.

21 See Section 3.3 on GERD

22 The share of BERD is higher than the share of GERD, because GERD includes government expenditures covering a much broader set of research domains than BERD, including non-industrial domains

itself. For example, much of the research done in the automotive sector involves electronic on-board systems, and much of the development work in aerospace concerns electronic steering and control.[23] Although a thorough literature review shows that nobody has quantified this embedded research yet,[24] according to OECD (2008b), a large share of the R&D in non-ICT industries (about one-quarter of economy-wide total ICT R&D) leads to ICT products.

Figure 2-3: Share of ICT in EU total BERD, 2005



Source: IPTS estimations based on EUROSTAT

2.3 R&D employment in the ICT sector

In 2005, the total number of R&D personnel in the ICT sector in the EU27 consisted of about 305,000 full time equivalent units (FTE), according to IPTS estimates,[25] out of which 203,000 were researchers. Thus, the European ICT sector provided 27% of the total business employment in R&D and employed 32.3% of all researchers in the total economy, confirming that this sector is the most important for business R&D, by far. Other knowledge intensive sectors employed much lower shares of the researchers in the total economy: 13.1% in the automotive industry, 8.5% in machinery and equipment, 7.7% in pharmaceuticals, and 5.1% in aerospace.

The ICT sector employs more researchers than any other in the economy. It also leads in R&D employment intensity (FTE researchers over total employment in the sector): in 2005, for the whole of the business economy, there were 3.8 FTE researchers per 1,000 people employed (up from 3.3 per 1,000 in 2001); this ratio stands at 34.6 for the ICT sector, 8.7 for aerospace, 8.2 for pharmaceuticals, 3.7 for cars, and 1.5 for the machinery and equipment.

In other words, the intensity of R&D employment in the ICT sector was nearly ten times higher than the average for the total economy, and about four times higher than it is in those high tech industries where R&D employment intensity is closest. As pointed out above, these figures do not take into account ICT researchers employed outside the ICT sector.

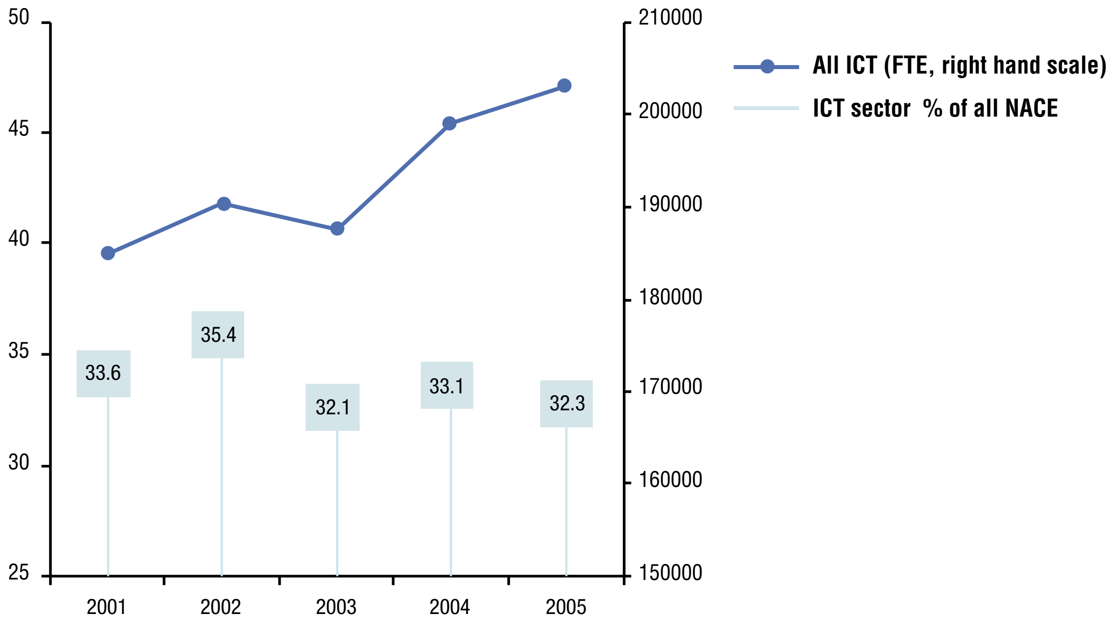
With respect to 2001, the number of researchers (FTE) in the ICT sector grew by about 10%, as can be seen in Figure 2-4. However, the ICT sector researcher share in the EU economy decreased by a little more than one percentage point (from 33.6% to 32.3%), due to higher growth in the rest of the economy. A similar pattern can be observed with respect to ICT total R&D employment (including both researchers and support personnel).

23 The opposite occurs in relation to R&D in photovoltaics, which use semiconductors for energy generation. However, the size of R&D in photovoltaics is much smaller than the size of R&D on ICT embedded systems in other sectors.

24 The IPTS is currently running a pilot project on behalf of DG INFSO to study the production and diffusion of embedded systems.

25 R&D employment includes all personnel employed in R&D units; researchers are professionals engaged in the conception or creation of new knowledge, products processes, methods, and systems, and in the management of the projects concerned (OECD Frascati Manual (2002)). A precise definition and a concise description of the estimation methodology can be found in Annex 5.

Figure 2-4: Researchers in the EU27 ICT sector: number (FTE) and % of total economy, 2001-2005



Source: IPTS estimates based on Eurostat, OECD and national sources

2.4 Conclusions

The ICT sector is a major R&D sector in the EU economy, in spite of the fact that it represents only about 3% of total employment in the EU and 4.9% of its GDP. With 18% of Gross Expenditure in R&D (GERD), 26% of overall Business Expenditure in R&D (BERD) and 32.3% of all researchers, the ICT sector is far ahead of the other sectors and a major contributor to the EU knowledge economy.

ICT services account for nearly 70% of total ICT employment, with Computer Services and Software alone reaching almost 50%. Among service activities, employment grew between 2000 and 2005 from 2.2 to 2.7 million in Computer Services and Software and fell from 1.2 to 1.1 million in Telecom Services. Meanwhile, ICT manufacturing employment shrank from about 2.25 to less than 2 million. The ICT sector is significantly ahead of other economic sectors in labour productivity, both in manufacturing and service industries.

The ICT sector employs more researchers than any other sector in the economy. Between 2001 and 2005, the number of researchers (FTE) in the ICT sector grew by about 10% to reach 203,000. R&D employment intensity in the ICT sector is nearly ten times higher than the average for the total economy, and about four times higher than it is in those high tech industries where R&D employment intensity is closest. These figures do not take into account ICT researchers employed outside of the ICT sector.

3 R&D in the ICT sector from an international perspective

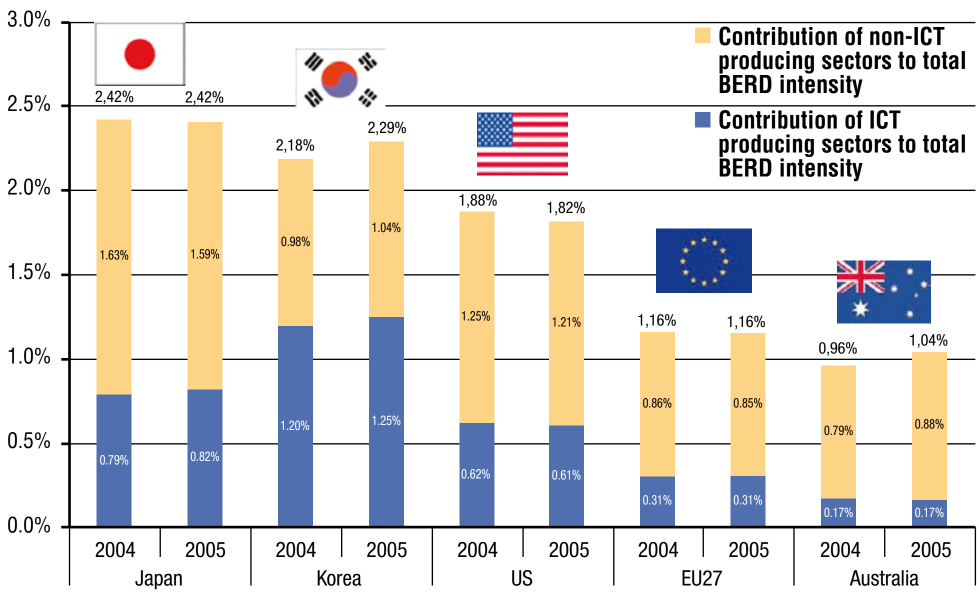
3.1 Business expenditure in ICT R&D (ICT BERD)

3.1.1 The contribution of the ICT sector to total BERD intensity (BERD/GDP)

The ICT business sector in the EU spent €33.7 billion on R&D in 2005 (BERD). This was far below the USA at €64.1 billion (in PPP exchange rates),[26] but more than Japan (€26.8 billion), Korea (€10.9 billion) and Australia (€1.5 billion). These €33.7 billion spent in ICT research amount to 0.31% of EU GDP (this is the *contribution of the ICT sector to total BERD intensity (BERD/GDP)* – see Figure 3-1), whilst the €64.1 billion spent in the USA correspond to 0.61% of the US GDP, a contribution twice the EU level. The contribution of the ICT sector to total BERD intensity was, however, much higher in Japan, and even higher in Korea, where it is four times the EU level. Among the countries used in this comparison, only Australia has a lower level than the EU.

In 2005, business spending on R&D in **all sectors together** in the EU amounted to 1.16% of GDP (total BERD intensity). Again, this is significantly less than the 1.82% of the USA, and even further behind Japan and Korea.

Figure 3-1: Contribution of the ICT sector to total BERD intensity (BERD/GDP): 2004-2005



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics

26 PPP (Purchasing Power Parity) adjustment is used in order to attenuate the impact of price differentials and exchange rate movements over time in international comparisons. It best portrays the *effort* in terms of non tradable inputs amongst which, notably, labour.

Table 3-1: ICT BERD broken down into size and intensity factors

	ICT BERD in the economy (ICT BERD/GDP)	=	Size (ICT VA/GDP)	x	Intensity (ICT BERD/ICT VA)
Korea	1.25%		10.4%		12.0%
Japan	0.82%		7.4%		11.1%
USA	0.61%		6.1%		9.9%
EU27	0.31%		4.9%[1]		6.2%[2]
Australia	0.17%		4.4%		3.8%

1 *The ICT VA includes Post and Telecommunications sector, for international comparisons. If only the Telecommunications sector is included, the share decreases to 4.4%*

2 *The ICT VA includes Post and Telecommunications sector, for international comparisons. If only the Telecommunications sector is included, the share increases to 6.9%*

Source: IPTS estimates based on data from Eurostat, OECD, EU KLEMS

Total BERD intensity in the EU remained at the same levels in 2004 and 2005. In fact, the ratio BERD/GDP saw very limited variation for the whole period 2003-2007, and so did the ICT sector's respective ratios.

One should also note that the ICT sector alone accounted for 46% of the total R&D intensity gap with the USA, 41% of the gap with Japan, and a staggering 83% of the gap with Korea. Indeed, in Korea the ICT sector invests more in BERD relative to GDP (1.25% in 2005), than all sectors together in the EU (see Figure 3-1).

3.1.2 Economic weight and R&D intensity of the ICT sector

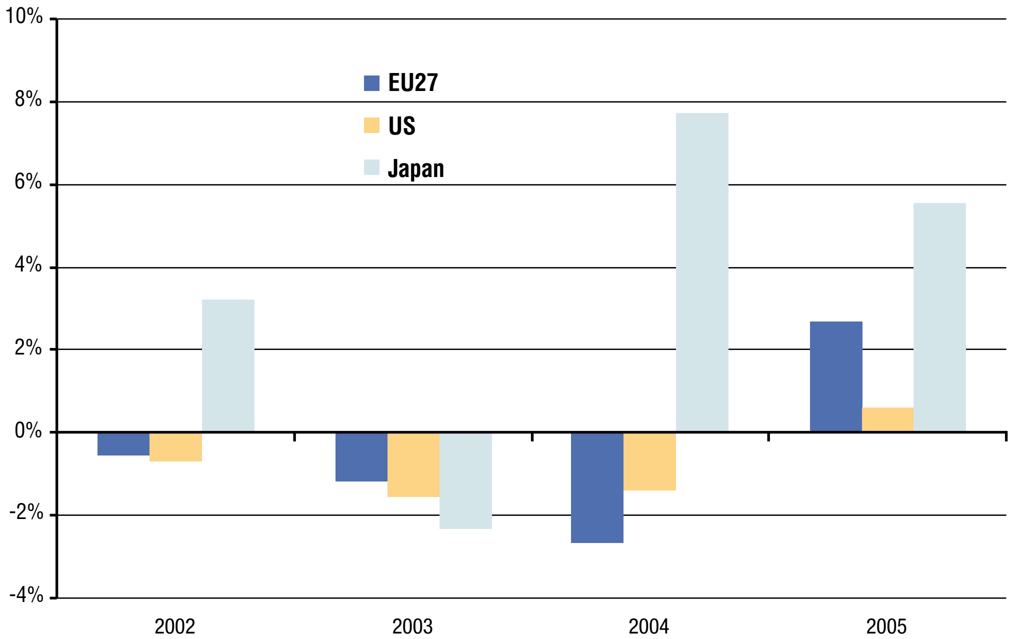
The contribution of ICT BERD to total economy BERD depends mainly on two factors: the relative size of the ICT sector in the economy (measured by its value added (VA) over GDP), and the R&D intensity of the ICT sector (measured as ICT BERD over ICT value added).[27] A relatively larger ICT sector will naturally have a higher share in total R&D, while a high R&D intensity in a sector indicates strong investment in technological advances. Breaking down the above data according to the formula ICT BERD/GDP = (ICT VA/GDP) * (ICT BERD/ICT VA), gives the results shown in Table 3-1.

As the data in Table 3-1 indicates, part of the reason why the ICT sector contributes less to total economy BERD intensity in the EU than in its main competitors is that the sector is relatively smaller, i.e., it has a smaller relative weight in the overall economy (ICT VA/GDP). The difference is particularly pronounced in comparison to Korea, where the ICT sector accounts for twice as much of the economy as it does in Europe. The difference with Japan and the USA is sizeable, but much less significant. Australia's ICT sector is smaller than the EU's.

However, the EU ICT sector also has a lower R&D intensity than its main competitors (ICT BERD/ICT VA). Indeed, in comparison with the USA, the gap in R&D intensity is much bigger than the difference in relative size: the higher contribution of ICT to total BERD intensity in the USA is therefore more due to the higher R&D intensity of the sector than to its larger relative size. This observation should, however, be interpreted with caution. It does not necessarily mean that the gap in R&D intensity is due to lower R&D expenditure by individual EU ICT companies than by their American counterparts. On the contrary, a recent JRC-IPTS report shows that company R&D intensity is similar for comparable EU and

27 The different R&D intensity ratios used in the PREDICT report and their specific features are discussed in Annex 2 – Description of R&D intensity indicators

Figure 3-2: Annual ICT BERD Growth in the EU27, the USA and Japan, 2001-2005, percentage changes; data computed using GDP deflators



Source: IPTS estimates based on data from Eurostat, OECD, EU KLEMS

US firms in the different ICT sub-sectors.[28] Further analysis at ICT sub-sector and company levels can be found in Chapter 4 (sections 4.4 and 4.5) and in Chapter 6 (sections 6.4 and 6.5). The case of Japan is similar, but both the R&D intensity of the ICT sector and the economic weight of the sector in the Japanese economy are bigger still than in the USA. Korea, meanwhile, has the highest R&D intensity, which is nearly twice as high as that of the EU. Additionally, Korea's ICT sector is also twice the weight of the EU ICT sector. Finally, the Australian ICT sector has a lower R&D intensity than the EU one.

3.1.3 ICT BERD growth: international comparison

As was seen in Figure 3-1, ICT BERD intensities (ICT BERD/GDP) changed only a little in absolute terms from 2004 to 2005, since they are expressed as small percentages. The figures for recent growth of ICT BERD are therefore more instructive. Figure 3-2 shows that ICT BERD has started to grow again in the three most important research spending regions in 2005, after three years of negative real growth, i.e. when growth in ICT BERD was either negative or lower than the inflation rate.[29]

ICT BERD grew faster in the EU27 than in the USA in 2005, reversing the situation of the year before. But even more spectacular is the performance of Japan: after the slump in 2003, it returned to strong growth a year before the EU and the USA, and has maintained that rhythm in 2005. Note, however, that the figure for Japan may be exaggerated due to negative inflation. As a result, real growth rates are higher than nominal ones, while the opposite is true for the EU and the USA.

28 See the JRC-IPTS Reference Report "Mapping R&D Investment European by the European ICT Sector" (Lindmark et al. 2008)

29 Data for Korea, Australia and Canada unavailable

3.2 Government financing of ICT R&D (ICT GBAORD)

This section presents European governments' total R&D financing and ICT R&D financing, respectively named total GBAORD[30] and estimates of ICT GBAORD. ICT GBAORD measures government support to ICT-related R&D activities, or, in other words, how much priority governments place on the public funding of ICT R&D, irrespective of the economic sector[31] or industry[32] in which these activities are performed. Hence GBAORD reflects techno-scientific priorities rather than sector or industry–based ones. GBAORD data include both current and capital expenditure.

ICT GBAORD data have nevertheless to be taken with caution, as the current methodology for collecting GBAORD data in EU Member States, based on a nomenclature of socio-economic objectives (NABS[33]), does not even allow us to calculate directly the public funding of ICT R&D,[34] imposing the need to work with estimates. The underlying methodology is to estimate the share of ICT-related research in each of the NABS categories. The result is an estimate of the total government funds for ICT R&D, irrespective of the industry in which this is spent.

The analysis of total GBAORD data (2005) shows that while the US government spends annually around €105.5 billion on R&D[35] (€111 billion PPP[36]), the EU27 spend €81.7 billion and Japan spends €26.1 billion (€23.3 billion PPP).

In Europe, research financed from "General University Funds" was the main socio-economic objective at EU27 level (31.4% of the total), followed by "Non-oriented Research" (15.1%) and by "Defence" (13.3%). Defence represents major shares of total GBAORD in the UK (31%), France (22.3%), Sweden (17.4%) and Spain 16.4%). In the period 2000-2005, GBAORD has been increasing in all EU Member States, at an annual average growth rate of 4.3% for the EU27.[37]

As a share of total GBAORD, ICT GBAORD represents approximately 5.4% of total government support in Europe to R&D activities, i.e. €4.5 billion of a total of €81.7 billion, while the US government dedicates some 9.5% of its total R&D spending to ICT, i.e. €10.6 billion PPP of a total of €111 billion PPP (Figure 3-3).[38]

The following figures show GBAORD and ICT GBAORD, first in absolute value (PPP), and second, expressed as a percentage of GDP. This makes it possible to compare across countries while neutralising the effect of the size of the economies.

The EU27 figure of 81.7 billion € of total GBAORD amounts to 0.74% of the European GDP, below the US GBAORD share of 1.06% of

30 Government budget appropriations or outlays on R&D (GBAORD): "are all appropriations allocated to R&D in central government or federal budgets and therefore refer to budget provisions, not to actual expenditure. Provincial or state government should be included where the contribution is significant. (…). Data on actual R&D expenditure, which are not available in their final form until some time after the end of the budget year concerned, may well differ from the original budget provisions. This and further methodological information can be found in the Frascati Manual, OECD, (2002). GBAORD data are assembled by national authorities using data for public budgets. These measure government support to R&D activities, or, in other words, how much priority Governments place on the public funding of R&D." (European Commission, 2008a)

31 Government, business enterprise, private non-profit, higher education and abroad.

32 In this report the classification used for economic sectors is NACE Rev.1.1

33 NABS: Nomenclature for the analysis and comparison of scientific programmes and budgets

34 The methodologies used for elaborating the ICT GBAORD data presented in this section are based on estimates by IPTS and will be fully described in a forthcoming IPTS Technical Report on "Public Expenditures in ICT R&D". A short summary is provided in the methodology Annex 6

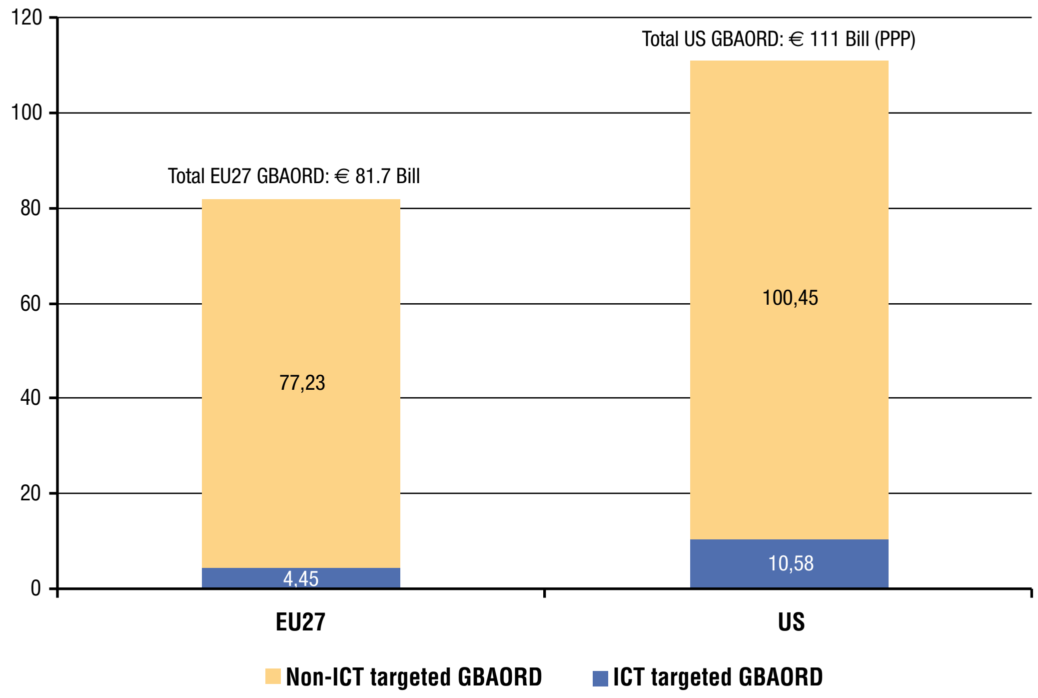
35 US GBAORD includes the financing of R&D by the Defence Advanced Research Projects Agency (DARPA), part of the Department of Defence (DoD)

36 PPP: Purchasing Power Parity: allows for adjusting for difference in price levels, before comparing with EU27

37 European Commission, 2008a, p.4

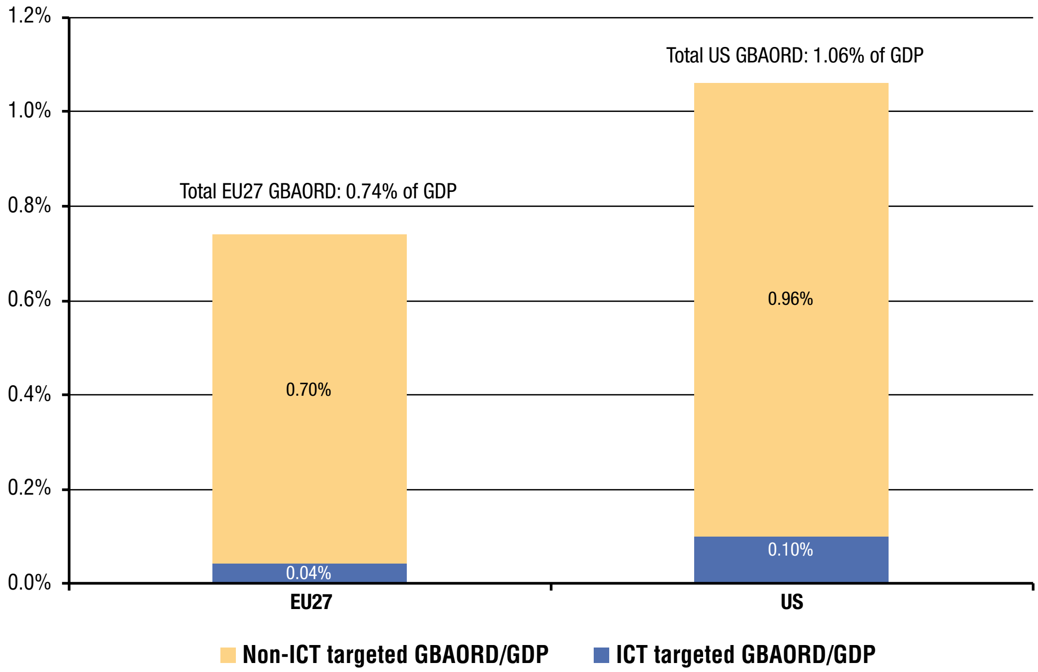
38 All data and estimates will be available in the above mentioned forthcoming IPTS Technical Report on "Public Expenditures in ICT R&D".

Figure 3-3: Public expenditures in R&D in the EU27 and the USA. (billion € PPP), 2005



Source: EUROSTAT and IPTS calculations.

Figure 3-4: Public expenditures in R&D as share of GDP in the EU27 and the USA, 2005



Source: EUROSTAT and IPTS calculations.

GDP, but slightly above the 0.71% share of GDP in Japan (not in the figure).

Finally, the €4.5 billion spent by the EU governments in ICT research amount to 0.04% of EU GDP, whilst the €10.6 billion PPP spent by the US government correspond to 0.1% of US GDP.

To sum up, in 2005 public expenditures on R&D represented some €111 billion (in PPP exchange rates) in the USA against some €81.7 billion in Europe. The share of this public expenditure targeted at ICT R&D is rather low, representing less than 10% of the total, both in the US and the EU, as governments support a wide variety of research domains including, for example, humanities. But European public expenditures in R&D, for both the whole economy, and specifically for ICT R&D, lag behind US spending in absolute value and also as a share of GDP. The US invests more in R&D proportionally to its GDP and in real terms, The US also invests more in targeted ICT R&D as a share of it overall public budget for R&D. In fact, in terms of share of ICT GBAORD relative to GDP, the EU27 value is less than half that of the US corresponding figure (see Figure 3-4), while the total GBAORD as a share of GDP is smaller only by one third. In other words, the ICT GBAORD is responsible for as much as 20% of the gap between the US and the EU27 (in terms of GBAORD as a share of GDP).

These observations are even more relevant if we remember that, contrary to the general rules applying to EU Member States for GBAORD data collection, the US data does not include individual States' GBAORD,[39] classified research to US security expenditures for R&D[40] which in itself represents an important share of the total R&D budget of the Pentagon, or public procurement of R&D by the Department of Defence. Taking these additional facts into account, the gap in public expenditures for ICT R&D between the US and the EU27 appears to be much larger than the one calculated strictly on the basis of available GBAORD data.

3.3 Contribution of the ICT sector R&D to the Barcelona target (ICT GERD)

The economic and social ambitions of the EU were set for the decade at the European March 2000 Summit in Lisbon.[41] This was followed by the March 2002 Summit in Barcelona where targets were set for the R&D domain. The Barcelona Summit aimed to give a significant boost to overall R&D in Europe, with a particular emphasis on increasing gross expenditure on R&D (GERD) to 3% of the European GDP, with business sector financing reaching an average share of two thirds of this gross expenditure on R&D (GERD).

GERD is defined as total intramural expenditure on R&D performed in European territory during a given period. As shown in Figure 3-5, GERD can be broken down according to the sectors *financing* the R&D effort or to the sectors *performing* the R&D.[42] The main objective of this section is to estimate the ICT sector GERD (ICT GERD), and its contribution to the Barcelona 3% target. Previous sections of this chapter presented data on ICT BERD (R&D performed in the ICT Business sector, Section 3.1) and ICT GBAORD (ICT R&D financed by the government, Section 3.2). The current section attempts to put these

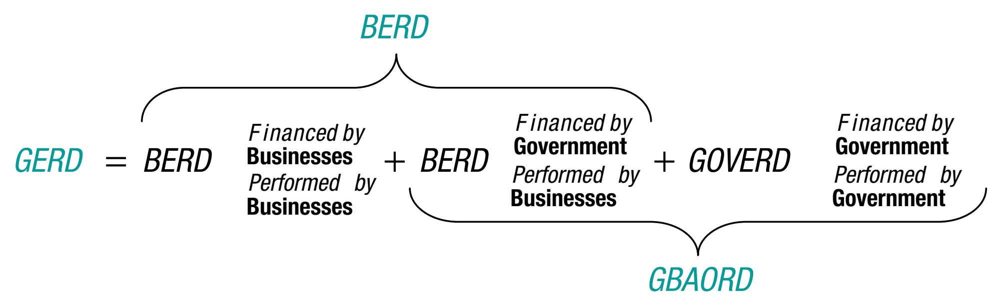
39 "In 2004, California was by far the largest spender with around $60 billion spent, the following state, Michigan spending "only" around $17 billion " (forthcoming IPTS Technical Report on "Public Expenditures in ICT R&D")

40 Unofficial sources in the US press specialised in the fields of defence and homeland security announce usually such budgets to amount to several dozen of $ billions, but quite evidently no official source is available or could be expected to make such information available or confirmed.

41 The 2000 Strategy has been reviewed since. In February 2005, the European Commission announced the re-launch of the Lisbon Strategy as "Partnership for Growth and Jobs".

42 The economic sectors considered are: Business enterprises, Government, Higher education, Private non-profit and Abroad.

Figure 3-5: Breakdown of GERD



data together to obtain a full picture of the overall ICT GERD.

Following the assumptions used in this report, GERD is the sum of R&D *performed* by the business sector (BERD) and the R&D *performed* by the government sector[43] (GOVERD). Data for economy-wide GERD is available from dedicated surveys, but at industry level, estimations need to be applied.

Following the French Association of Electronic Information Industry (GFII, 2006), GOVERD is estimated here as a part of the R&D *financed* by the government sector (GBAORD). In a nutshell, GBAORD consists of funds oriented towards universities and state institutions and towards businesses. The part of GBAORD that finances ICT research performed by universities and public research institutes is therefore taken as an estimate of ICT GOVERD.[44]

ICT GERD data, estimated as above, must be taken with caution. The current methodology for collecting expenditure data for financing and/or performed R&D in EU Member States or in the USA at sector level does not yet allow us to calculate directly, or in full detail, the ICT GERD data within a completely coherent and methodological framework (see Annex 6). Nevertheless, the results presented here can shed some light on the total relative position of the EU27 vs. the USA and provides interesting insights.

The EU27 spends €201.5 billion on R&D (total GERD) while the USA spends €274.5 billion (PPP). The results of our estimations show that out of this total R&D expenditure, the EU27 spends as ICT GERD €35.9 billion while the USA spends €68.5 billion (PPP). Respectively, these ICT R&D figures correspond to 18% and 25% of total R&D expenditures in the EU and the USA. These are important shares and underline the leading role of this domain in R&D, and even more so in the USA.

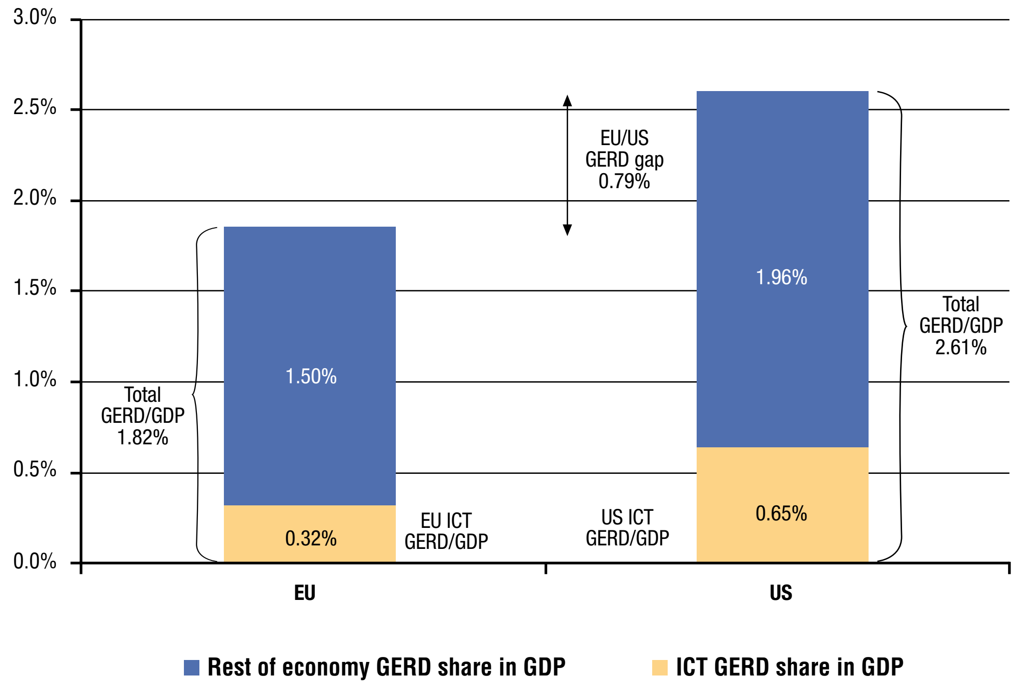
The gap between the EU27 and the USA regarding total GERD amounts to €73 billion, while the ICT GERD gap amounts to some €33 billion. The ICT sector is therefore responsible for almost half of the R&D gap between the USA and the EU27.

Indeed, throughout this report it is observed that figures on EU27 ICT R&D are consistently at around half the corresponding figures for US

43 In this report, we use a broader definition of the business sector (that includes the private non-profit sector) and of government (that includes the higher education sector). Funds from abroad are considered to be included either in business sector funds or in public sector funds, according to their concrete origin. Research performed abroad is marginal and not taken into account in GERD. For further methodological details, see Annex 6 - Methodology for GERD and GBAORD data

44 There are nevertheless a number of methodological limitations to this assumption, explained in Annex 6

Figure 3-6: The Barcelona target: Total GERD and ICT GERD as % of GDP, for the EU27 and the USA, 2005.



Source: EUROSTAT and IPTS calculations.

ICT R&D: this is true for ICT BERD, ICT GBAORD and ICT GERD. The following paragraphs look at structural issues further, in order to contrast the positions of the government and business sectors, from the point of view of both performance and financing.

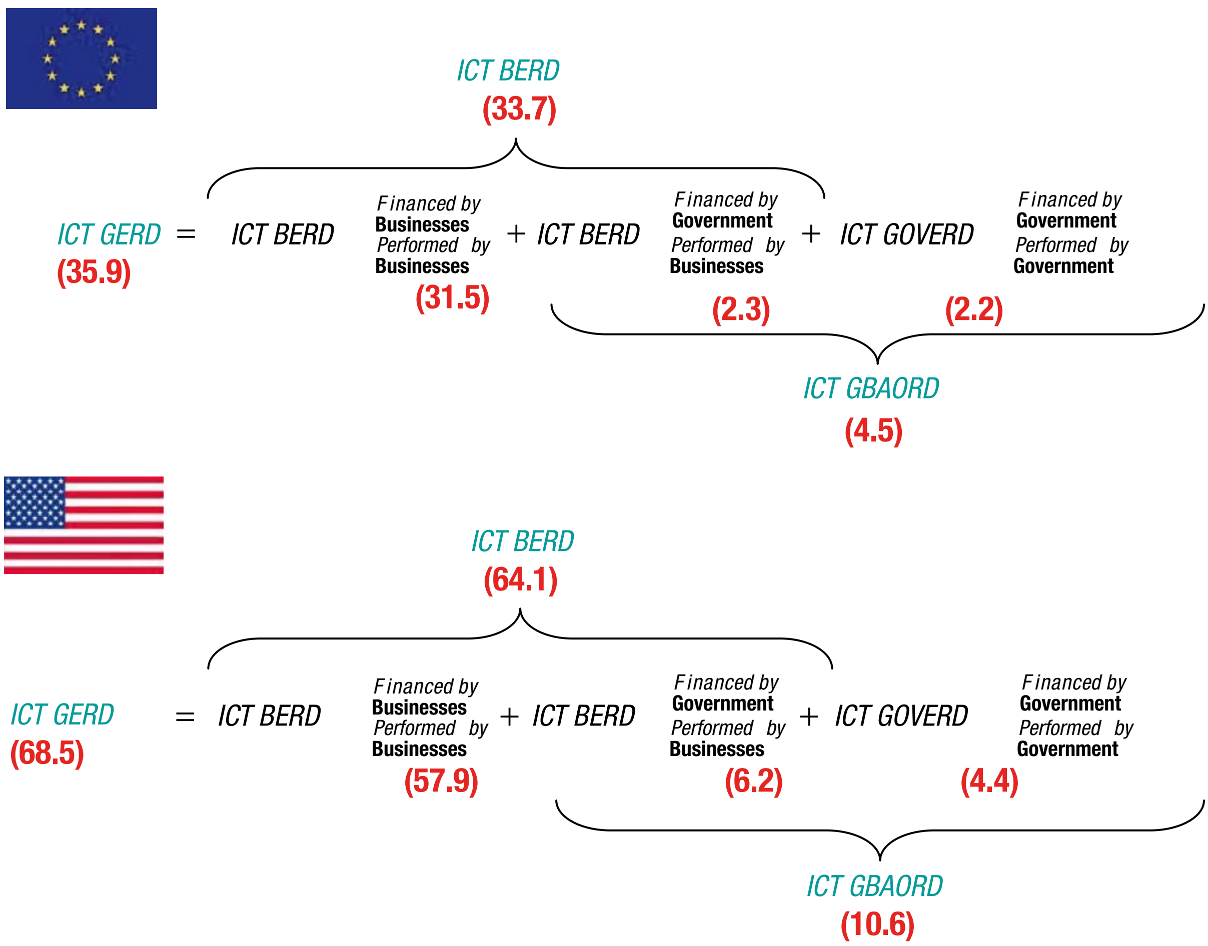
The calculations made to estimate ICT GERD provide all the elements needed for this purpose. Following the approach described above, the two equations presented in Figure 3-7 provide values for ICT GERD and its breakdown on financing sources and performing sectors for the EU and the USA (in € billion PPP**).**

Several interesting observations arise. Both in the USA and the EU27, the share of total ICT GERD *performed* by business sector (ICT BERD) is as high as 94%. This is different from the situation at the level of the total economy R&D, where the ratio BERD/GERD is 70% for US and 63% for the EU27.

On the financing side, structural similarities between the USA and the EU27 exist as well. In both cases, the *share of ICT BERD financed by the business sector* is over 80%, and significantly higher than the share of total R&D financed by the business sector (64% for the EU27 and 74% for the US). This is to be expected, since national R&D budgets also cover areas of non-commercial "frontier" R&D, while ICT activities are driven mostly by applicative R&D with fast commercialisation. This applicative R&D tends to be performed by businesses as seen above, and also financed by them.

The main structural difference between the EU27 and the USA is in the *share of ICT BERD financed by the government*. According to the estimations made here, the share of ICT BERD financed by the government is 9% of ICT GERD in the USA and only 6.4% in the EU27. Further research is needed to explain this difference and to assess its impact on general R&D performance. On a statistical level, this induces a 3 percentage

Figure 3-7: Breakdown of ICT GERD for the EU27 and the USA (billion €), 2005



point difference in the structure of business versus government financing between the USA and the EU27 at ICT sector level. This difference is in favour of the ICT BERD financed by businesses in the EU27 (they cover 87.7% of total ICT GERD in the EU27, and 84.5% in the USA). In contrast, at the level of the economy as a whole, the share of R&D financed by business in the USA is 10 percentage points higher than in the EU27.

To sum up, the EU27 Barcelona target of GERD at 3% of GDP is still rather a long way ahead, with the EU27 at 1.82% of GDP (in 2005), while the USA is at 2.61%. Here, the well known total R&D gap with the USA amounts to a GERD/GDP difference of 0.79%. Figure 3-6 also shows the EU/USA ICT GERD gap in relative terms: the USA invests 0.65% of its GDP in the ICT sector R&D, while the EU27 invests only 0.32%. Hence, there is an ICT GERD intensity (ICT GERD/GDP) gap of 0.33%.

The data analysed in this section on GERD can be summarized in three major observations:

- First, the USA invests about twice as much as the EU27 in ICT R&D. This "two-to-one" ratio, already observed with BERD data (business expenditures in *performing* R&D), is confirmed when adding Business and Government *financing* data into GERD.
- Secondly, the only notable structural difference between EU27 and US data refers to a higher share of government financing of ICT R&D performed by businesses in the USA than in the EU27.

- Thirdly, the contribution of ICT R&D to the total R&D intensity (GERD/GDP) gap between the USA and the EU27 (0.79%) can be explained as follows: close to half the total R&D intensity gap between the USA and the EU27 is due to the European ICT sector's lower R&D expenditures. This underlines the importance of this R&D domain.

3.4 Conclusions

The EU ICT sector contributes a significant share of the gap in R&D expenditure intensity between the EU and its main global competitors. For example, it contributes 46% of the gap in total BERD intensity (measured by BERD/GDP) in the USA, 41% in Japan, and 83% in Korea. These gaps are caused by a combination of the fact that, in the EU, the ICT sector is smaller (measured by value added/GDP), and the ICT sector R&D intensity is lower (measured by BERD/value added). The lower EU R&D intensity is responsible for more than half of the above gaps.

After several years of negative growth, ICT BERD growth picked up in 2005 across the EU, Japan and the USA, with the EU growth rate outperforming that of the USA in 2005.

The USA invests about twice as much as the EU27 in ICT R&D. This "two-to-one" ratio is observed not only with ICT BERD data but also when adding in business and government financing data to ICT GERD: the USA invests 0.65% of its GDP in ICT R&D, while the EU27 invests only 0.32% of its GDP. In the USA, there is also a higher share of government financing of ICT R&D performed by the business sector than there is in the EU27.

4 R&D in ICT by ICT sub-sector

4.1 Economic weight, BERD and trade

The ICT sector is composed of five sub-sectors, three of which are in manufacturing (NACE 30, 32 and 33) and two in services (NACE 642 and 72). As shown in Table 4-1,[45] these are very different from each other in terms of relative size, BERD and competitive strength.

As can be seen from Table 4-1, more than 65% of turnover and over 75% of value added are accounted for by the two service sectors. These also have higher value added/turnover ratios, indicating a lesser dependence on intermediate inputs, especially in Computer Services and Software, which are labour intensive. Measurement Instruments also create a relatively high value added, while the other two ICT manufacturing sub-sectors have comparatively lower value added/turnover ratios.

Not surprisingly, a large share of ICT BERD (about two thirds) is performed in the manufacturing sub-sectors, in particular in Components, Telecom and Multimedia Equipment and in Measurement Instruments. Computer Services and Software also have a high absolute amount of BERD, but it appears small relative to the large size of this sub-sector. Telecom Services have only a small share of ICT BERD.

The negative trade balance is dominated by IT Equipment, which is responsible for nearly 90% of the trade deficit in the overall ICT sector. It is noteworthy that Measurement Instruments is the only manufacturing sub-sector with a trade surplus.

45 Due to unavailable value added data at three digit level for the non-EU countries, when making comparisons between the EU27 and other countries, we use an ICT sector aggregate that includes the value added for Post and Telecommunication Services (NACE 64). For better precision, when performing EU level benchmarking, only the value added by the Telecommunication Service sector is considered (NACE 642). At the EU27 level, Telecommunication Services make up approximately 75% of the total Post and Telecommunications Services sectors

Table 4-1: Turnover, value added, BERD and trade-balance for the ICT sub-sectors, 2005

Sub-Sector	Turnover		Value added		BERD		Trade balance
	€ bn	(%)	€ bn	(%)	€ bn	(%)	€ bn
30 IT Equipment	59	(5 %)	13	(3%)	2.3	(7%)	-40.8
32 IT Components., Telecom & Multimedia Equipment	207	(18%)	45	(9%)	14.0	(42%)	-15.3
33 Measurement Instruments	140	(12%)	55	(11%)	6.5	(19%)	6.3*
642 Telecom Services	421	(36%)	180	(37%)	3.1	(9%)	-0.7
72 Computer Services and Software	340	(29%)	195	(40%)	7.8	(23%)	6.3
Total ICT	**1167**	(100%)	**488**	(100%)	**33.7**	(100%)	**-44.3**

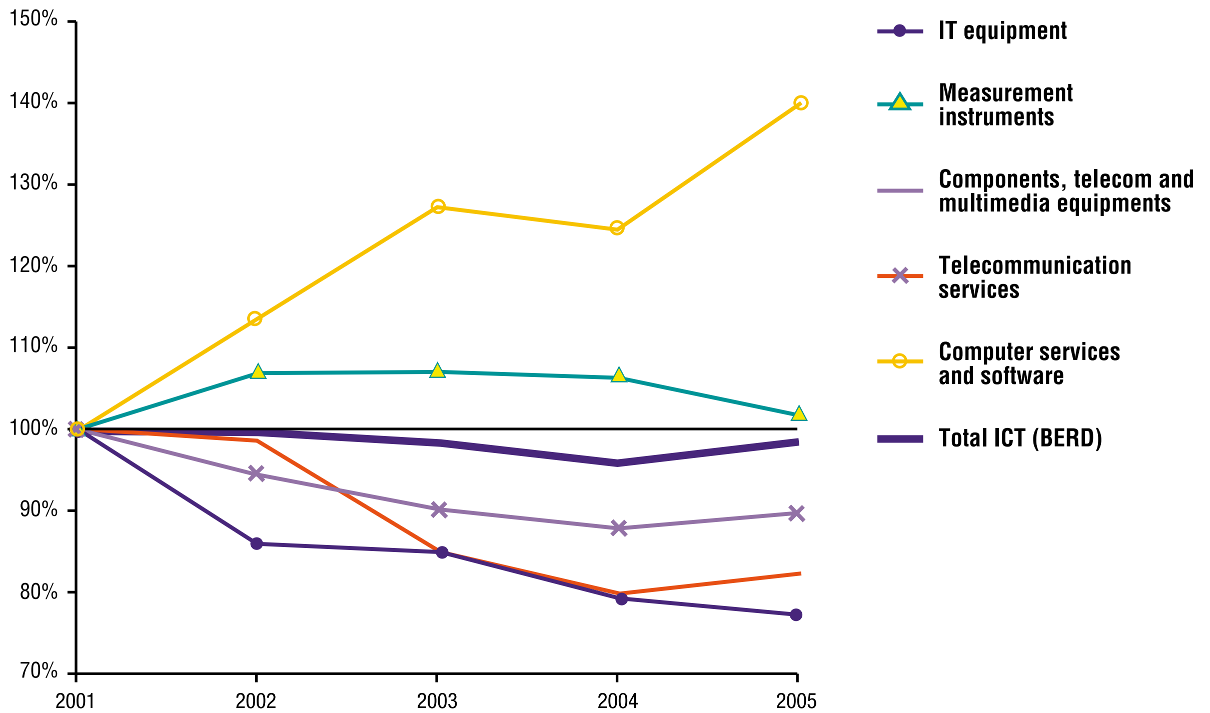
Source: IPTS estimates based on data from Eurostat, OECD, EU KLEMS
*Note: *Trade balance for ISIC 3312 and 3313 (Electronic Measurement Instruments)*

4.2 BERD growth: comparison by ICT sub-sector

Analysing BERD growth by ICT sub-sector (see Figure 4-1) provides further evidence of the different trajectories of the different sub-sectors. However, what springs to mind first is that total ICT BERD went down between 2001 and 2005, when measured in real terms, i.e. adjusted for inflation, even if nominal spending went up. Following the burst of the Internet bubble in 2000 that caused R&D budgets to be squeezed in the ICT sector, it was not until 2005 that the sector recovered positive R&D growth. This observation is confirmed by company data (see Chapter 6).

It is striking that the two sectors just identified as having trade surpluses are also the only ones with an increase in BERD. This increase is, however, much bigger and more sustained for Computer Services and Software than for Measurement Instruments that show a clear decline towards the end of the period. Indeed, Computer Services and Software is the only ICT sub-sector for which a clear long-term trend towards increased BERD can be discerned. As a result, it now has the second-largest BERD in the ICT sector, as was shown in Table 4-1, but it is still far behind Components, Telecom and Multimedia Equipment, despite the pronounced decrease in the latter. The decline in 2005 of Measurement Instruments is due to a decrease of over 10% in the sectoral BERD in France and the UK, out of which only half is compensated by increases in other EU countries, mostly in the new Member States. The international dynamics of R&D and of production at a disaggregated level normally have very specific sectoral/regional explanations which call for further and deeper research into the specific cases. Moreover, the figures for BERD growth in Telecom Services should be taken with care, since the total is quite small and the number of players is very low. Hence adjustments, that may be part of normal business strategies at company level, may induce fluctuations in the total.

Figure 4-1: Real growth of ICT BERD in the EU27. 2001=100%



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics

Finally, the IT Equipment sub-sector continues to reduce its R&D effort from an already low base.

4.3 ICT R&D employment by sub-sector

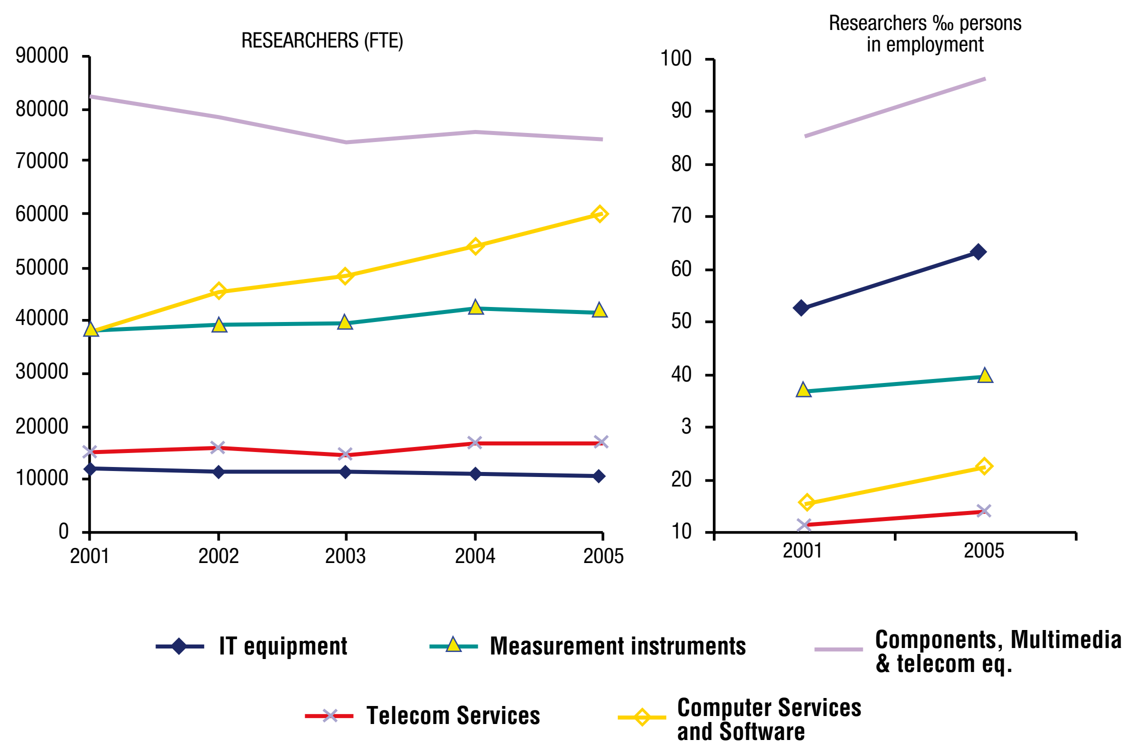
A similar picture of the ICT sub-sectors emerges by looking at numbers of researchers and researcher intensity (Figure 4-2). In 2005, the 74,500 researchers in the Components, Telecom and Multimedia Equipment sub-sector alone accounted for 36.7% of the 203,000 total ICT sector researchers. The Computer Services and Software sub-sector is next, at almost 30% (61,000 researchers), followed by Measurement Instruments, at just above 20% (41,000 researchers). ICT manufacturing industries together employ nearly two thirds of the total number of ICT sector researchers.

From 2001 to 2005, the number of researchers fell by 13% in IT equipment and by almost 10% in Multimedia and Telecom Equipment, mirroring the overall drop in employment in these sub-sectors. The research labour force expanded roughly at the same pace as the rest of the ICT sector in Measurement Instruments and in Telecom Services. Computer Services and Software were by far the most dynamic: the number of researchers grew by 22,400 FTE units (almost 60%), which is more than the growth for the whole ICT sector.

R&D employment research intensity,[46] too, is very diverse among the ICT sub-sectors, spanning from nearly 100 (FTE) researchers per 1,000 employed in Telecom and Multimedia Equipment to about 15 per thousand in Telecom Services. Services have, on average, much lower

46 The different R&D intensity ratios used in the PREDICT report and their specific features are discussed in Annex 2 – Description of R&D intensity indicators

Figure 4-2: EU27 ICT sector researchers and R&D employment intensity by industry, 2001-2005



Source: IPTS estimates based on Eurostat, OECD and national sources.

R&D employment intensity than manufacturing. From 2001 to 2005, this intensity grew in all ICT sub-sectors, although at different speeds: by less than 3 percentage points in Telecom Services and Measurement Instruments, by 7 points in Computer Services and Software, and by up to 11.5 points in the IT equipment and Telecom and Multimedia Equipment sub-sectors. For the last two cases, however, this growth reflected a decrease in the number of researchers, accompanied by an even faster decrease in total employment.

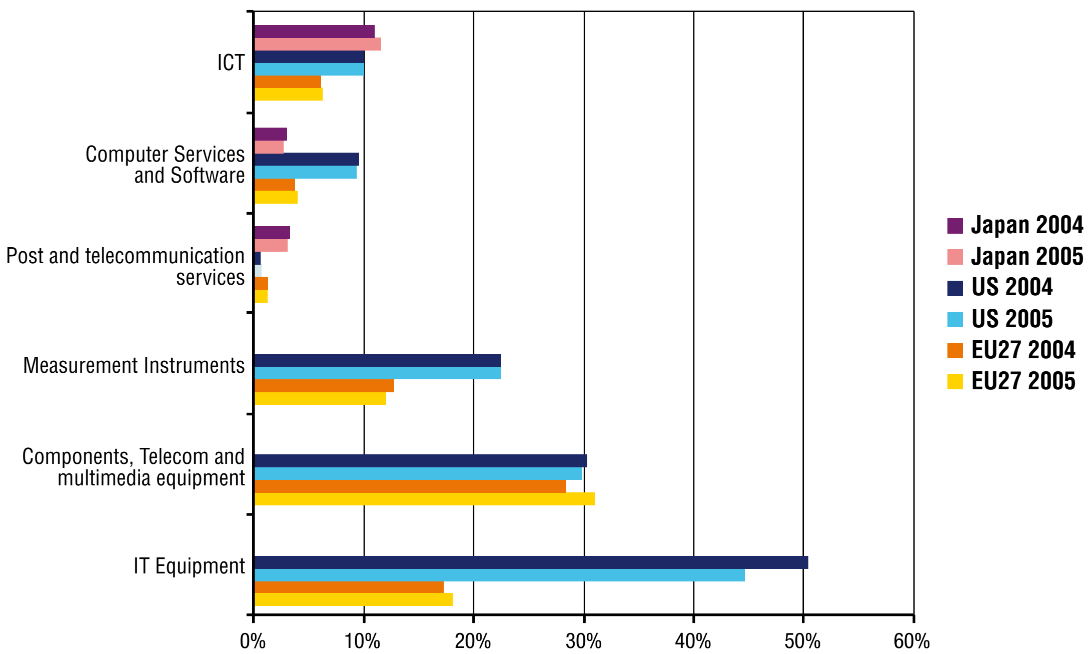
Finally, the share of researchers in total R&D personnel (both in FTE units), is overall about 20% higher in the ICT sector than the business sector average, and it is rising. In 2005, this ratio was about 70% in Telecom and Multimedia Equipment and in Telecom Services (rising 15 percentage points in the latter since 2001), 65% in Measurement Instruments and in Computer Services and Software, and only 54% in IT Equipment, where it fell slightly. Intensity measured on total R&D employment would thus lower the figure for Telecom Services, and further increase it for IT Equipment.

4.4 The R&D intensity of the ICT sub-sectors from an international perspective

When analysing the ICT sub-sectors from an international perspective, we will look first at the R&D intensity (BERD/VA) of each of them, before gauging their relative economic importance (VA/GDP) in the next section. Figure 4-3 shows that the overall lower R&D intensity of the ICT sector in the EU relative to the USA is reflected in three sub-sectors, i.e. Computer Services and Software, Measurement Instruments, and IT Equipment. Japan's intensity is lower than the EU's in Computer Services and Software; indeed, its R&D intensity in Post and Telecom Services is higher than in Computer Services and Software.

From 2004 to 2005, it can be observed that both the USA and the EU show a relatively stable pattern: the few noticeable changes in the manufacturing sectors do not impact overall ICT performance. Japan has increased its overall R&D intensity despite the slight decrease in both ICT

*Figure 4-3: ICT sub-sector R&D intensities (BERD/VA in 2005)**



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and NSF

** Data are not available for Korea and Australia. Data for Japan does not distinguish between the three ICT manufacturing sub-sectors.*

services sectors, tilting its research even further towards ICT manufacturing.

4.5 The weight of the ICT sub-sectors from an international perspective

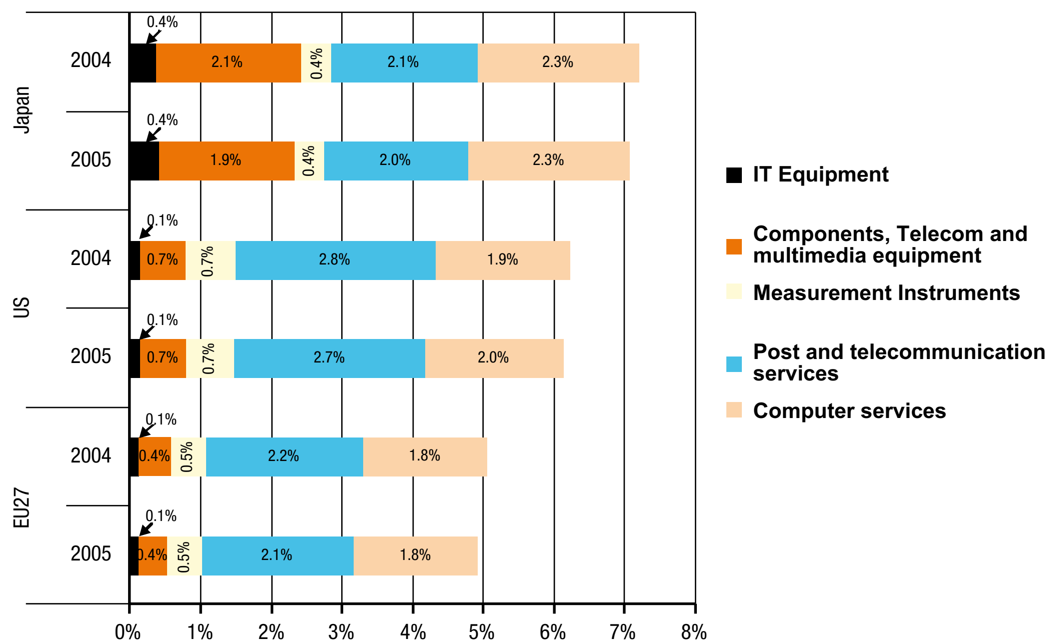
As was shown above in Table 3-1, the relative economic weight of the ICT sector (ICT VA/GDP) is smaller in the EU than in either Japan or the USA. Looking at the same indicator (VA/GDP) by sub-sector, it is striking that the structure of the ICT sector is fairly similar in the EU and the USA, but quite different in Japan (see Figure 4-4).[47] Japan has a comparatively much bigger ICT manufacturing sector, especially due to the Components, Telecom and Multimedia Equipment sub-sector, while the weight of the Measurement Instruments industry is relatively smaller. This preponderance of ICT manufacturing in Japan explains to a large degree why Japan's overall ICT R&D intensity is higher than in the EU or in the USA as shown in the previous section (Figure 4-3), given the much higher R&D intensity of ICT manufacturing than of ICT services.

Contrary to the case of Japan, the higher R&D intensity of the USA's ICT sector does not seem to be related to a much stronger concentration in R&D-intensive sub-sectors. Each sub-sector is a bit larger, as a share of GDP, in the USA than in the EU, but represents a fairly similar share of the sector. Yet, the ICT manufacturing sub-sectors have slightly more weight in the USA compared to the EU. Therefore, this slight compositional effect appears to also contribute to the higher R&D intensity in the USA, in addition to the main contribution coming from higher R&D intensity of ICT sub-sectors

Indeed, the previous section identifies three sub-sectors with significantly higher R&D intensity (BERD/VA) in the USA than in the EU: Computer Services and Software, Measurement Instruments,

47 No data available for Korea and Australia

Figure 4-4: Economic weight of the ICT sub-sectors in Japan, the USA and EU 27. % of sub-sector's value added in GDP, 2005



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and IT Equipment (see Figure 4-3). Figure 4-4 shows the relative economic weight of these sub-sectors. Two of these three sub-sectors, namely IT Equipment and Measurement Instruments, have a relatively small economic weight (which does not mean that impact on the ICT sector of their higher R&D intensity is necessarily small). The Computer Services and Software sub-sector has however the biggest impact, due to its important economic weight.

The lower R&D intensity in the EU than in the USA does not necessarily mean that individual EU companies in these sub-sectors invest less in R&D than their US competitors. Other factors play an important role, for example the quasi-absence of large international EU companies in these sub-sectors developing a global activity, as compared to the US competitors. This question is again documented at the end of Chapter 6 (sections 6.4 and 6.5).but it will require further analysis.

4.6 Conclusions

Within the ICT sector, services account for the lion's share of value added, turnover and employment. The majority of R&D spending takes place, however, in manufacturing, although most of BERD growth is accounted for by Computer Services and Software, which is also the only ICT-sub-sector with growing R&D employment.

BERD intensity in the EU is less than half as high in IT Equipment, Measurement Instruments and in Computer Services and Software as it is in the USA. The difference is biggest in IT Equipment, which is, however, a small sub-sector, while the difference in Computer Services and Software has the largest weight due to the size of the sub-sector. The EU only has the advantage in BERD intensity over the USA in the Telecommunications sub-sector.

Japan's higher overall ICT BERD intensity is due to the ICT manufacturing sector, which in relative terms, is twice as large as in the USA and nearly three times the size of EU ICT manufacturing, and is also much more R&D intensive than ICT services. As regards ICT services, however, the EU has a higher BERD intensity with respect to Japan in Computer Services and Software, but a lower one in Telecommunications.

Sustained growth of the EU Computer Services and Software sub-sector observed in recent years may indicate that this sub-sector could be a real asset for future development of the EU ICT sector. However, to confirm this potential, further investigation is required.

5 EU R&D in ICT by Member State

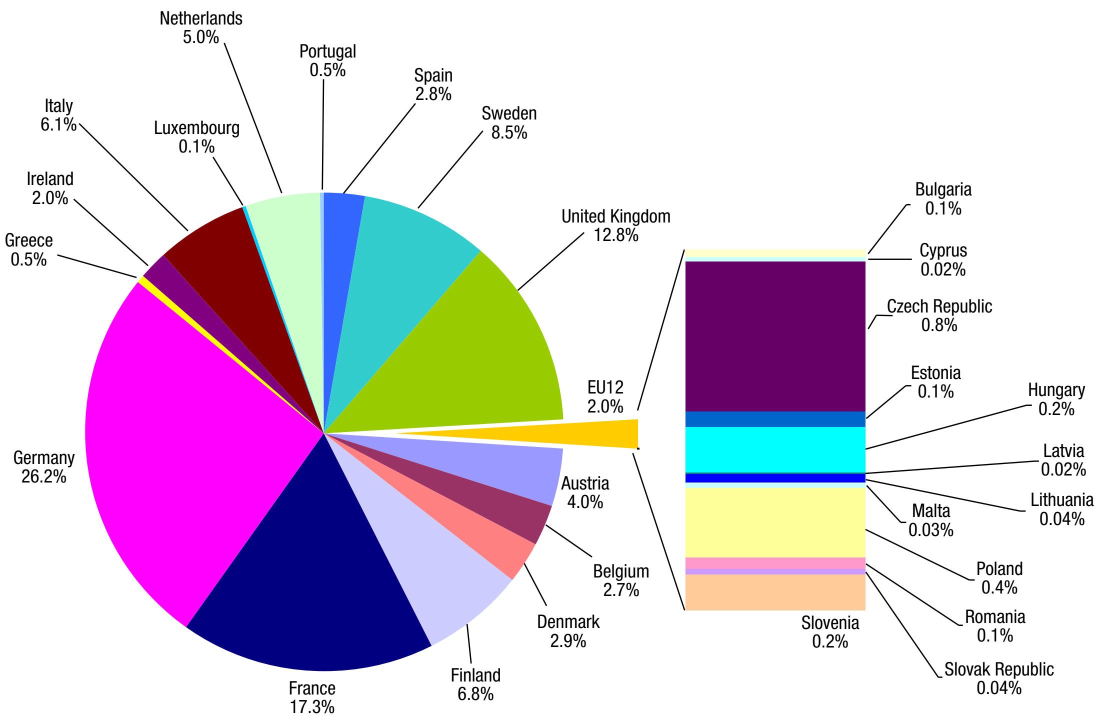
5.1 National shares in ICT BERD

Within the EU, ICT sector BERD is heavily dominated by some of the largest economies, i.e. Germany, France and the UK, followed by Sweden, Finland and Italy. Compared to 2004, the shares in the EU of the three biggest investors have diminished (their collective share is down 2%) whilst the shares of Sweden, Denmark and Austria have augmented. In general, EU15 countries contribute 98% of the ICT business R&D expenditures while the new Member States (EU12) contribute only 2% (see Figure 5-1).

Methodological note

This report uses purchasing-power parities rather than current exchange rates, including inside the Eurozone, in order to adjust for differences in price levels.[48] As a result, the Nordic countries Sweden, Finland and Denmark, which have high price levels, have a lower share than they would under current exchange rates (18.1% together instead of 20.1%) whilst Spain and Germany have higher shares. Most importantly, though, new Member States double their share in the total, because of generally much lower price levels.

Figure 5-1: Distribution of ICT BERD shares in EU27 countries. % of total EU25 ICT BERD, 2005



Source: IPTS based on data from Eurostat, at Purchasing Power Parities (PPP)

48 The JRC-IPTS 2008 Reference Report "Mapping R&D Investment European by the European ICT Sector" (Lindmark et al., 2008) uses current exchange rates for the 2004 data. Data are therefore not entirely comparable with this report.

5.2 National shares in business ICT R&D employment

R&D employment in the ICT sector follows a similar pattern to that of BERD. Germany, France and the UK together make up 57% of total R&D employment (and 60% of researchers). Another 12% is added by Finland and Sweden. In comparison, larger economies such as Italy and Spain have lower shares (Figure 5-2).

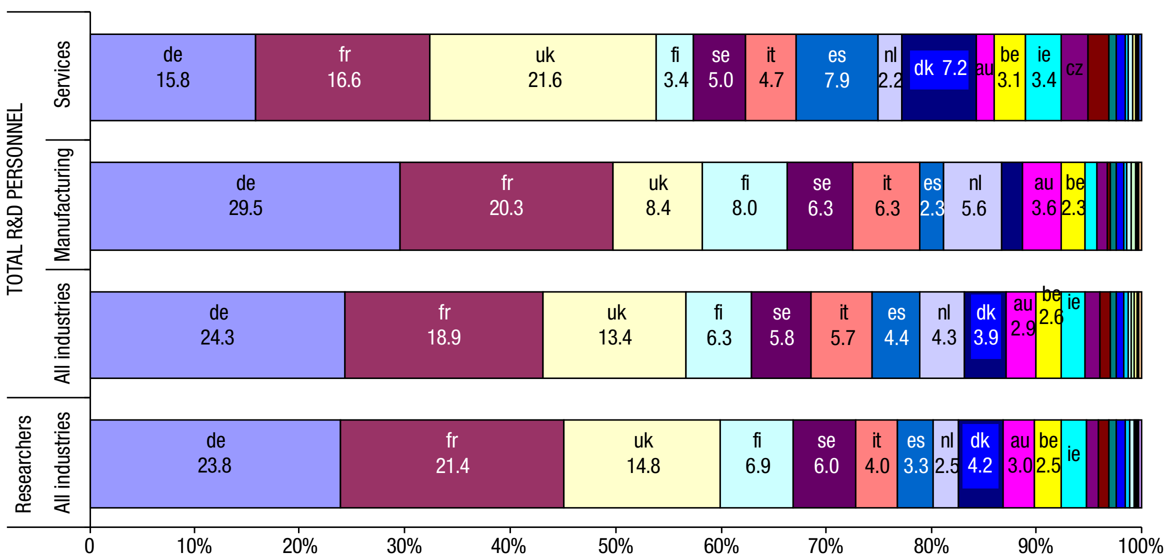
Country shares in ICT R&D employment hide large sub-sector variations, which in part mirror the pattern of industrial activity. Hence, the share of Germany approaches 30% in manufacturing, while in services it is less than the 16%, ranking third after the UK and France. Comparatively high shares in manufacturing are recorded also for Finland, Sweden, Italy, the Netherlands and Austria. In services, the UK leads with a share of over 20% the UK leads in services. Fourth and fifth places are occupied by Spain and Denmark and Ireland and the Czech Republic are also relatively strong in services.

Changes in business ICT R&D employment since 2001 have significantly affected the share of each Member State. Excluding the smallest countries with very "thin" bases, the most notable losses since 2001 are those of Germany (about 7,000 units, a decrease of 9%) and of the Netherlands (3,700 units, down 22%). Remarkable gains are those for Denmark (3,800 units, a 47% increase), Spain (3,400 units, up 33%) and the Czech Republic (3,200 units, an increase of 250%!).

ICT manufacturing has lost about 17,000 R&D FTE units of personnel since 2001, a loss mainly explained by Germany (11,000 units, down 16%) and the UK (6,000 units, down 27%). Other countries lost even higher percentages of R&D personnel in ICT manufacturing (a quarter of the total in Belgium and Ireland, and more than 50% in Greece and Slovakia), but these are smaller absolute numbers compensated by increases elsewhere (Czech Republic and Portugal recording the most important increases).

On the other hand, the overall growth in EU27 R&D personnel in ICT services was 34%. All countries but the Netherlands experienced a rise, most notably the UK, Germany (though not sufficient in this case to compensate for decreases in ICT manufacturing, as the above figures indicate), Denmark, Spain, Italy and the Czech Republic.

Figure 5-2: Country shares in EU27 ICT sector FTE R&D personnel, 2005



Source: IPTS estimates based on Eurostat, OECD and national sources.

5.3 The contribution of ICT to total BERD intensity by Member State

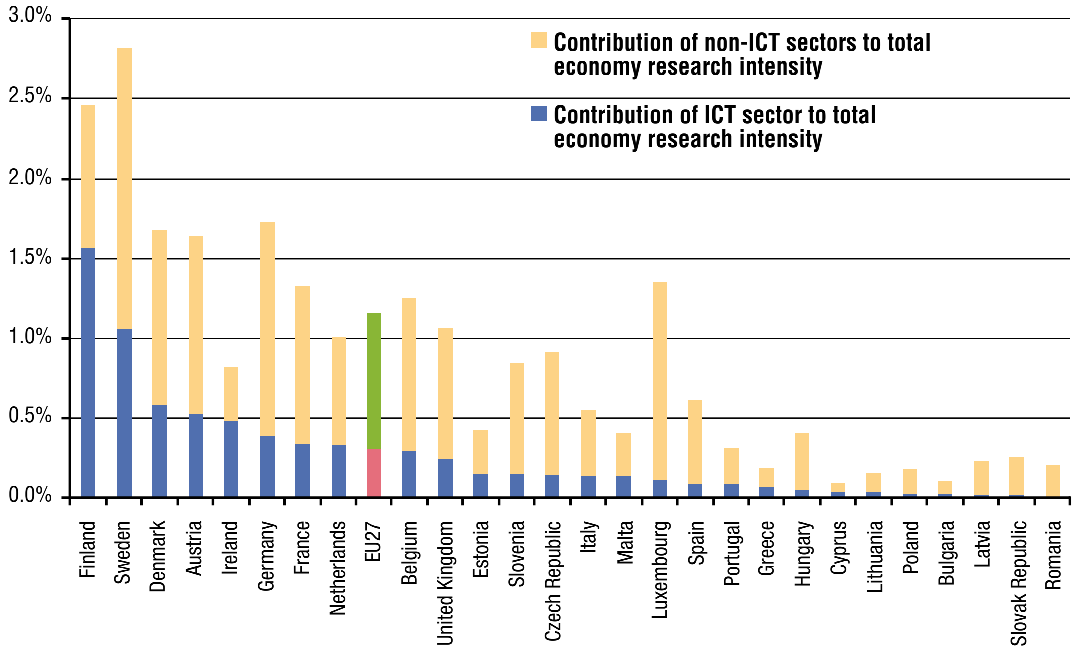
This section looks at the contribution of ICT BERD intensity (ICT BERD/GDP) to total economy BERD intensity (BERD/GDP), by EU Member State. As Figure 5-3 shows, not surprisingly the Nordic states Finland, Sweden and Denmark invest the highest amount in ICT BERD in relation to the size of their economies. In particular, Sweden and Finland have a much higher figure than the rest. However, while Finland has an outstanding ICT BERD intensity, its non-ICT BERD intensity is close to the EU27 average. In the case of Sweden, high ICT sector contribution is accompanied by the highest non-ICT BERD intensity of all Member States. For Sweden, ICT contributes to a general excellence in BERD intensity.

The Nordic states are followed by most of North-western Europe, for which ICT BERD constitutes a smaller share of their total BERD intensity. Italy, Spain, Portugal and Greece combine low ICT BERD intensity with low BERD intensity for the rest of the economy. Most of the new Member States combine extremely low ICT BERD intensity with low BERD intensity for the rest of the economy. The overall picture is one of a decreasing ICT BERD intensity contribution as one moves from North to South and from West to East.

5.4 The weight of the ICT sector in the economy by Member State

The contribution of ICT BERD intensity (ICT BERD/GDP) to total BERD intensity (BERD/GDP) depends on the size of the ICT sector, which can be measured as ICT value added/GDP, and on the R&D intensity of the ICT sector which can be measured as ICT BERD/ICT value added. This contribution also varies depending on the composition of the ICT sector in each Member State. This section compares the size (or "weight") of the ICT sector in the national economies of the 27 EU Member States, and provides a breakdown per ICT sub-sector. Figure 5-4 shows that the ICT sector has the largest share of the economy in Finland and the lowest in Greece. Figure 5-4 also shows that the ICT sector in Finland is heavily

Figure 5-3: Contribution of ICT sector to total BERD intensity (BERD/GDP) by Member State – EU27, 2005



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics

dependent upon the Components, Telecom and Multimedia Equipment sub-sector, while in Sweden the ICT sector has a more balanced structure. This confirms the previously identified structural differences between Finland and Sweden.

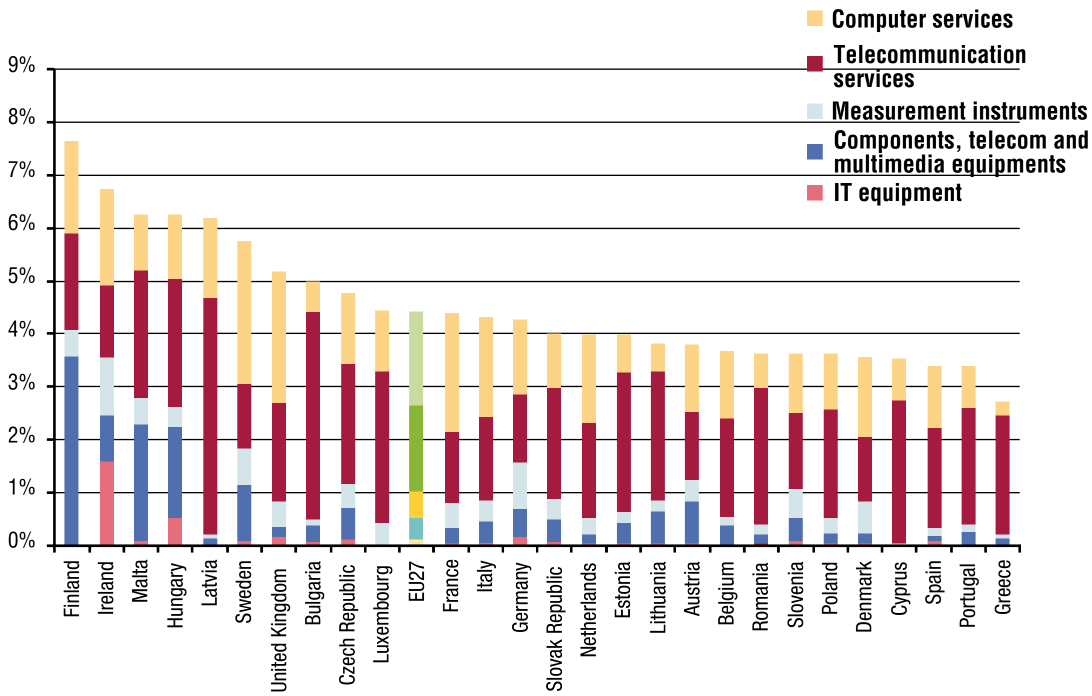
Countries with a large ICT manufacturing sector, especially in the Components, Telecom and Multimedia Equipment industries, are more likely to have ICT sectors that contribute significantly to total BERD intensity. The chart above indicates that the ICT sectors in Finland, Malta, Hungary and, to a lesser extent, Sweden and Austria could be expected to make high contributions. However, as was seen in Section 5.3, Malta and Hungary do not show a strong ICT contribution to total BERD intensity, reflecting the orientation of their ICT sector towards assembly rather than innovation.

5.5 Change in the weight of the ICT sector in the economy by Member State

A discussion on change in weight of the ICT sector in national economies must take into account the change that occurred in the size of the national economies themselves. Figure 5-5 indicates that national trends regarding the dynamics of the ICT sector and of economic performance are very different in the 27 Member States.

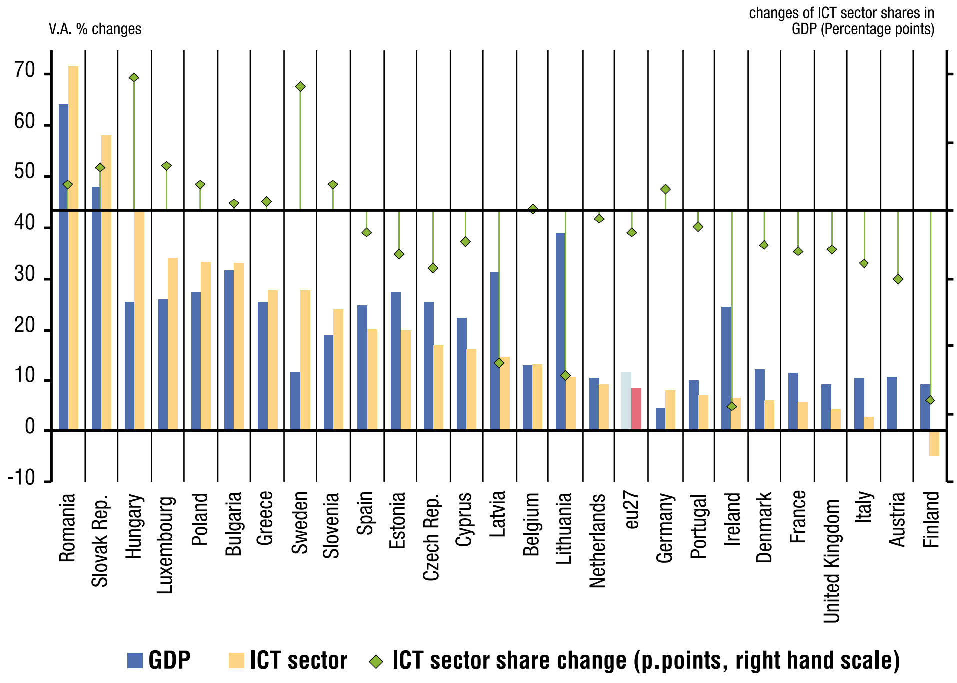
From 2002 to 2005, the two countries most heavily specialised in ICT, i.e. Finland and Ireland (as seen in Figure 5-4), saw significant decreases in the shares of the ICT sector in their economy (as measured by ICT value added/GDP, in percentage points). However, while Finland was the only country to present a contraction of the ICT sector's value added in absolute terms, the decrease in the shares of the ICT sector in Ireland, as well as in Lithuania, Latvia, Spain

Figure 5-4: Weight of the ICT sector in the economy of EU27 countries. ICT VA / GDP, 2005



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics
Note: In this graph, Post is excluded from the Post and Telecommunications Services sector

Figure 5-5: Change in GDP and in weight of the ICT sector in the economy of EU27 countries, difference 2005-2002



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics

and the Czech Republic stemmed instead from a faster growth in the rest of the economy.

The slight decrease overall in the share of the ICT sector in the EU27 is mostly attributable to Italy, the UK, France and Austria, where slow growth of GDP was accompanied by even slower growth of ICT value added. In Germany, on the other hand, a moderate growth in the ICT sector value added outpaced the slow growth of the economy. Finally, the weight of the ICT sector rose in Sweden, and in several new Member States which experienced a very fast economic growth.

5.6 The BERD intensity of the ICT sector by Member State

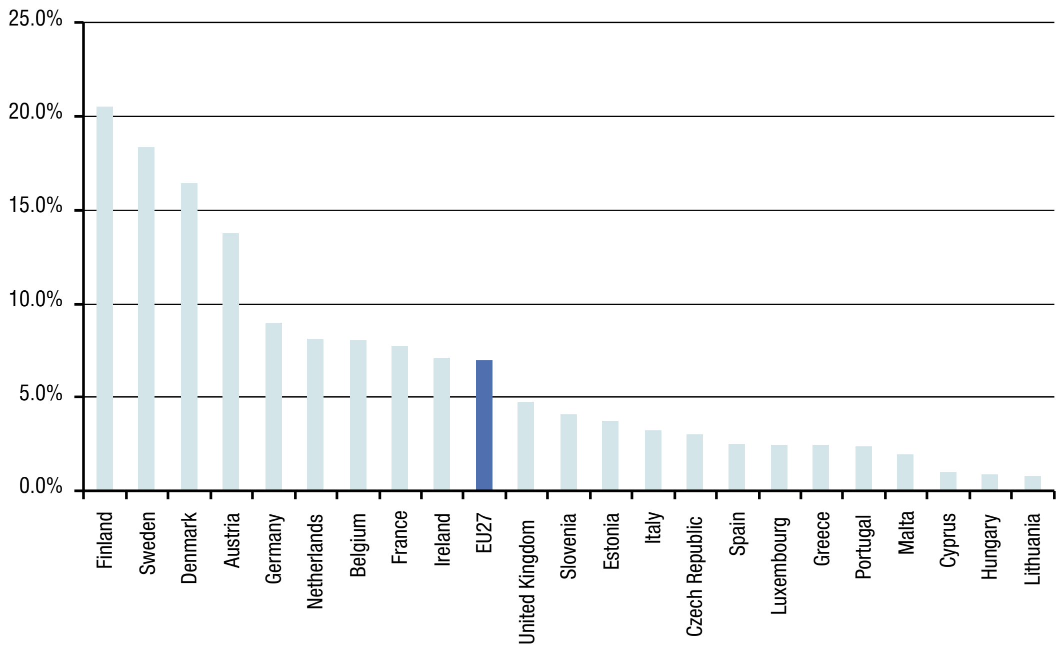
Looking at the BERD intensity[49] of the ICT sector (ICT BERD/ICT value added) by Member State (Figure 5-6) provides a very similar figure (in terms of Member State ranking) as the contribution of ICT BERD intensity to total BERD intensity (shown in Figure 5-3): Nordic Member States, led by Finland, are at the forefront, followed by Austria and the bulk of north-western Member States. The UK and southern Member States are below the EU average. Southern Member States are at a comparable level with Estonia, Slovenia, the Czech Republic and Malta.

5.7 Change in the BERD intensity of the ICT sector by Member State

How has the contribution of ICT BERD intensity (as measured by ICT BERD/ICT value added) evolved in recent years in the EU Member States? How is this associated with the movements of the underlying variables, i.e., of ICT BERD and ICT value added? Did national dynamics differ? As shown by Figure 5-7, quite a lot.

49 The different R&D intensity ratios used in the PREDICT report and their specific features are discussed in Annex 2 – Description of R&D intensity indicators

Figure 5-6: ICT BERD Intensities in EU27 countries. ICT BERD/ICT value added, 2005



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics

From 2002 to 2005 for the EU27 as a whole, there is a slight decrease (0.28 percentage points) in ICT BERD intensity (ICT BERD as a share of ICT value added), as shown in part A of Figure 5-7.

The dynamics of the two EU leaders, Finland and Sweden, are extremely different, with an increase of ICT BERD intensity by 4.2 percentage points in Finland, and a decrease in Sweden by the same percentage. As is shown in part B of Figure 5-7, Finland was the major contributor to the increase of ICT BERD in the EU. In the case of Sweden, however, ICT BERD *intensity* significantly dropped (see part A of the figure) in spite of an increase in BERD (part B of the figure), because of the important growth of the ICT sector (increased value added) outlined in Section 5.5. Similar dynamics happened in Germany.

Notable increases in ICT BERD intensity (A) were also recorded for Austria (3.7 percentage points, and about 40% in value [€]), making it the second largest contributor to ICT BERD growth in value (B); for Denmark (about 2 percentage points, thanks to an increase of 20%); and for a number of new Member States, where initial levels were very low and overall contributions to R&D were very small.

Amongst other relevant cases, it is also worth mentioning those of Ireland and Italy, where an increase in ICT BERD intensity (A) was accompanied by a rise in BERD (B).

5.8 Government financing of ICT R&D by Member State (GBAORD)

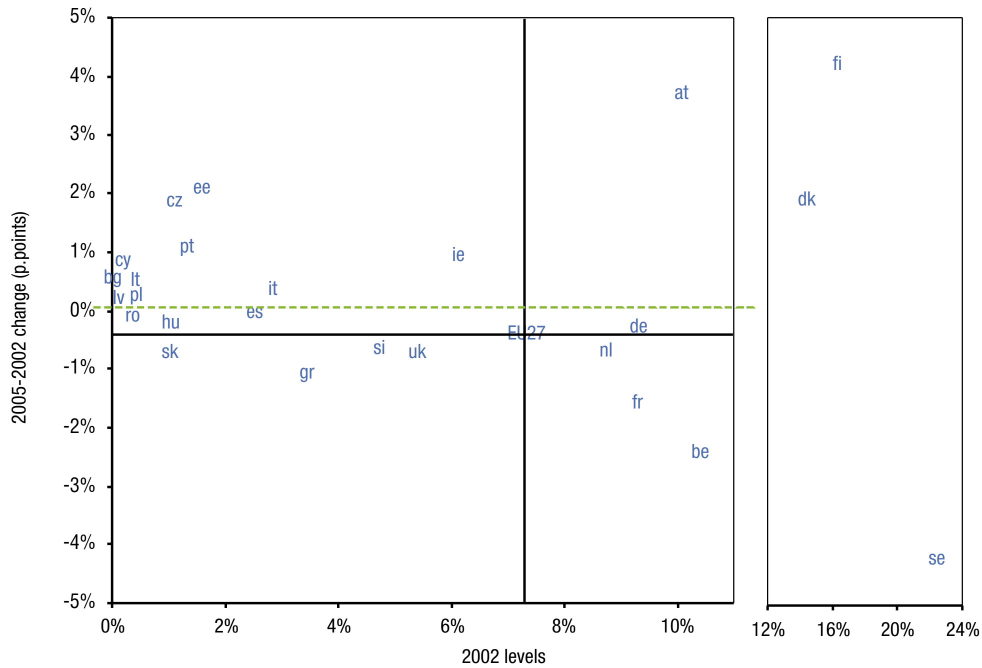
5.8.1 National shares in ICT GBAORD

This section presents EU27 Member State data on *government ICT R&D financing*: Government Budget Appropriations and Outlays in Research and Development related to ICT (ICT GBAORD). ICT GBAORD measures government support to ICT-related R&D activities.[50]

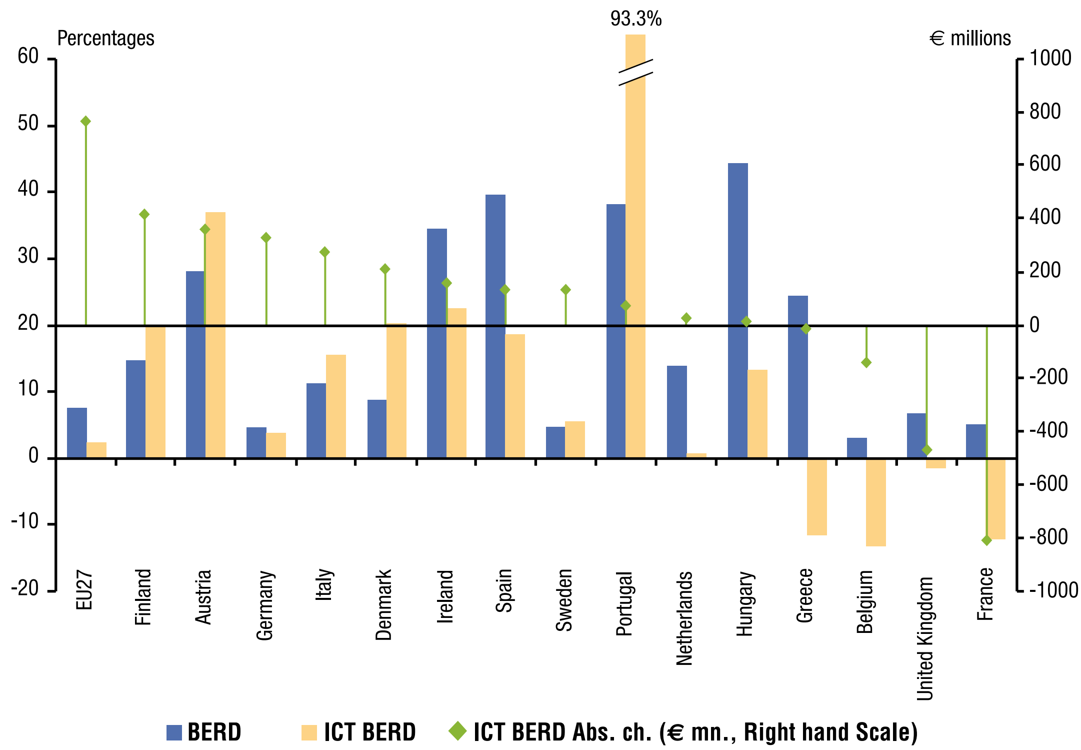
50 For more information about GBAORD definition and methodologies, see Annex 6 - Methodology for GERD and GBAORD data

Figure 5-7: The dynamics ICT BERD intensities in the EU27:

A) ICT BERD as a % of ICT value added in 2002 and change 2005-2002, in percentage points

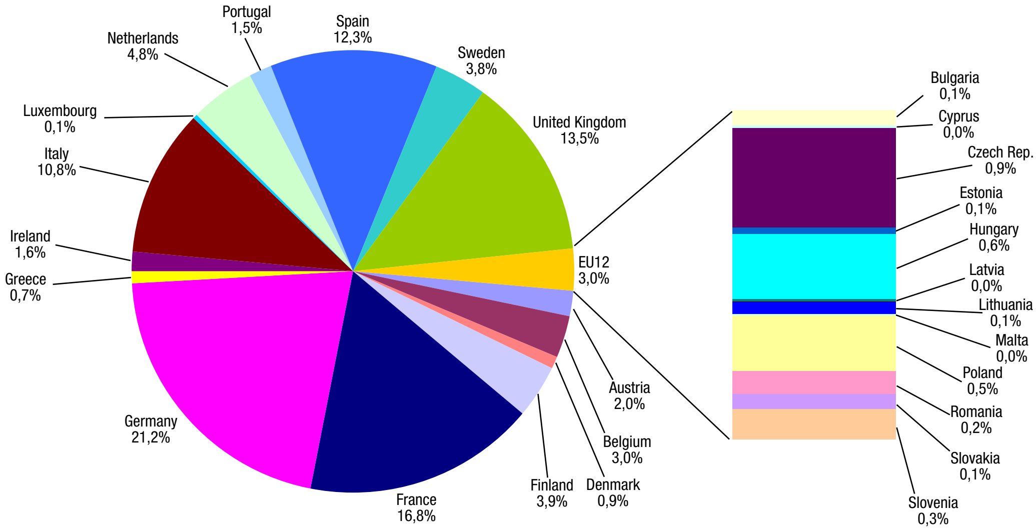


B) BERD percentage changes (total and ICT sector, left), and ICT BERD change in € mn (right) selected Member States



Source: IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics
Percentage changes are computed from nominal values in €, and in national currencies for Sweden and the UK

Figure 5-8: Distribution of ICT GBAORD in EU27 countries. % of total EU27 ICTGBAORD, calculated on PPP values, 2005



Source: EUROSTAT and IPTS calculations.

As observed in Section 5.1 with ICT BERD, ICT GBAORD is heavily dominated by the largest economies (see Figure 5-8). Germany (21.2%), France (16.8%), the UK (13.5%), Spain (12.3%) and Italy (10.8%) represent together 75% of European ICT GBAORD. This size effect applies also to total GBAORD (not presented here). As expected, governments invest in proportion to their financial capacities. The new Member States contribute only 3% of the total EU27 ICT GBAORD, which is a share far below their economic weight (but higher than their 2% share for ICT BERD).

Notes: ICT GBAORD data at Member State level have to be taken with even more caution than those presented at European level in Section 3.2, because ICT GBAORD is obtained by applying estimated national shares in selected categories of the NABS[51] classification.[52] It is also important to note that GBAORD figures also include government financial support to ICT R&D that is performed in the business sector. Therefore, GBAORD figures should not be interpreted as corresponding to government financial support to ICT research performed by government establishments or universities. Only a share of that money will go to public research institutions.

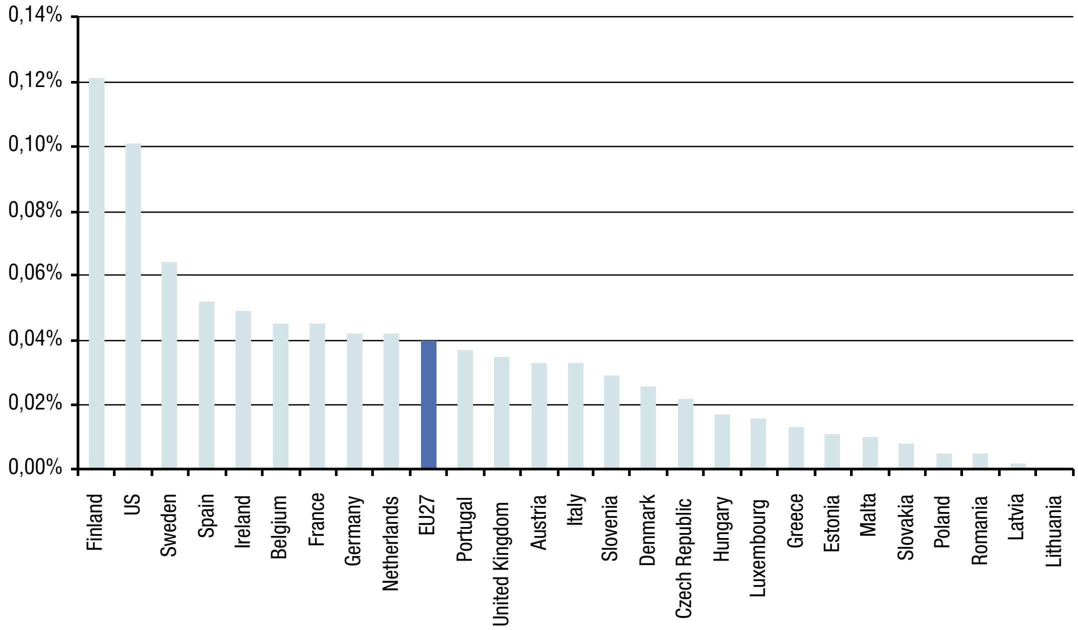
5.8.2 ICT GBAORD intensity by Member State (ICT GBAORD/GDP)

Observation of the share of GDP dedicated to public financing of ICT research (ICT GBAORD/GDP) can most clearly show the importance given to ICT research in national R&D policy priorities.

Figure 5-9 shows that Finland is again a clear leader, with a share of publicly-financed ICT research in GDP well above other Member States and even above the USA. Sweden comes second. This lead clearly underlines one of the possible sources of success of these countries in the ICT domain. While it shows that ICT support is a public policy priority, it does not simply mean that direct government support to R&D in ICT

51 NABS: Nomenclature for the analysis and comparison of scientific programmes and budgets
52 The methodologies used for elaborating the ICT GBAORD and the data presented in this section are fully described in the forthcoming IPTS Technical Report on "Public Expenditures in ICT R&D"

Figure 5-9: Share of ICT GBAORD in GDP – EU Member States and the USA, 2005



Source: Eurostat and IPTS calculations.

companies is high. As a matter of fact, in both countries the share of ICT BERD financed by the government is among the lowest in EU. Finland is seen as a case of co-ordinated public policy to support SMEs and R&D in services, while in Sweden the defence budget covers an important share of ICT research (European Commission, (2008a) and (2008b)).

Among other countries that invest highly, Spain and Belgium are worth highlighting. Though they are not among the high performers in terms of ICT BERD intensity, both their ICT GBAORD shares indicate voluntary public policies to support ICT R&D.

5.9 Conclusions

EU R&D in the ICT sector is relatively concentrated in a few Member States: Germany, France and the UK together make up more than 55% of the EU27 ICT BERD. Sweden, Finland and Italy add another 22%. From the employment data, it is remarkable that the UK – and Spain – have oriented their research much more towards ICT services than France, Italy, and especially Germany.

BERD intensity of the ICT sector (ICT BERD/ ICT Added Value) remains highest in the Nordic countries and north western Member States, and lowest in the southern and new Member States. Finland and Sweden lead -again- a group of nine Member States that are above the EU average and that include Denmark and Austria, in third and fourth position respectively. The development from 2002 to 2005 was very different within the groups of countries. For example, Finland's already high BERD intensity further increased whereas Sweden's decreased quite a lot. In Sweden, however, this decrease is not necessarily a negative signal, since it is due to the important growth of the size of the ICT sector (i.e., to an increase in ICT value added). Some new Member States have seen considerable increases (Estonia, Czech Republic), others have experienced drops (Slovenia, Slovakia).

ICT GBAORD distributes very similarly –but not exactly- to ICT BERD, with Italy and Spain showing higher shares of ICT GBAORD than ICT

BERD. The five largest EU economies represent 75% of EU ICT GBAORD, with Germany, France and the UK contributing 52% of ICT GBAORD and Spain and Italy adding another 23%. The Netherlands, Finland, Sweden, and Belgium add another 16%.

Finland and Sweden lead again in ICT GBAORD intensity (ICT GBAORD/GDP). These two countries come first in a group of eight Member States that are above the EU average. In this group, Spain is third, immediately after Sweden. Finland is above the USA in ICT GBAORD intensity, and both Finland and Sweden are above the USA in share of ICT GBAORD in total national GBAORD (at a level that is twice the EU average).

The share of the ICT sector in national economies remains much more important than the EU average in Finland, Malta, Hungary and Sweden, where this is due to large Semiconductor and Telecom Equipment industries; and in Ireland, where the IT Equipment sub-sector is strong. However, with the exception of Hungary and Sweden, its importance has decreased most in those countries where it was most significant, including Finland, and Ireland, indicating a reduction in structural disparities.

6 ICT sector company R&D

The analysis in this chapter is based on company data from the 2007 EU industrial R&D Scoreboard[53] (henceforth the *Scoreboard*) in which R&D investment data, and economic and financial data from the last four financial years are presented for the 1000 largest EU and 1000 largest non-EU R&D investors in 2006. From the Scoreboard, we have extracted a sub-set of companies in the ICT sector, and made a number of additions to that data set (see Annex 7 - Methodology for company data).

This data is not directly compatible with the data used in the previous chapters.[54] Data for the *Scoreboard* are taken from companies' publicly available audited accounts. Most often, these accounts do not include information on the place where R&D is actually performed. Therefore, the approach of the *Scoreboard* is to attribute each company's total R&D investment to the country in which the company has its registered headquarters. In addition, all R&D is attributed to one single sub-sector (NACE and ICB class[55]), regardless of whether the performed R&D concerns products or services related to other sectors. For example, this means that all the R&D for Philips will be attributed to the Netherlands and to NACE 3230 (here labelled *Multimedia equipment*) and to ICB 247 (*Leisure goods*), in spite of the fact that Philips invests in R&D in other countries and in other sectors as well (primarily in medical/health and lighting equipment).

R&D investment in the *Scoreboard* is the cash investment funded by the companies themselves, and is subject to R&D accounting definitions. It excludes R&D undertaken under contract for customers such as governments or other companies. The analysis covers R&D investments for the aggregate ICT sector and for its sub-sectors, over time (2003-2006), for the EU and three benchmark countries/regions (the USA, Japan and the Rest of the World (RoW)) as well as for individual countries.

Table 6-1: Distribution of companies across ICT sub-sectors and regions

NACE Class	EU	Japan	RoW	USA	Total
IT components	24	33	37	100	194
Computer services and software	30	3	16	84	133
Telecom equipment	11	2	8	32	53
IT equipment	4	8	12	33	57
Multimedia equipment	3	5	3	1	12
Telecom services	11	2	9	5	24
Total ICT	**83**	**53**	**85**	**252**	**473**

53 European Commission (2007)

54 For a discussion on the issue of BERD versus company R&D data, see e.g. Azagra Caro & Grablowitz (2008), European Commission (2007) or Lindmark *et al.* (2008)

55 The Industry Classification Benchmark - see http://www.icbenchmark.com/

In total, there are 473 ICT companies in our data set. The population of these companies is distributed as indicated in Table 6-1. It can be seen that more than half the companies are from the USA, and that most companies are in the IT Components and Computer Services and Software sub-sectors.

6.1 ICT sector company R&D in perspective

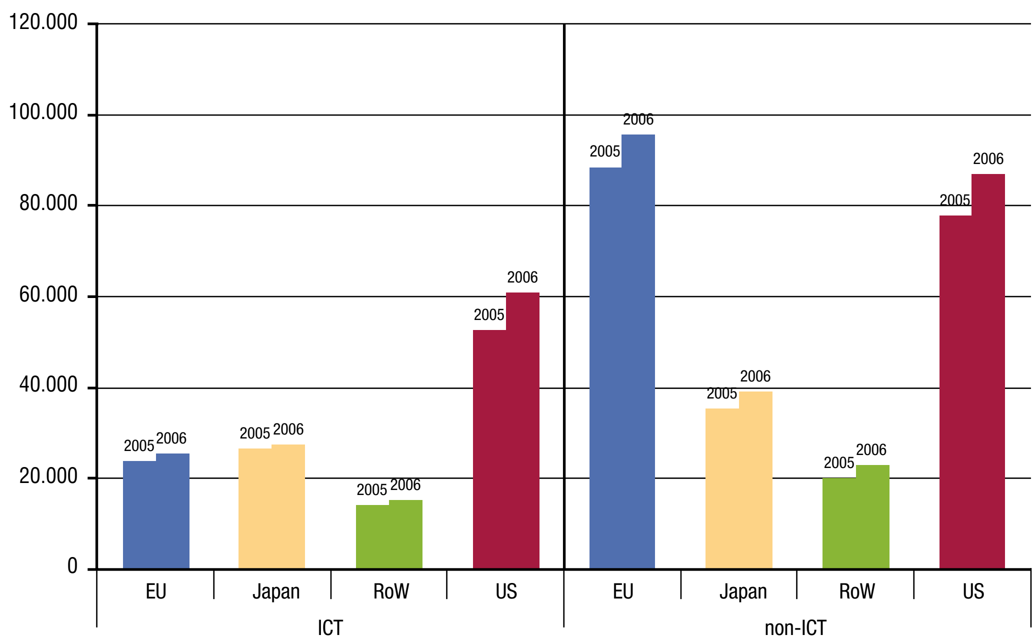
The ICT sector is clearly one of the key R&D investors. In 2006, to put the ICT figures in perspective, the 1,392 top global R&D investing companies spent €368 billion on R&D, of which €127 billion (or 35%) were invested by ICT sector companies. Figure 6-1 shows the company R&D investments inside and outside the ICT sector for 2005 and 2006. It can be seen that for non-ICT sectors, EU company investments are in fact higher than for any other region, including the US. As illustrated in Figure 6-1, EU firms (as an aggregate) perform much worse in the ICT sector than in the non-ICT sectors. Figure 6-2 also shows that, as regards R&D, the ICT sector is more important outside than inside the EU. Viewed from another angle: for company data in 2006, there is a total R&D gap between the EU and the USA of €33 billion (up from €24 billion in 2005). This gap, however, can be more than entirely explained by the ICT sector, since the ICT sector R&D gap is actually larger than that (€37 billion – an increase from € 30 billion the year before).[56]

Figure 6-3 shows the evolution of ICT sector R&D investments for companies based in the above mentioned geographical regions between 2003 and 2006.[57] It can be seen that EU ICT firms' R&D investments increased again

56 There are also non-ICT sectors where the EU is lagging behind the USA, notably Pharmaceuticals and Biotechnology, see the 2007 *Scoreboard* report (European Commission 2007). In total, EU companies invested € 115 billion in R&D, which was less than the USA (€ 148 billion) but more than Japan (€ 67 billion) and the rest of the world combined (€ 38 billion). Thus, in absolute terms the EU is only trailing behind the USA.

57 When analyzing trends based on Scoreboard data it should be noted that yearly data are not completely comparable, since the scoreboard includes only top investors for 2006.

Figure 6-1: R&D investments in the ICT sector and non-ICT sectors by EU, US, Japanese and RoW companies, in millions of € (2005 and 2006)



(Compound Annual Growth Rate – CAGR 3.1%), after a decrease in the early 2000s (not shown in the figure) until 2004. Companies from the other regions consistently increased ICT R&D investments from 2003 to 2006. While R&D growth in Japan appeared to be relatively modest (CAGR 2.7%), the RoW increased R&D investments relatively rapidly (CAGR 15.4%) but with rates slowing down. Remarkably, the increases shown by US companies were very high (€14 billion in three years only) and appeared to be accelerating. In 2006, ICT R&D investments of

Figure 6-2: ICT sector and non-ICT sector company R&D Investment as a percentage of total R&D investment (2006)

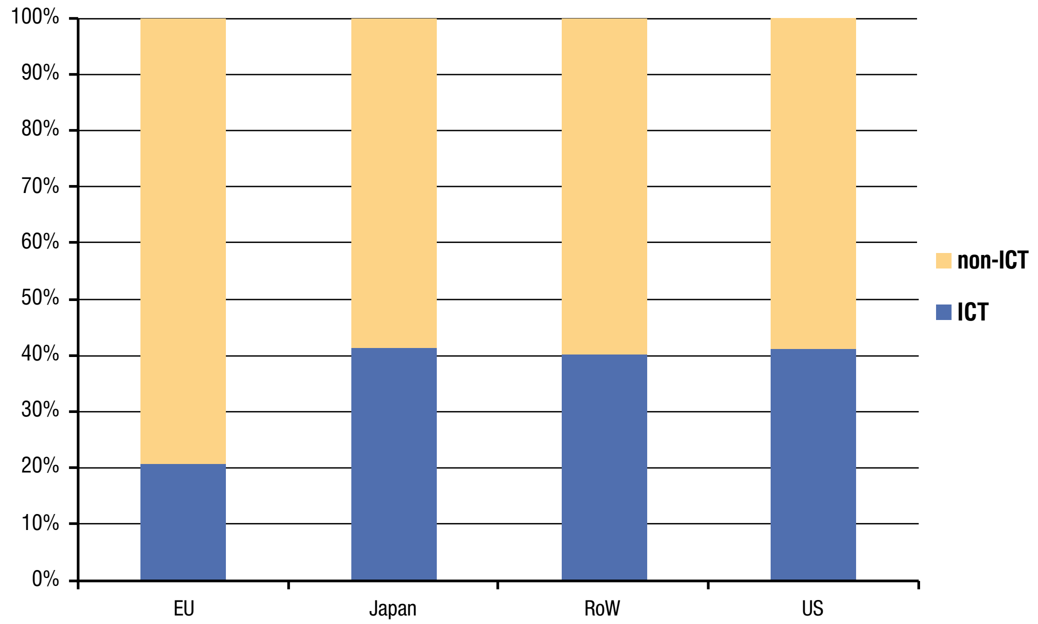
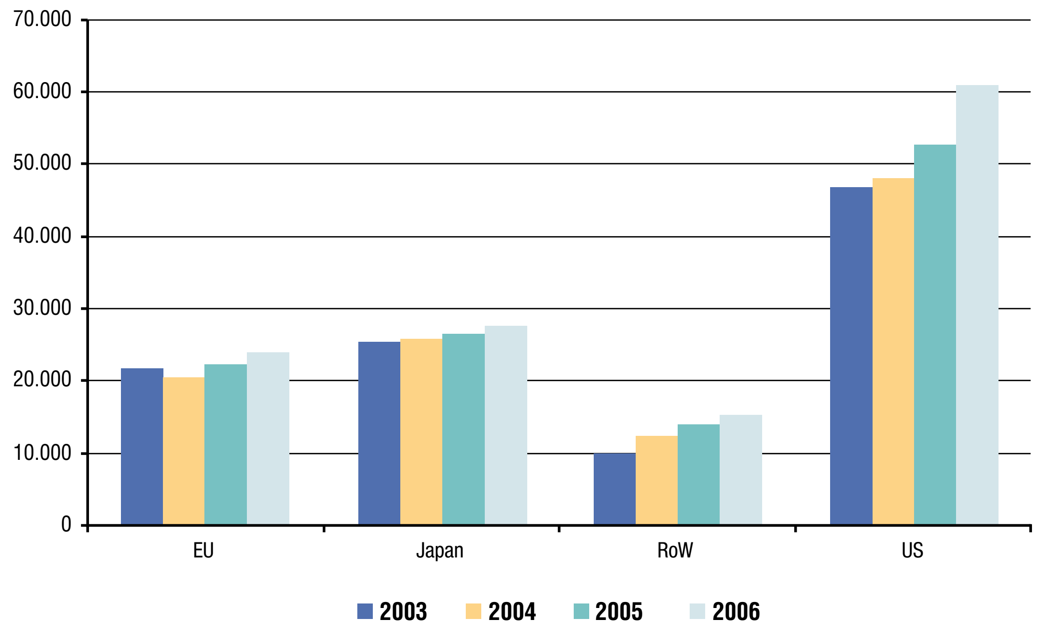


Figure 6-3: R&D investments in the ICT sector by EU, US, Japanese and RoW companies, in millions of € (2003-2006)



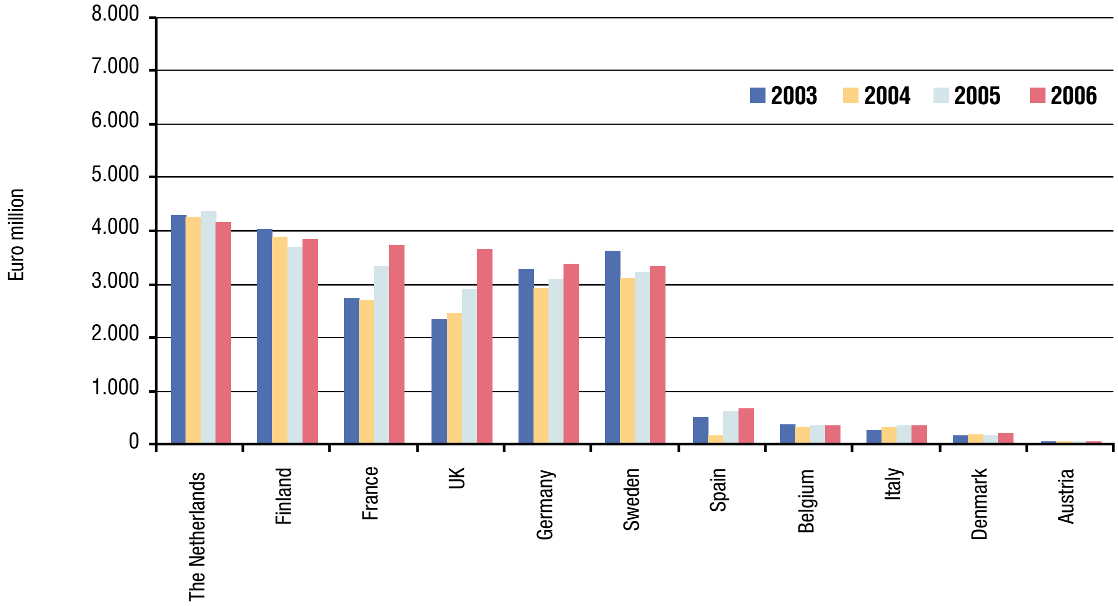
US firms grew by almost €9 billion, well above the growth of all other countries taken together, and with a very high relative growth rate (9.2%).

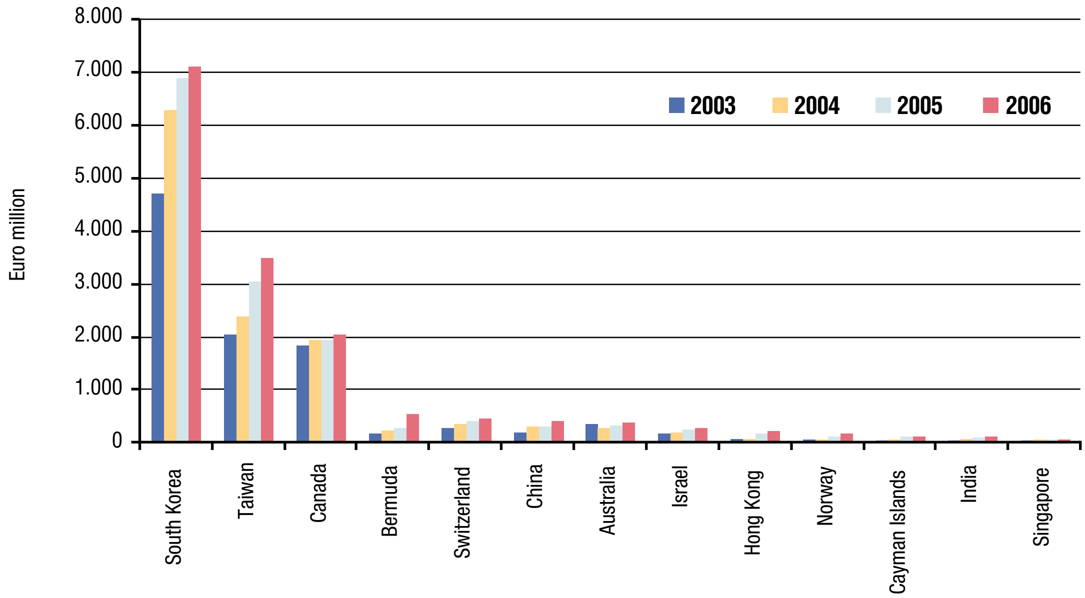
In other words, the data suggest that the already dominant US companies further increased their R&D investment lead.

6.2 Country-level analysis

Breaking down R&D figures of the EU and the RoW to country level, we find that the major R&D investing companies outside the USA and Japan are registered in the Netherlands, Finland, France, the UK, Germany and Sweden within the EU, and in South Korea, Taiwan and Canada outside the EU (see Figure 6-4). In terms

Figure 6-4: R&D investments by ICT firms per country of registered head quarters in the EU and RoW in millions of €, 2003-2006





of absolute growth between 2003 and 2006, Korean companies stand out with an increase of R&D investment of €2.4 billion, followed by Taiwanese companies (€1.4 billion). The R&D growth (2003-2006) in companies from these two countries was on a level comparable with EU companies' aggregate growth (€2.1 billion). Chinese and Indian companies also increased their R&D investments rapidly, but starting from very low levels. Within the EU, most of the ICT sector R&D growth can in fact be attributed to UK (€1.3 billion) and French (€1.0 billion) companies.[58]

6.3 Sub-sector analysis

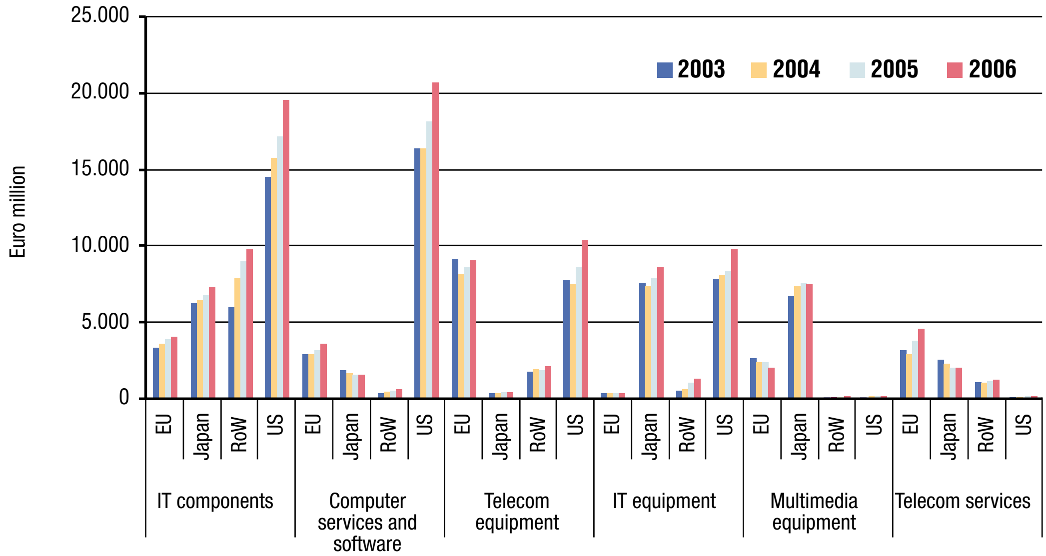
Figure 6-5: illustrates that the most important sub-sector in terms of R&D is IT Components. This sub-sector accounts for about one third of the global R&D investments in the ICT sector and an even larger share of R&D growth. It includes a number of specialized semi-conductor companies such as Intel and STM, but also more diversified (primarily Asian) electronics firms such as Samsung, Canon and Sharp.59 R&D investments in this sub-sector are increasing more rapidly and at higher levels by firms from outside the EU, especially from the USA, but also from the RoW (mainly a few large Korean and a large number of smaller Taiwanese companies – and some Swiss ones).

Second to IT Components is Computer Services and Software, both in terms of size and growth of R&D investments. This sector is completely dominated by US firms, with EU firms far behind in second place. The third largest R&D investing sub-sector is Telecom Equipment, with most R&D invested by North American (much of the RoW R&D investments are made by the Canadian company Nortel) and EU companies. In this sub-sector, too, US companies have increased their R&D investments more rapidly than EU ones as of 2006. It could also be noted that in the EU, €8.7 billion (of €9.1 billion in 2006) is invested by just three firms (Nokia, Ericsson and Alcatel-

58 Note that the increase in the UK is due to BT alone and the increase in France is largely due to R&D increases by France Telecom only.

59 Since this sub-sector includes several large companies, whose main lines of business are not necessarily in components, *Scoreboard* data may overestimate the importance of this sector as compared to national statistics.

Figure 6-5: R&D investments in the ICT sub-sectors by EU, US, Japanese and RoW companies, 2003-2006



Lucent). This could be contrasted with the USA, where much of the R&D growth can be attributed to a large number of rapidly growing "medium-sized" companies (e.g. Juniper), although there are big companies as well (Motorola and Cisco). These and other indications question the assumptions about the strength and dynamism of the EU Telecom Equipment sector. IT Equipment has about the same R&D size, growth and composition as Telecom Equipment, except that it is Japanese companies (instead of EU ones) that are challenging the USA for the global R&D investment leadership position in this sub-sector.

The only sectors where the US has a weak R&D presence are Multimedia Equipment and Telecom Services. Both these sub-sectors also show lower levels of R&D investment and growth than the other ones. R&D in Multimedia Equipment is largely conducted by Japanese companies. It should also be mentioned that the European R&D investments in this sub-sector are overstated by *Scoreboard* data, because Philips is classified as a Multimedia sub-sector company, whilst - as mentioned in Annex 7 on methodology - its figures include substantial R&D activities from outside the ICT sector, for example in lighting, domestic appliances, and personal care and medical systems (although part of the R&D in those segments may, in turn, be ICT R&D).[60] Finally, Telecom Services is the only sector where

60 See Philips Annual Report (2007) available online at http://www.philips.com/about/investor/financialresults/annualreports/index.page

Table 6-2: Top R&D investing ICT sector companies in 2006

Rank	Company	NACE Class name	3 digit ICB sector	Country	R&D (€ mill.)	Sales (€ mill.)	R&D/ Sales
1	Microsoft	CSS	Software	USA	5400	38767	13,9%
2	Samsung Electronics	IT components	Electronic equipment	South Korea	4660	69658	6,7%
3	Intel	IT components	Semiconductors	USA	4454	26831	16,6%
4	IBM	CSS	Computer services	USA	4304	69329	6,2%
5	*Nokia*	*Telecom equipment*	*Telecommunications equipment*	*Finland*	*3712*	*41121*	*9,0%*
6	Matsushita Electric	Multimedia equipment	Leisure goods	Japan	3594	56607	6,3%
7	Sony	Multimedia equipment	Leisure goods	Japan	3385	44192	7,7%
8	Motorola	Telecom equipment	Telecommunications equipment	USA	3114	33169	9,4%
9	Cisco Systems	Telecom equipment	Telecommunications equipment	USA	3084	21600	14,3%
10	*Ericsson*	*Telecom equipment*	*Telecommunications equipment*	*Sweden*	*2976*	*19702*	*15,1%*
11	Hewlett-Packard	IT equipment	Computer hardware	USA	2723	69507	3,9%
12	Hitachi	IT equipment	Computer hardware	Japan	2578	60238	4,3%
13	Toshiba	IT equipment	Computer hardware	Japan	2370	40373	5,9%
14	NEC	IT equipment	Computer hardware	Japan	2130	29612	7,2%
15	*Alcatel-Lucent*	*Telecom equipment*	*Telecommunications equipment*	*France*	*1988*	*14381*	*13,8%*
16	Sun	IT equipment	Computer hardware	USA	1970	9910	19,9%
17	NTT	Telecom services	Fixed line telecommunications	Japan	1963	68361	2,9%
18	Canon	IT components	Electronic equipment	Japan	1962	26455	7,4%
19	*Philips Electronics*	*Multimedia equipment*	*Leisure goods*	*Netherlands*	*1948*	*30851*	*6,3%*
20	Oracle	CSS	Software	USA	1665	13647	15,0%

Note: CSS = Computer Services and Software

EU R&D investment levels and trends are more positive than for the other regions.[61]

6.4 Major R&D investing companies

The 20 major R&D investing ICT companies are listed in Table 6-2. Of these, four are EU-based while most of the others have their headquarters in either the USA or Japan. Of the four EU firms, three are in the Telecom Equipment sub-sector.

61 We may also note that the EU ICT R&D system is very much concentrated in the telecom-related sub-sectors, especially Telecom Equipment. €13.7 billion out €23.8, or almost 60%, billion are invested by telecom companies. The corresponding rates in other regions are between 9 and 23%.

Looking instead at R&D increases for the time period 2003-2006, a quite different set of companies emerges. The majority of these companies are based in the USA, including Internet-related firms such as Google and Yahoo!. Among the four EU companies on the list, two are the telecom operators BT and France Telecom. It would therefore be interesting to investigate what activities are behind such increases in reported R&D investments.

6.5 Major R&D investing companies in Computer Services and Software

This section briefly focuses on the Computer Services and Software sub-sector, as it is the most dynamic in R&D in the EU, as identified in Chapter 4. We do so, by looking at the ten top R&D investors in the EU and the USA (Table 6-4).

Table 6-3: Top growth R&D investing ICT sector companies in (2003-2006)

Rank	Company	NACE Class name	3 digit sector name ICB	Country	R&D Growth 2003-2006 €
1	Samsung Electronics	IT components	Electronic equipment	South Korea	1741
2	*BT*	*Telecom services*	*Fixed line telecommunications*	*UK*	*1165*
3	Intel	IT components	Semiconductors	USA	1147
(4)	(Freescale [a.])	(IT components)	(Semiconductors)	(USA)	(906)
5	IBM	CSS	Computer services	USA	815
6	Qualcomm	Telecom equipment	Telecommunications equipment	USA	769
7	Google	CSS	Internet	USA	758
8	Cisco Systems	Telecom equipment	Telecommunications equipment	USA	707
9	Oracle	CSS	Software	USA	695
10	Sun Microsystems	IT equipment	Computer hardware	USA	577
11	Sony	Multimedia equipment	Leisure goods	Japan	564
12	Yahoo!	CSS	Internet	USA	489
13	EMC	IT equipment	Computer hardware	USA	484
14	LG Electronics	IT components	Electronic equipment	South Korea	468
15	Symantec	CSS	Software	USA	466
16	*Alcatel-Lucent*	*Telecom equipment*	*Telecommunications equipment*	*France*	*395*
17	*France Telecom*	*Telecom services*	*Fixed line telecommunications*	*France*	*378*
18	Broadcom	IT components	Semiconductors	USA	352
19	*STMicroelectronics*	*IT components*	*Semiconductors*	*Netherlands*	*342*
20	Texas Instruments	IT components	Semiconductors	USA	339

Notes: CSS = Computer Services & Software
a.) Freescale is a spin-off from Motorola, formed in 2004. Thus the increase from 2003/2004 is not really relevant.

Table 6-4: Top 10 EU & US R&D investing companies in the CSS subsector (2006)

EU						USA				
Company	Count.	R&D 06 (€ mn)	Δ 03-06 (€ mn)	CAGR	Age	Company	R&D 06 (€ mn)	Δ 03-06 (€ mn)	CAGR	Age
SAP	D	1,298	302	9.2%	36	Microsoft	5,400	-499	-2.9%	33
Dassault	F	281	65	9.2%	27	IBM	4,304	815	7.3%	97
Telent	UK	206	-279	-24.8%	122	Oracle	1,665	695	19.8%	31
Bus. Obj.	F	148	76	26.9%	18	Google	932	758	74.9%	10
Fujitsu-Sie.	J	145	3	0.6%	23	Symantec	657	466	50.9%	26
Amdocs	UK	142	51	16.1%	27	Yahoo!	646	489	60.2%	13
Sage	UK	141	55	17.9%	27	CA	604	69	4.1%	32
Misys	UK	132	0	0.1%	29	Adobe	409	199	24.9%	26
UBIsoft	F	131	57	21.3%	22	Cadence	367	94	10.3%	26
Indra	ES	96	24	9.9%	87	Intuit	331	137	19.5%	25
Total		2,720	354	4.8%		Total	15,315	3,223	8.2%	

Note: CAGR = Compound Annual Growth Rate.
Colours: Blue: Companies older than 40 years. Red: Companies younger than 15 years.

Clearly the US companies, as an aggregate, outperform the European ones in almost every respect: R&D investments are about six times higher. From 2003 to 2006, US firms increased R&D investment by €3.2 billion, almost ten times the increase by EU firms. In spite of their much larger size, US firms increased their R&D at a rate almost double that of EU firms (8.2% annual increase, as compared to 4.8% for Europe).

From the table, it can also be seen that most firms are relatively young, around 30 years old, several of them taking advantage of the opportunities presented by the growth of a PC software market. However, it should be noted that among the very young rapidly growing Internet/WWW services firms, only two have made it to the top ten list – Yahoo! and Google. Clearly, the USA seems more capable of growing companies in the new emerging software and services parts of the ICT sector.

6.6 Summary and conclusions

EU ICT sector companies make very substantial R&D investments but, at an aggregate level, they invest less in R&D than companies from other regions, and they represent a smaller share of total R&D in the EU than elsewhere. In comparison with the USA, there is a gap in ICT sector R&D, which is in fact larger than the total economy R&D gap. However, as shown by earlier IPTS research,[62] this is not because individual US companies are more R&D intensive than European ones. R&D intensity is instead most likely to be sector-specific rather than region-specific. This suggests that the ICT R&D gap is, in fact, mostly due to there being more and larger US ICT sector companies.

R&D investments by EU companies in the ICT sector have been increasing recently, but more slowly than elsewhere. In **relative** terms, the fastest growth can be observed outside the triad (the USA, the EU and Japan). Most of this growth can be found in South Korea and Taiwan, but there are also a number of other countries (e.g. Israel, India and China) with high relative R&D growth rates at low absolute levels. However, in **absolute** terms, more than half of the R&D growth between 2003 and 2006 can be found among US companies, thus increasing their lead over the non-US companies.

62 Lindmark et al (2008), European Commission (2007)

The major R&D investing companies in the EU are registered in the Netherlands, Finland, France, the UK, Germany and Sweden, while a large share of the increased R&D investments in the EU can be traced to just a few firms (BT, Alcatel-Lucent, France Telecom, STM and SAP) headquartered in just a few countries (the UK and France).

Globally, at sub-sector level most R&D investments as well as most R&D growth are recorded in the IT Components sector (which also includes major electronic equipment firms). Second to IT Components is Computer Services and Software, both in terms of size and growth of R&D investments. This sector is however completely dominated by US firms, with EU firms far behind in second place. US firms in this sector also include recently and rapidly growing Web services firms such as Yahoo! and Google. The third largest R&D investing sub-sector is Telecom Equipment, with most R&D invested by US and EU companies, but with US R&D investments again increasing faster and where much of this R&D growth can be attributed to a large number of rapidly growing "medium-sized" companies. In IT Equipment, it is Japanese companies (instead of EU ones) that are challenging the USA for the global R&D investment leadership position. Multimedia Equipment and Telecom Services show lower levels of R&D investment and growth than the other sub-sectors. In fact, Telecom Services is the only sub-sector where EU R&D investments outperform the other regions.

Part 2 Thematic Analysis: Output of ICT R&D in the European Union

7 From inputs to outputs in R&D activities

7.1 Introduction

The previous chapters presented quantitative information on various aspects of inventive effort in ICT. The relationship between those efforts and the desired outcomes of R&D is not straightforward. An R&D investment does not necessarily produce an invention. Even when it does, the invention may or may not be useful and/or productive in an economic sense. In the next chapter, patent statistics will be presented as indicators of the *output* of the inventive process. As a way of introducing and contextualising these figures, a conceptual framework is also presented for the analysis and assessment of innovative activities and related public policies. This framework will first trace the mutual relations of the principal quantities (and, eventually, policies) involved. Secondly, it will indicate venues for the quantification of the relations between the distinct *indicators* of innovative activities,[63] and of the impact of innovation policies.

One important simplification made is in the exclusive focus on formal R&D activities, more likely to be detected by official statistics. These are, for the most part, the routine innovation tasks that are carried out in formal settings, such as firms' R&D laboratories, (with the few very large actors clearly outweighing the many small ones), or public laboratories of various types (see Baumol, 2002).

In doing so, we ignore two important types of innovation. First, we do not consider those innovations which are not reflected in R&D statistics, although they may seem particularly relevant for productive processes and business practices in general. These innovations could be detected by ad hoc surveys, and certainly better characterise the innovative activities of small and medium sized enterprises, than of big ones. Moreover, entrepreneurs who succeed in innovating processes, or who develop innovations in informal contexts, are more likely to resort to trade secrets, than to seek intellectual property rights protection, so that this type of innovation also is often not detectable in patent statistics.

Secondly, innovative activities carried out by users and outside of formal *productive* contexts are also largely ignored. There is a sense of the growing importance of this type of innovation, at least in particular contexts (see Von Hippel, 2005). Anecdotal evidence on such "user-generated innovation" is abundant – from the advances in skateboarding, surfing and wind surfing, to amateur astronomy. In these fields, important innovations by (communities of) users have been documented, in some cases giving birth to highly innovative start-up firms. It is in information and communication technologies that, arguably, some of the most interesting

63 On the linkages between these different indicators, the selection of key statistics and the position of EU countries with specific reference to the role of ICT, see de Panizza and Visaggio (2007)

instances of user-generated innovations occur.[64] Lastly, user-driven innovation has, at times, taken the form of users bending available innovations to their needs. A good example, once again, pertains to the realms of information and communication technologies: text messaging was introduced by telecom operators slowly, and no one predicted how it would be used and the extent of its success.

There are two broad reasons for focussing exclusively on what may be dubbed "mainstream" innovation. First, this type of innovation, carried out within big enterprises, results in most of today's new products. It is the world of "Schumpeter Mark II", centered on the might of those firms whose size allows them to be the first to set up R&D labs, and to use them to carry out the complex chain of activities from the initial research of new products, right down to their development and eventual production, and includes the management of all issues related to the protection of the related intellectual property rights. The second reason for a selective focus has to do with a need for coherence with the overall format of this report.

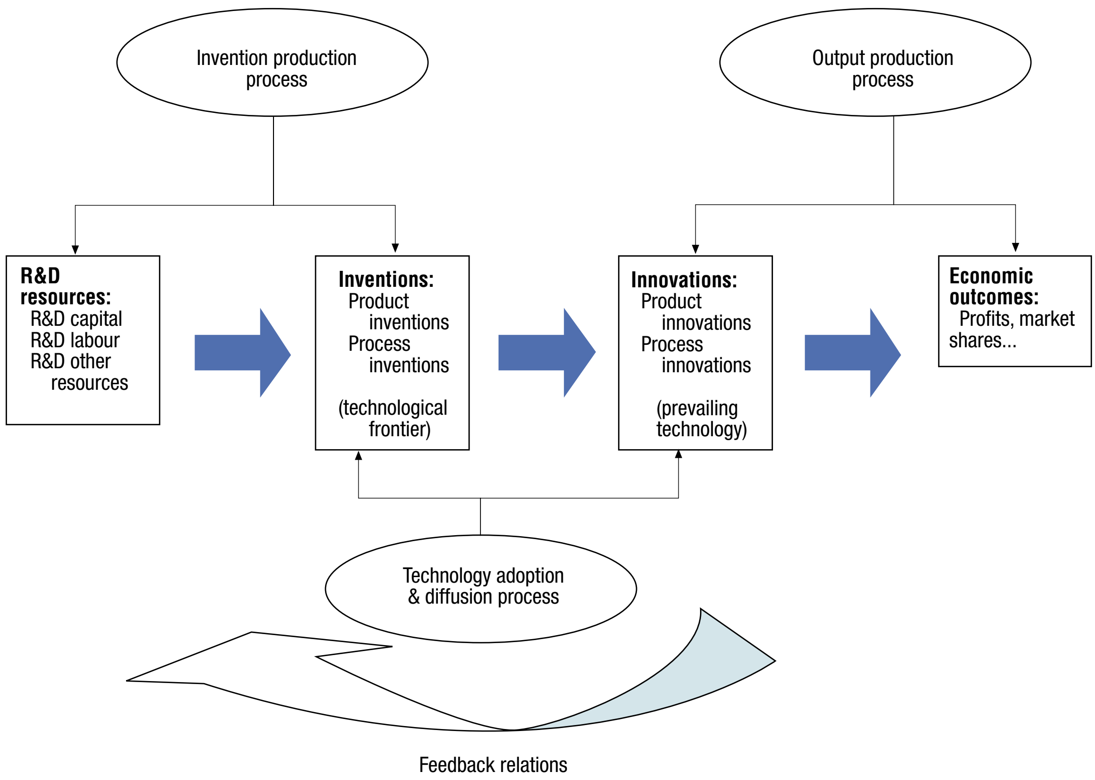
7.2 A conceptual framework

The overall innovation process is illustrated in Figure 7-1, and is divided into three parts marked with ovals.

The first oval shows the invention production process, through which R&D resources are

64 Open source software is one prominent case. In this domain, creations are often motivated by users' needs (Lerner and Tirole, 2005), and are carried out using productive methods that are at odds with the traditional tenets of software engineering (Koch and Gonzales-Barahona, 2005; Picci, 2006).

Figure 7-1: A conceptual framework of innovation: a graphical representation



turned into innovations. These inventions are not necessarily taken up by industry. They may be useless or inapplicable or, when useful, firms may not know of them Even when firms do know about the new production possibilities, they may have difficulties in adopting them, either because they do not understand the technology, because market conditions are not favourable, or because they do not reach an agreement with the owner of the technology. Moreover, whenever an invention becomes an innovation, a time lag separates the two events. The time needed for an invention to be adopted may be minimal – as when a firm starts producing a new product it has invented itself – or may be substantial, as when a firm, in order to use a given technology, has to wait for the expiry of a patent that it does not own. For example, James Watt's steam engine patent precluded adoption (and arguably, further desirable technological progress) by others until it expired (see the account in Boldrin and Levine, 2008, pg. 1). In other words, inventions must undergo a process of *adoption* and *diffusion* in order to become part of mainstream technology, which in Figure 7-1 is represented by the central oval.

Last, the prevailing technology explains how given productive inputs – the most important being labour and the private capital stock – turn into the economy's output, see the oval on the right in Figure 7-1.

In Figure 7-1, the arrows from left to right represent causation links from R&D inputs to inventions, then from inventions to innovations, and finally from innovations to economic output. While the presence of a basic, *univocal* relationship between science/technology inputs, outputs and growth results has a solid grounding in the literature (starting at least from Griliches, 1957), it is useful to consider the intrinsically more complex and interactive nature of the innovation process, characterised by causation flows that are not unidirectional.[65] These complex feedback relations are summarised by the big arrow at the bottom of Figure 7-1, pointing from right to left.

The three phases transforming inventive activities into observed economic outputs are labelled as *processes*. In fact, they could also be seen, more narrowly, as *production functions*, allowing for the more concise formulation of the model, proposed in Figure 7-2.

The representation in Figure 7-2 suggests more explicitly the possibility of quantifying the invention and the production processes, with the help of appropriate econometric techniques, than the original one in Figure 7-1.

Innovation policies can intervene in the model's three different processes. In particular, policies may aim to increase an input or an output of one of these processes, or may attempt to make it more efficient. The model, in principle, allows for a systematic classification of policies. This aspect is not pursued here, but it should be noted that the analysis of policies could be carried out in relation to the vast literature on national innovation systems. For example, when we consider policies that intervene in the innovation process as opposed to those that try to improve the adoption diffusion process, we may expect the first ones to dominate within "mission-

65 In this respect, it is worth mentioning the "chain-linked model" outlined by Kline and Rosenberg (1986) for the relationship between research, invention, innovation and production. These authors introduce small and larger feedback loops, within each part of the chain and to preceding parts respectively, and the broader representation, including adaptation cycles for organisation (i.e. not only for technology) developed by Leonard-Barton (1988). At the EU level, the current wide approach to innovation is stated in the Green Paper on Innovation [European Commission (1995)], where innovation is defined as "the renewal and enlargement of the range of products and services and the associated markets; the establishment of new methods of production, supply and distribution; the introduction of changes in management, work organisation, and the working conditions and skills of the workforce".

Figure 7-2: A conceptual framework of innovation: A production function representation

1. Invention production function: $A = fn(R\&D^{tech}, R\&D^{K}, R\&D^{L}, ...)$

2. Adoption & diffusion process

3. Output production function: $Y = A' \cdot fn(K, L, ...)$

Prevailing technology

oriented" (national) innovation systems, whereas the second ones would be "diffusion oriented" (this distinction was originally proposed by Ergas (1987)).[66]

The framework we propose here is similar to the one used by Crepon et al (1989) in their analysis, which represented the point of departure for many other contributions (but see also Pakes and Griliches, 1984). This is based on a four-equation system. First, the "research equation" explains the decision of firms to carry out R&D activity and how much (in our wording, this equation explains the input of the *invention process*). The second, the "innovation equation" - as named by Crepon et al - is analogous to our *invention production function*. The third equation in their model is the "innovative sale equation". This links inventions (what the authors call innovations) to the share of firms' sales that are due to innovative products. This equation captures our *adoption and diffusion process*, but only to a limited extent. Since the analysis is carried out at firm level, with no role for spillovers across firms, it ignores the issue of whether, how, and with what time lags, inventions by one actor become innovations available to others. Their fourth equation is the "productivity equation" and corresponds to our *production process output function*. Crepon et al consider explicitly the issues of the econometric estimation of their whole system, while taking into consideration the particular nature of some of their variables.[67]

7.3 The invention production process

Chapters 2 to 6 of this report present information on the innovation process, and the next chapter deals with a typical measure of inventive output, patents. As a consequence of this selective focus, a description of the inventive process only is presented in this section, and particular attention is paid to the issue of measurements of the relevant quantities.

The production of inventions is, arguably, unlike most other productive processes. First, its outputs are non-rival information goods. Secondly, the production process itself is characterised by the paramount importance of a highly skilled labour force. A good starting point for a discussion of these aspects, and the impact on them of structural changes induced by ICTs and globalisation, is the characterisation of R&D activities originally proposed by Baumol (1967,

66 Amongst the most relevant sources of information on R&D policy instruments in place in EU countries, the US and Japan, it is worth mentioning IBDF (2004). On the *policy mix* for R&D, the EC DG Research promotes a specific project (www.policy mix.eu), and the *Erawatch* analytical assessments, undertaken jointly with the Commission's JRC-IPTS.

67 In particular, they use a generalised Tobit model for R&D investment, a heterogeneous count data for patents that they take as a proxy of innovation (here, *inventions*), and an ordered Probit specification for their variable on innovative sales, since in the survey they use the variable of interest is only available as interval data.

2001). This author examined a number of service activities (including R&D), that he deemed were characterised by comparatively slow productivity growth. He predicted a rise of relative unit costs for their outputs (due to wages) and, ultimately, a fall in their demand or, otherwise, an overall decline of growth rates.[68]

Though Baumol's model has a number of weaknesses (e.g. it ignores the dependency of demand on income levels), it does have the important merit of considering that inventions are also *produced*. Thus, both their production process and its cost structure require understanding, and consideration of (the impact of productivity gaps on) comparative costs and prices among different sectors of the economy.

Following this line of thought, we can consider that some of the changes occurring in the world economy contributed to render R&D activities more productive and, also, profitable. Indeed, there are good reasons to believe that, thanks to the assistance of computers and the Internet, researchers did indeed become more productive overall, while the price of R&D information inputs decreased. Also, it may be that the current exploitation of new General Purpose Technology –information and communication technologies – goes hand in hand with the presence of an exceptional number of exciting inventive opportunities that are reflected in rising productivity in R&D activities. Moreover, market expansion allows higher sales of products which embed the output of R&D activities, increasing the value of inventions.

Another relevant issue, when describing the transformation of R&D resources into inventions, is the size and age distribution of firms. Are younger firms more innovative than old ones, all other characteristics being equal? What are the relations between the demographic characteristic of firms, their size, and their innovative activities? These questions are not new, and can be traced back to the works of Schumpeter. The question is of particular relevance in Europe, given the observed marked difference between the demographic structure of European and US firms, the latter having a much larger share of younger firms of relevant size (Véron, 2008).

7.3.1 Measuring the inputs: R&D resources

The inputs of the R&D process are R&D resources spent on labour, research instruments and infrastructures. Conceptually at least, it is useful to maintain the traditional distinction between labour and capital input. Also, the origin of these resources may be private or public, the latter typically being the result of policies aimed at encouraging R&D activities. The distinction between sources of funding is nonetheless important, because they may lead to crowding–in or crowding–out phenomena (for an empirical study at an international level, see OECD, 2006).[69]

68 In the first version of his model, Baumol underlines the fact that the production of many services, such as those in the health sector, the performing arts, and legal activities, are characterized by the presence of a "handicraft component of their production processes and the relative difficulty of achievement of reductions in the overall role of that component" (Baumol, 2002, p 271). Generalized productivity increases taking place in the other sectors of the economy push the real wages of these "artisans" up, so that the real cost of their services increases in time. As the real cost of artisan-provided services increases, their demand decreases, as resources are progressively shifted to sectors of the economy that do experience an increase in productivity. This, in a nutshell, is the Baumol's *cost disease* argument. According to Baumol (2001), the case of R&D production is better seen not as a stagnant, but as a *hybrid* sector, where inputs from the progressive sectors of the economy (such as computers, and research infrastructure in general) are used more or less in a fixed proportion. As a consequence, the effects of the progressive increasing real cost of the labor input is weakened, but still relevant. Baumol calls sectors of this type "asymptotically stagnant". The prediction, although in an attenuated form, is still one of diminishing importance of R&D activities, relative to other economic activities.

69 An attention towards the estimation of the effects of public policies on private decisions to invest in R&D is present in European Commission (2008a), where the total of "R&D spending **financed** by the Government" (emphasis in the original) is taken to be the *input* measure, while "Business Enterprise Expenditure on R&D **financed** by Business Enterprises" is considered among *output* indicators, together with the "Number of R&D Personnel in the Business Enterprise Sector", and the "Number of Patents".

Information on R&D in most countries is collected by means of a dedicated survey with a common scheme based on the OECD (2002) *Frascati Manual*, referring to expenditures by type of activity, source of funds, and structure, and to personnel.[70] Notwithstanding the provisions of this manual and of EU regulation, data on R&D expenditure by cost structure, separating physical capital from current (and, specifically, labour) costs, are usually not available in the EU, hence this distinction is seldom addressed in analysis.[71] Regardless of this, a number of authors have estimated the stock of intangible R&D capital by capitalising past R&D expenditures, irrespective of their nature. There seems to be a double rationale in these exercises. First, as with what happens for tangible forms of capital, it is intuitively appealing to consider the product of R&D activities as an intangible asset for the firm that depreciates with time.[72] Secondly, while this kind of intangible asset contributes to defining the firm's technology of production (the way inputs are used to produce an output), and not an input of production proper, it is true that, in some specifications of production functions commonly used for the purpose of econometric estimation, the technology component appears in exactly the same way as any production input, so that the distinction between "technology" and "production inputs" is debatable.[73]

Other measures of inputs of R&D effort regard the labour input (researchers and total R&D personnel) on which information is collected in the same (R&D) survey.

Based on data collected in R&D surveys, the first part of this report offers the only available comprehensive EU level statistical information on both business R&D expenditure and personnel in the ICT sector.

Other relevant statistics include data on human resources in science and technology, which draw on the definitions of the *Canberra Manual* (OECD-Eurostat, 1995), and that part of the Community Innovation Survey (CIS) which refers to innovation expenditure[74] (this is based on the third edition of the *Oslo Manual,* OECD-Eurostat, 2005).

Other sources of statistical information, even if they do not explicitly measure R&D input, are at times useful. Statistics on educational attainments may be of interest, since researchers are very often (although not always) people with at least a university degree. Also, the information from the EU survey on ICT usage patterns by enterprises is usually considered a complementary source of information with respect to firms' innovative behaviour, particularly as regards inputs.

In the context of the general analytical framework presented in this chapter, it is also worth mentioning the emerging wave of micro-funded internationally run analytical projects based on official statistics, which address the nexus between

70 This manual, now in its sixth edition (the first edition came out in 1962), is the forerunner of the *Frascati family* of OECD Manuals – often produced in collaboration with Eurostat. These manuals aimed to portray scientific and technological activities, covering innovation as such at the level of the firm (The *Oslo Manual*), the availability of human resources (The *Canberra Manual*) and patenting activity (The *Patent Manual*) – see *infra*.

71 An example is the work by Krogh Graversen and Mark (2005), on the effect of R&D capital on productivity of Danish firms.

72 This line of thought is also reflected in a debate on how R&D and other types of intangibles should be recorded, both in firms' and in national accounts (see the discussion in Bontempi and Mairesse, 2008).

73 For example, log linearing a textbook Cobb-Douglas production function, we obtain: , so that known elements of A, the technology, can be added as regressors when estimating such functions. This approach is followed in the studies by Krogh Graversen and Mark (2005), on the effect of R&D capital on productivity of Danish firms, and by Bontempi and Mairesse (2008) on different methods of estimating R&D intangibles, and on the role of intangibles in explaining the value added of a large sample of Italian firms.

74 The CIS (and harmonised surveys in a number of other countries) is the main source of information on innovation activity at the micro level, and it encompasses (technologically related) innovations related to **products**, to **productive processes**, to **organizational aspects** within the enterprise and, also, to **marketing**. The CIS also provides data on all the different facets of the innovation process: besides innovation activity overall and by type, including a specific voice for R&D and related expenditure, information is collected on material and informative sources of innovation, on the continuous or occasional nature of the innovative activity, on whether or not is undertaken in collaboration, on factors hampering it, and on its economic results.

enterprises' characteristics, inventive activity, innovation and performance. In particular, at the time of writing, projects are being launched on the role of business demographics with respect to firms' growth and patents (OECD) and R&D activity (IPTS-Eurostat-DG Information Society and Media), while another OECD-led project (also with the participation of IPTS) aims to address the issue of ICT-enabled innovation. First results of these projects are expected in 2009.

7.3.2 Measuring the outputs: inventions.

An R&D activity can result in (one or more) inventions, or just give no (immediate) fruit, while inventions themselves may come out of R&D or other non-formal research activities or intuitions. As a matter of fact, and for different reasons, inventions arising from R&D activity are the most likely to be protected from the possibility of exploitation by third parties by patenting them, so that patents are often used as measures of the output of (formal) inventive processes. As the next chapter shows in a particular case, the cross-country correlation between R&D effort (as measured by R&D expenditure on GDP) and its outcome (as measured by the number of patents per inhabitant) is typically positive (see Section 8.4.4).

Patent data, as a measure of inventive output, have virtues and shortcomings (Smith, 2005, and Griliches, 1990; see also the OECD, 1994 *Patent Manual*). Many innovations, particularly of production processes, do not result in any patent applications, and firms often prefer to protect their inventions by keeping them secret, rather than by asking for the protection afforded by patents. The possibility of patenting software is particularly relevant in the case of ICT. Software patenting is possible in the United States but is severely limited in Europe. The next chapter briefly returns to this issue, though a detailed analysis is outside the scope of this report.

While not all innovations are patented, the opposite is also true - that is, not all patented inventions produce innovations. Patents may have very different values, and for each superstar patent, which introduces a very relevant and successful product or process, there are countless others with limited or no use. Possibly a more serious problem is the fact that patenting activity is increasingly just one of many strategies that oligopolistic firms have at their disposal. “Defensive patenting”, in particular, has become a way of accumulating a sizeable patent portfolio to be used as a bargaining chip. Indeed, at times the collections of patents owned are better summarised as ammunition for lawyers, than blueprints for engineers. While the worst excesses of such “patent inflation” are probably confined to the United States, the issue is obviously a very serious one (see Jaffe and Lerner, 2004 for an assessment and a critique; and Archontopoulos et al, 2007 for a quantitative assessment of the problem at the European Patent Office (EPO)).

One way of filtering out low-quality patents is to only consider the applications presented at particularly important patent offices. Another possibility is to consider “triadic patents”, meaning all patents filed at least at the EPO, the United States Patent and Trademark Office and the Japan Patent Office (see Dernis and Khan, 2004). Since a triple filing is quite expensive, it may be expected that applicants choose to incur the related costs only when they believe that their invention deserves it. However, this approach does not filter out strategic patenting activities, and in fact may achieve the opposite, since such a strategy is more likely to address the patenting offices covering the widest markets.

Approaches that aim to exclude low-quality patents also overlook relevant inventive activities. Even when they do not represent a genuine advancement of the technological frontier, patents hint at the presence of an absorptive capability, because learning about existing technologies is an integral part of R&D activities. As Cohen and Levinthal (1989) put it, R&D is always “innovation and learning”.

The value of patents can also be ascertained by means of citations in other patents, using dedicated databases which, as we shall see in the following, allow us to track applicants, i.e. in most cases enterprises who paid for the R&D activity.

Measures of output of the inventive process are provided by the CIS survey, which supplies information on patents, trademarks, industrial design and copyright, accompanying that on inventive activity and (R&D) expenditures. Other valuable information may be found within structural business statistical surveys and, at the macro level, in the technology balance of payments. Outside the realm of official statistics, information on the output of intellectual work also includes data on scientific publications (bibliometrics) and literature-based indicators of innovation output (publications, citations, etc.) in technical journals.

7.3.3 Linking R&D inputs with inventive outputs

The quantity and quality of inventions depend on the inputs that are spent. The amount of aggregate R&D input is equal to the sum of many individual decisions that, as in Crepon et al (1998), should logically be divided into two parts: first, the decision to carry out R&D projects, and second, if the answer to the first question is positive, the decision on the amount of resources to dedicate to R&D. Such a distinction is relevant from a practical point of view, because, for example, most firms do not carry out any (formal) R&D activity, and neglecting the first stage of the decision would probably result in a selectivity bias.

The public part of R&D expenditure, being a policy variable, as a first approximation can be considered as exogenous. However, in reality the amount of public resources dedicated to R&D (either as direct financing, or as tax breaks) is influenced by several outside factors, the lobbying power of firms already engaged in R&D being one of them.

Turning to the estimation of the invention production function proper, efficiency in transforming inputs into outputs can be assessed econometrically using either a production function approach, or an analysis of the distance of the productive units from the production possibility frontier. either using a Data Envelopment Analysis (DEA, a deterministic technique related with linear programming), or stochastic Frontier Analysis (see Coelli et al, 2005).

7.4 Conclusions

Estimating the relation between R&D inputs and outputs is not a simple exercise. This chapter attempted to provide a general framework for analysing a complex issue. It presented a general characterisation of the innovation process, and focused on its first component, the transformation of inventive efforts into inventions. This characterisation will help us to interpret the patent statistics that will be presented in the next chapter, and show the complex relation linking measures of the inputs of the R&D production process, with observed outputs of the same process.

8 ICT patents in the European Union

8.1 Introduction

This chapter analyses the generation of technological innovation in the field of ICT, as measured through the analysis of patent applications in Europe. Using patent data as a proxy for inventive activity has a series of shortcomings, but it also allows us a very objective look, albeit incomplete, at the advancement of technologies.

The following analysis uses the April 2008 release of the worldwide PATSTAT database, which contains data from over 80 patent offices around the world and was developed by the European Patent's Office (EPO). The PATSTAT database is particularly relevant to the analysis of the European patenting activity as it contains all applications filed at any one of the European national patent offices and at the EPO, for the period between 1990 and 2005.

A vast amount of literature documents both the virtues and the shortcomings of patent data as a measure of R&D inventive output (for example, see Smith, 2005, and Griliches, 1990). The main criticism levelled against patent-based measures of innovation argues that many inventions, particularly of productive processes, do not result in any patent applications, and ample evidence shows that firms often prefer to protect their inventions by keeping them secret, rather than by asking for the protection afforded by patents. Also, patentability of software - an obviously important component of ICT – is an issue in Europe. It is not immediately clear whether the rules prevailing in Europe regarding the granting of patent protection to software-related inventions could affect patent-based measures of innovation in ICT.[75],[76]

While not all inventions are patented, not all patented inventions produce innovations. More to the point, patents may have very different values, and for each relevant patent, which introduces a successful product or process, there are countless others with limited or no applications. Also, increasingly, patenting activity is often just one of many strategies that firms in oligopolistic competition have at their disposal. "Defensive patenting", in particular, has become a way of accumulating a sizeable patent portfolio to be used as a bargaining chip. Indeed, at times the collections of patents owned are better understood as "ammunition" for the lawyers than as blueprints for the engineers. While the worse excesses of such "patent inflation" are probably confined to the United States, (see Jaffe and Lerner, 2004 and, for an assessment of the problem at the EPO, van Zeebroek et al, 2008) the issue is obviously a very serious one for the use of patent data as an R&D output indicator.

Finally, if patent analysis offers a very interesting proxy for measuring inventive activity, it does not capture elements of explanation when comparing the performance of various countries as these differences may rely on the nature of the inventions, the demographics of the domestic industry, the local conditions for patenting, etc. All such aspects need to be taken into account

75 For an overview of the situation in Europe, after the rejection by the European Parliament in 2005 of the Proposal of the European Parliament on the Patentability of Computer-implemented Inventions, see Guadamuz González (2006).

76 Software patenting is not analysed in the present report. It may be analysed in the next edition of the PREDICT report, since data from the US Patent Office will be included in 2009, so that comparisons between the EU and USA are possible.

when further investigating the inventive activity of a given country or industry.

8.2 Methodology

In order to develop a measure that is well suited to assessing the inventive capability of the European economies, the present analysis takes into account patent applications, and not granted patents.[77] Focusing on applications instead of granted patents, besides being a common practice in the literature, has the important advantage of allowing an analysis of more recent data, considering that several years typically elapse between the filing and the granting of a patent. Note that, according to the prevailing laws, an application is made public only after 18 months have elapsed from filing. This determines the minimum time lag of the data observed.[78]

Only "priority" applications are considered in this analysis. In other words, successive filings of the same inventions in distinct patent offices are discarded. This approach is best suited to building a measure of the inventive capability of a country, rather than the productivity of a given patent office. Applications are taken into account if they are filed at any one of the patent offices of a Member State of the European Union, or at the European Patent Office (EPO), since firms typically apply for a patent in their country of origin (or, in Europe, at the European Patent Office), and then later decide to use the priority right that follows from the original application to also file the patent application elsewhere.

In what follows, when we speak of 'patents' for the sake of brevity, we will always be referring in fact to *priority* patent *applications*.

77 The methodology, here summarised, is explained in full detail in Picci (2009).

78 Taking into account the time necessary to update PATSTAT and diffuse it, the latest available release of PATSTAT gives reliable data up to 2004. Year 2005 data cannot yet be considered as fully stable.

Such an approach is different from the methodologies adopted, for example, by the OECD and Eurostat to obtain patent statistics. These organisations do not consider the EU Member States patent offices but only the EPO, and, in most cases, focus on all applications (not just priority ones). However, most applications by European entities are still carried out at national patent offices, and only some of them are eventually transferred to the EPO. Focusing on the EPO alone may therefore provide a biased measure of inventive capability when the purpose is to draw cross-country comparisons.[79]

Finally, the present analysis is based on two more methodological rules that are common practice. First, in order to assign patents to countries, two alternative criteria may be chosen: either according to the nationality of the applicant(s), or of the inventor(s). The former is called the "applicant criterion", and the latter the "inventor criterion". Quite often, an application has more than one inventor or applicant, and at times they come from different countries. In this case, assignments of patents to countries are carried out by resorting to *fractional counts*. For example, consider an application with two inventors, one from Germany and one from the United States, and three applicants, two of whom are from Germany, and one from the Netherlands. According to the inventor criterion, the application would be one half for Germany and one half for the United States. According to the applicant criterion, the application would be two thirds for Germany, and one third for the Netherlands. In this simple example, the same application is attributed to different countries depending on which criterion is adopted.[80]

79 In Picci (2009), the significant differences between the measures here produced and those reported in OECD (2007) and Eurostat (2008) are highlighted and analysed. The present approach is very similar to the one adopted in de Rassenfosse and van Pottelsberghe de la Potterie (2007 and 2008), and will be further documented in De Rassenfosse et al. (2009).

80 Unfortunately, at times PATSTAT does not report the country of inventor or applicant. Picci (2009) contains an explanation of the procedure adopted to solve most of these occurrences, based on the consideration of successive transfers of priority filings. In most cases, adopting one criterion or the other does not lead to very different results.

Second, to identify ICT patent applications we adopt the taxonomy of the International Patent Classification (IPC) technology classes proposed by the OECD (OECD, 2008a)[81] taking into account those corresponding to Information and Communication Technologies: Telecommunications, Consumer Electronics, Computers and Office Machinery, and other ICT. For applications that refer to more than one technology class, fractional counts of applications are computed. For example, a patent that has three IPC classes, one of which is ICT, and the others are not, is counted as 1/3 of an ICT patent, and 2/3 of a non-ICT patent. The distinction between ICT and non-ICT technologies is unrelated to the ISIC classification of economic activity. The concordance of patents to industry of manufacture and sector of use is a problematic and only partially solvable issue that the present analysis does not consider (see Johnson, 2002).

It is important to note that, even if the present approach considers applications filed at many different (European) patent offices, leading to accurate intra-European comparisons, it is unsuited to comparing European with extra-European countries. The reason is that inventors and applicants tend to prefer the patent office of their own country. This results in a "home bias effect" - when we look at the data from the patent office of a single country, we typically observe a disproportionally high share of patent applications filed by inventors and applicants residing in that same country. As a result, patent statistics based on applications filed at a group of patent offices attribute a disproportionate weight to the inventive activities taking place in the countries where those offices provide protection. In 2009, it is planned to include in the PREDICT analysis the applications filed to the United States Patent Office.[82] Along the same line of argument, this overview of European inventiveness in ICT does not consider the issue of internationalisation of research which, in principle, can be studied by observing those patent applications that are the produced by inventors and/or applicants residing in different countries.

Patent statistics are presented in this chapter for the period 1990 - 2005. It should be noted that the feeding of the data from the different patent offices to the EPO is not always very timely. As documented in Picci (2009), the most serious problem is represented by the Italian patent office, which has only provided complete data up until 2001. All subsequent data for Italy mostly refer to patent applications filed at the EPO. A few other national patent offices may also present a delay in feeding their data to the EPO, presumably confined to the last or the last two years under consideration. On the other hand, patent applications to the EPO are included into PATSTAT in a timely fashion – that is, shortly after it becomes legally possible, or 18 months after their filing to the EPO occurs. The choice of 2005 as the last year of reported data is a compromise between the necessary accuracy of the information to be presented, and the desire to provide an analysis of recent phenomena. It should be added that, according to conversations with EPO, the feeding of national patent data into PATSTAT should become more timely in the future, thus making the analysis of patent statistics that will be carried out in future editions of the PREDICT report more up to date.

81 Telecommunications: G01S G08C G09C H01P H01Q H01S3/ (025 043 063 067 085 0933 0941 103 133 18 19 25) H1S5 H03B H03C H03D H03H H03M H04B H04J H04K H04L H04M H04Q; Consumer electronics: G11B, H03F, H03G, H03J, H04H, H04N, H04R, H04S; Computers, office machinery: B07C, B41J, B41K, G02F, G03G, G05F , G06, G07, G09G, G10L, G11C, H03K, H03L]; Other ICT: G01B, G01C, G01D, G01F, G01G, G01H , G01J, G01K, G01L, G01M, G01N, G01P , G01R, G01V, G01W, G02B6, G05B, G08G, G09B, H01, B11 , H01J (11 13 15 17 19 21 23 25 27 29 31 33 40 41 43 45), H01L.

82 In general, the possibility of considering applications filed at many patent offices, while keeping track of their mutual priority relations, is an important novelty that is afforded by the maturity of the PATSTAT database.

8.3 ICT patenting activity at European level

8.3.1 ICT and total patenting activity

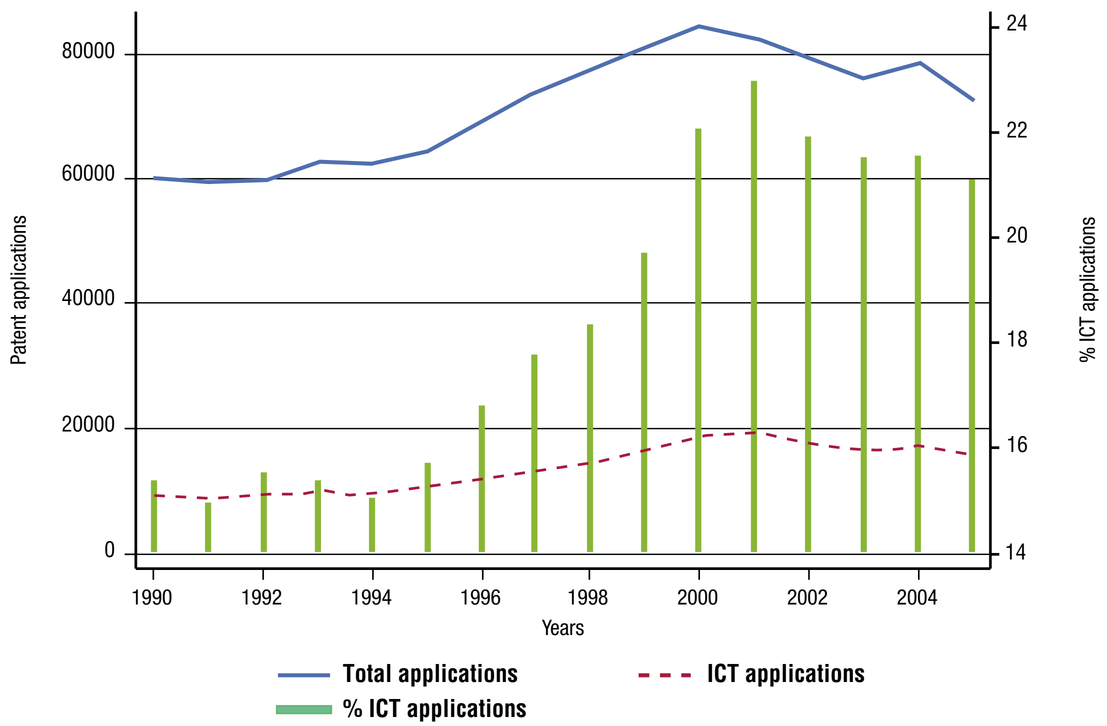
Figure 8-1 shows the total number of priority applications filed in any of the EU Member State patent offices or the EPO, between 1990 and 2004, in all the technology classes and also in the ICT classes on their own. Both totals show an increase during the 1990s, and a decrease afterwards. The share of European ICT applications steadily increased in the second part of the 1990s, from around 15% to about 23% in 2001. In the last few years under observation, a decrease in total applications can be observed, as well as a sharper decrease (in relative terms) in ICT applications from their peak in 2001.

8.3.2 ICT patenting activity in Europe by ICT technological class

The ICT classes (OECD, 2008a) admit a further subdivision into four types of ICT technologies: Telecommunications, Consumers Electronics, Computers and Office Machinery, and a fourth residual class named "Other ICT". Figure 8-2 presents the evolution over time of the shares of these subdivisions of ICT priority applications filed in any of the EU Member States patent offices or the EPO.

During the 1990s, the relative importance of Telecommunications technologies increased, mostly at the expense of the "Other ICT" family of technologies. In more recent years, a slight decline in the Telecommunications, Computer and Office Machinery and Consumer Electronic classes can be observed, reflected in an increase in the residual category.

Figure 8-1: ICT and total priority patent applications, EU27



Source: IPTS analysis of the PATSTAT database (April 2008 release). Inventor criterion

Only an in-depth analysis of the priority applications in this residual category would allow us to describe in more detail the features of this evolution.

8.4 ICT patenting activity at European Member States level

8.4.1 Member States ICT patenting activity

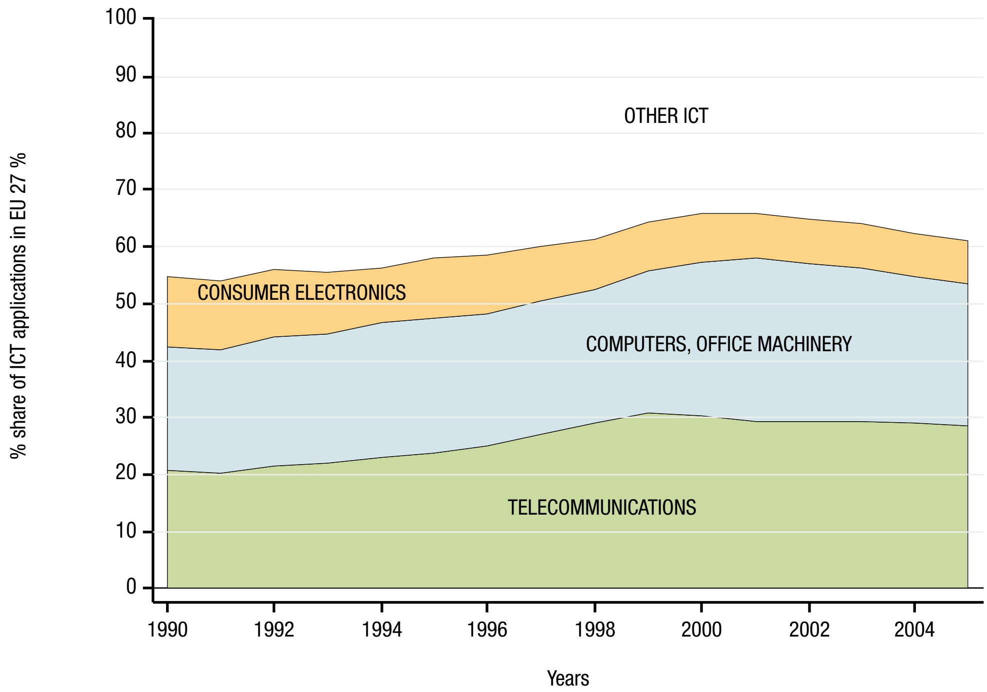
Patent statistics offer a useful view of the innovative prowess of a given country, and this section presents quantitative information, with a view to making cross-country comparisons. Obviously, when performing such comparisons, it should be remembered that bigger countries will tend to be more active in patenting. For example, it should come as no surprise that inventors or applicants from Germany file more patents than those, say, from Portugal.

Column I of Table 8-1 indicates the number of ICT priority applications in the year 2004 by EU Member State, according to the inventor criterion. Values in Columns II and III have been normalised so that the value corresponding to the first ranking country is equal to 100. The countries are ranked according to the values reported in column I.

In the patent counts, the presence of decimal figures is a consequence of the adoption of fractional counting, as explained earlier. As expected, bigger countries file more patent applications, and Germany, France and the UK, with a total of 13,620 patents out of a European total of around 17,000, account for 80% of European applications. This comes as no surprise given the size of the economies of these three countries, and their known technological prowess.

Columns II and III of Table 8-1 report application counts in ICT and attribute them to countries, divided respectively by population and by GDP. The highest value is normalised to 100 so as to facilitate cross-country comparisons. We

Figure 8-2: Share of ICT priority patent applications, by type of technology, EU27



Source: IPTS analysis of the PATSTAT database (April 2008 release). Inventor criterion.

Table 8-1: ICT Priority patent applications by EU Member State, 2004*

	I ICT Patent Applications	II Applications/capita (Germany = 100)	III Applications/GDP (Germany = 100)
DE	8079.76	100.00	100.00
FR	2976.85	48.77	49.09
UK	2563.86	43.76	40.41
SE	505.05	57.30	49.07
FI	461.42	90.08	82.74
IT	398.66	7.09	7.83
AT	349.05	43.57	40.43
NL	320.93	20.13	17.90
PL	300.66	8.03	40.41
ES	288.83	6.91	9.39
BE	183.30	17.91	17.33
DK	89.11	16.85	12.41
HU	87.35	8.81	32.97
IE	69.94	17.68	12.95
GR	67.37	6.20	8.65
CZ	56.29	5.63	17.67
SI	31.55	16.11	32.73
BG	26.48	3.48	36.97
SK	16.77	3.16	13.55
PT	15.25	1.48	2.89
RO	14.18	0.66	6.38
LT	6.87	2.03	10.36
LU	5.41	12.27	5.47
EE	3.35	2.53	9.77
MT	1.00	2.62	6.25

Source: IPTS analysis of the PATSTAT database (April 2008 release). Inventor criterion
** Data for Italy are partly missing (see Picci, 2009). Columns II and III of Table 8-1 report application counts in ICT attributing them to countries, divided respectively by population and by Gross Domestic Product. The highest value is normalised to 100 so as to facilitate cross-country comparisons.*

observe that Germany in 2004 filed the highest number of ICT patent applications, both in absolute and relative terms, after controlling for either its population or GDP. In relative terms, France and the UK occupy some of the top positions. Even after controlling for the sizes of their population or for their economies, Germany, France and the UK still remain among the most active innovators.

The Nordic countries (Finland and Sweden) and Austria do obviously well. Finland and Sweden, in particular, occupy the 2nd and 3rd positions in terms of applications per capita, with Finland being quite close to Germany. Southern and Eastern European countries, on the other hand, have lower numbers of ICT applications, both in absolute terms, and also relative to their population and, to a smaller extent, their GDP.

Countries whose GDP per capita is lower than that of Germany score higher in the measure normalised by GDP (column III) than in the measure normalised by population. The difference is particularly conspicuous for some eastern countries. For example, in 2004 Poland had 8% of the ICT patent applications per capita with respect to Germany. When we consider the number of patents divided by GDP, however, the normalised number of Polish patents rises to 40% that of Germany. A comparison of ICT patenting activities of the countries constituting the European Union is shown in Table 8-1 which indicates that many countries file very few ICT patent applications. They are usually the same countries that also have low R&D intensities, as seen in the previous chapters. For this reason, in what follows we mostly concentrate on the group of ten countries that filed the highest number of applications: Germany, France, the United Kingdom, Sweden, Finland, Italy, Austria, the Netherlands, Poland and Spain.

8.4.2 Member States contribution to total ICT EU27 priority patent applications

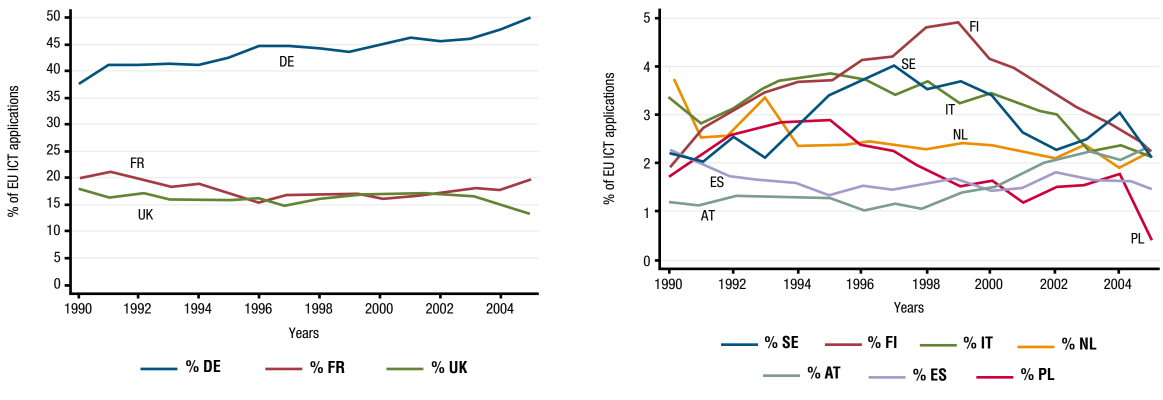
Figure 8-3 shows the evolution over time of the contribution to total ICT applications in Europe from the ten European countries most prolific in filing patent applications. It confirms that the European patenting activity in ICT over the period under consideration has been, to a great extent, the result of the inventive activity of only three countries: first Germany, and then France and the UK (left panel of the Figure). Together, these 3 countries always contributed over 75% of total ICT patenting in Europe, and sometimes over 80%. The share of Germany, the veritable powerhouse of European ICT patenting, increased from about 40% of the European total at the beginning of the period, to about half the total at the end.

The share of Sweden and of Finland peaked towards the end of the 1990s and diminished afterwards. We similarly observe a reduction in Italy's share, which is certainly influenced by the very incomplete reporting from the Italian patent office after 2002 (see Picci 2009). The sharp reduction in Poland's share in 2005 may likewise be due to incomplete reporting from the Polish patent office. The Netherlands' share slightly decreased over time, and Spain's and Austria's shares of total European ICT patent applications are between 1% and 2%.

Figure 8-4 shows the same patent counts as Figure 8-3, but in per-capita terms. Again, the results have been normalised so that the value for Germany in 2004 is equal to 100, as in Table 8-1.

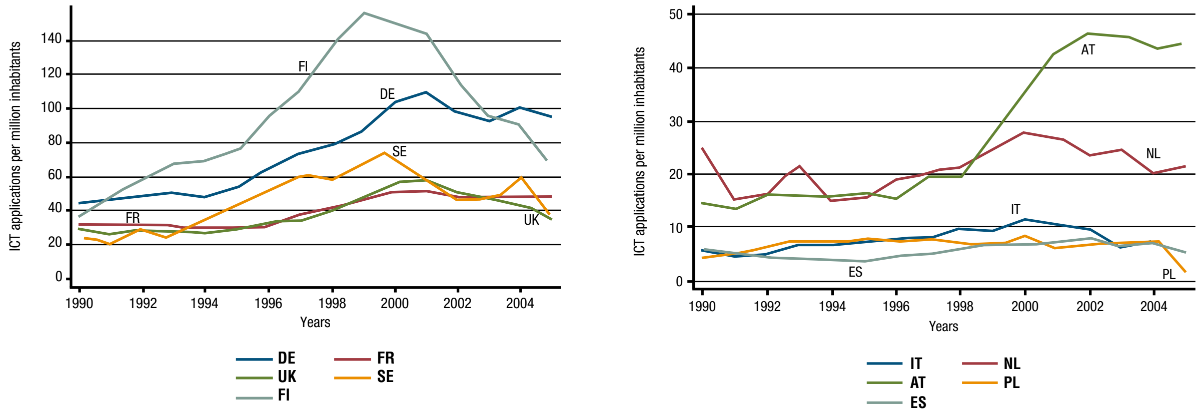
Data normalised so that the value for Germany in 2004 is equal to 100.

*Figure 8-3: Contribution (%) to total ICT EU27 priority patent applications**



Source: IPTS analysis of the PATSTAT database (April 2008 release). Inventor criterion.
** Data for Italy are partly missing for 2003 and 2004 (see Picci, 2009).*

*Figure 8-4: ICT priority patent applications per capita**



Source: IPTS analysis of the PATSTAT database (April 2008 release); Inventor criterion
** Data for Italy are partly missing for the year 2003 and 2004 (see Picci, 2009).*

The absolute number of ICT patent applications increased over the years in most countries, contributing to the increase of the European figures shown in Figure 8-1. However, Figure 8-4 indicates that those European totals hide important cross-country differences. Of the five countries that showed the highest number of patents per capita in 2005 (left panel of Figure 8-4), Finland's patenting activity increased dramatically until 1999, and then decreased sharply. The countries occupying positions 6 to 10 (right panel of Figure 8-4) did not increase significantly their number of ICT patent applications per capita, with the exception of Austria, which more than doubled its per capita ICT patenting activity in less than 10 years.

8.4.3 Member States relative specialisation in ICT patenting

The share of European ICT patent applications over the total European patenting activity is observable in Figure 8-1. This European average pattern hides important cross-country differences.

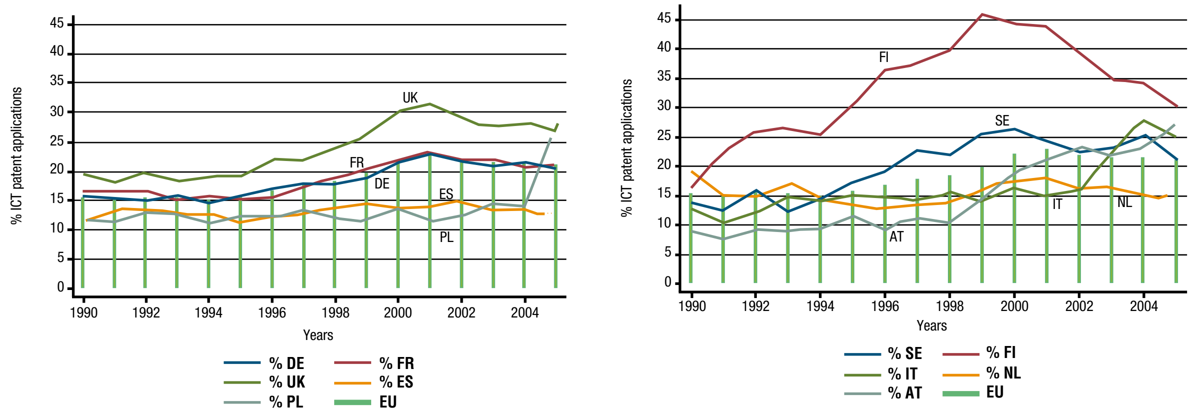
Figure 8-5 indicates the share of ICT patent applications over the total, for a given country, while the vertical bars show the corresponding value for the EU27 as a whole (the same as the right-hand vertical axis of Figure 8-1). The ten selected countries are divided into the two panels so as to facilitate the reading of results.

In the left hand panel, the France and Germany's shares of ICT patent applications are always very close to the European average. Obviously, the mere fact alone that each one of them represents an important share of the European aggregate tends to dampen any difference with respect to the European average. Nonetheless, we observe a rather pronounced specialisation in ICT technology patenting in the UK, which peaked in 2001. Spain and Poland have a lower share of ICT patent applications than average.[83]

However, the most striking departures from the European average may be observed for the countries shown in the right hand panel. In particular, Finland is highly specialised in ICT patenting, with a peak in 1999. In some years, its shares over total patent applications were more than twice as high as the European average. During the 1990s, Sweden experienced an increase in its ICT specialisation, which has

83 Note that the sudden increase of the percentage of ICT applications in Poland in 2005 is almost certainly due to incompleteness of its data for that year.

Figure 8-5: Contribution of ICT to total priority patent applications*



Source: IPTS analysis of the PATSTAT database (April 2008 release). Inventor criterion
** Data for Italy are partially missing for the year 2003 and 2004 (see Picci, 2009).*

then decreased over the last years of the period under consideration. The other major European countries, on the other hand, have shares of ICT patents that are below the European average.

Austria is an interesting case, which would require further analysis. In the space of a few years, it more than doubled the share of ICT patent applications over its total. This shift is also reflected in what was reported in the right panel of Figure 8-4, indicating a steep increase in per-capita ICT patent applications in this country.

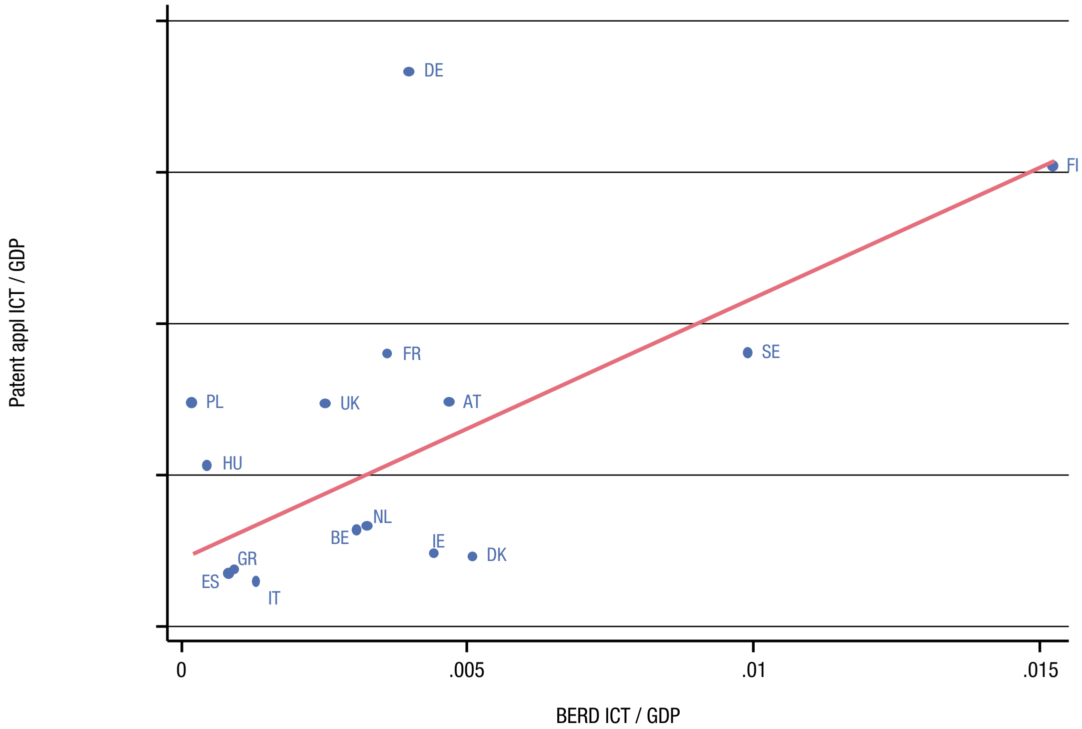
8.4.4 ICT BERD and ICT patenting activity in European Member States

This section analyses in a rudimentary way whether there is a correlation between inputs to R&D activities in ICT and observed outputs. Knowledge in general, and in particular in the field of product and process innovation, may be thought of as the result of a production process where a series of inputs are transformed into a knowledge output. Thinking in terms of a "knowledge production function" seems to be particularly appropriate in today's corporate contexts, where R&D activities are an institutionalised part of the activities of major corporations and, as such, are highly standardised (as stressed, for example, in Baumol, 2004). A count of patent applications is an indicator, albeit imperfect, of this output. Inputs can be proxied by available data on R&D expenditures, such as BERD. Figure 8-6 presents results for the 15 countries that presented the highest number of ICT patent applications in 2005 (see Table 8-1). It shows, for 2004, the relation between ICT patent counts and ICT BERD, both variables being normalised by GDP.[84]

There is a positive correlation between the two measures, indicating that countries with a higher ICT BERD intensity also file more patents relative to GDP or to ICT value added. However, this correlation is not very strong. Germany appears to have a high application intensity relative to ICT BERD intensity. France and the UK, respectively the second and the third contributor to ICT patents in the EU27, and also Austria, Poland and Hungary, are above the least square regression line for both types of normalisations. Finland is a case on its own, displaying the highest ICT BERD intensity, and the second highest ICT patent intensity. All the other countries are below the least square regression line. A southern European group composed of Italy, Spain and Greece has low ICT BERD intensity and low patenting

84 The different R&D intensity ratios used in the PREDICT report and their specific features are discussed in Annex 2 – Description of R&D intensity indicators

*Figure 8-6: ICT priority patent applications / GDP vs. ICT BERD / GDP. By country, 2004**



Source: IPTS analysis of the PATSTAT database (April 2008 release) (Inventor Criterion), and this report.
** Data on Italian patent applications are partly missing (see Picci, 2009).*

activity. A central European group, composed of Belgium, the Netherlands, Ireland and Denmark, has ICT BERD intensities that compare to those of Germany, France and the UK, but a much lower ICT patenting intensity. Sweden scores between these two groups and Finland, with the second highest ICT BERD intensity, and a patenting activity intensity that is slightly below the least square regression line.

In observing the results, two important caveats must be addressed. First, as explained earlier, the identification of ICT patents is carried out using a taxonomy of technologies, while ICT BERD refers to the ICT sector of the economy (see Section 3.1 on BERD data). Not only are the two concepts different, but also, the differences may be country-specific (for example, a country which has many firms developing embedded systems – i.e., ICT technologies in non-ICT goods – would have many ICT patents relative to the size of its ICT sector, and vice-versa). Secondly, there is typically a time lag, which may be of several years, between R&D expenditure and an observed inventive output. In the case in hand, however, where only a simple cross-section is analysed, this aspect is rather inconsequential, because R&D expenditures at the country level are characterised by a very high degree of persistence.

As indicated in Section 7.4, estimating the relation between R&D inputs and outputs is a very complex issue. Figure 8-6 proposes only a rudimentary analysis of the complex relationship linking inputs and outputs in R&D processes. It is, however, instructive to observe the important differences between countries in transforming ICT BERD into ICT patent applications. A dedicated study of these themes would be necessary to develop a viable framework linking inputs with outputs in R&D processes, building on the framework introduced in Chapter 7.

8.5 Conclusions

ICT's share in total patenting in the EU increased significantly throughout the 1990s, peaking in 2000. Since then, it has stabilised somewhat below the peak level, but significantly above the level of the early 1990s. The European average hides important national differences. The UK and Finland, in particular, are characterised by a marked specialisation in ICT technology patenting.

In terms of ICT sub-sectors, telecommunications has gained ground at the expense of consumer electronics over time.

Most European inventive activities in ICT, if measured in terms of patenting activity, are carried out by Germany, which together with France and the UK accounts for 80% of ICT priority applications. Germany's share has risen from less than 40% to about 50% over the last 15 years, and this country occupies the first position in the list, not only in absolute terms, but also relative to population and to GDP.

In relative terms, Finland and Sweden occupy the second and third positions of the ranking. Most other EU Member States form a vast periphery that is characterised by small numbers of ICT patent applications. This is certainly true in terms of the absolute number of ICT patent applications, and also to some extent in relative terms: for the most part, ICT inventive activities, as measured by patent applications, are concentrated in very few countries.

Regarding the relation between input and output of the R&D effort, the present analysis remains rudimentary. Preliminary analysis of the data indicates that some countries (mostly Germany, but also France, the UK and Austria) transform R&D expenditures (as proxied by BERD) into ICT priority patent applications more efficiently than most other EU Member States. Finland and, to a smaller extent, Sweden, are in general exceptions, with BERD intensities that are much higher than those of all other countries, and patenting activities that, in relative terms, are among the highest in Europe.

Finally, as underlined in the introduction to this chapter, patent statistics are only a proxy of inventive activities, albeit a very informative one. What is invented and patented does not necessarily translate into useful innovations. Moreover, when carrying over international comparisons, it should be kept in mind that idiosyncratic country factors may cause different propensities to patent inventions. Disentangling these aspects would require deeper investigation.

Technical Report Series

80

9 Conclusions

The ICT sector is the main motor of research and development in Europe. Although it is a sizeable economic sector in terms of output, measuring the importance of ICT by its almost 5% share of GDP vastly underestimates its significance for Europe. In the EU, ICT accounts for one third of all (business) research employment, almost one fifth of the total of business and government R&D expenditure, and more than a quarter of all business R&D expenditure. ICT patents represent more than one fifth of all EU patents, a share which has risen considerably over the last fifteen years. The ICT sector is not only the most important sector for research, but it is even way ahead of other high-tech sectors such as pharmaceuticals or aerospace. Moreover, R&D employment intensity in the ICT sector is almost ten times higher than the average for the total economy and four times higher than in other high-tech sectors.

Even so, the ICT sector remains the Achilles heel of the EU in its competition with other advanced economies in terms of R&D intensity. As regards the Barcelona target figure of R&D spending as a share of GDP, the ICT sector alone accounts for a bit less than half the gap with both the US and Japan, and for 80% of the gap with Korea. The USA spend twice as much as the EU on ICT R&D, at both company and government levels, in spite of having comparable GDPs. Company data (which is not directly compatible with national accounts data) even suggest that, among the biggest R&D spenders, the entire advantage of the USA is due to the ICT sector alone.

Not only does the EU ICT sector invest less in R&D as a function of its size than its main competitors, but, in addition, its weight in the economy is smaller in Europe, especially compared to Korea and Japan. This is mostly due to Europe's weakness in ICT manufacturing. ICT manufacturing is much more R&D intensive than ICT services, and this also contributes to the lower R&D intensity of the overall ICT sector in Europe compared to Korea and Japan.

Nearly all the R&D growth in the EU ICT sector takes place in the Computer Services and Software sub-sector, in terms of both R&D employment and business R&D spending. This sub-sector does not appear very R&D intensive relative to its size, which accounts for 40% of the ICT sector, but in absolute terms it could become the largest R&D investing ICT sub-sector on current trends within the next five years. This observation deserves further investigation. Nevertheless, company data (which is not directly compatible) indicate that the growth of R&D spending in Computer Services and Software by European companies is completely overshadowed in absolute terms by the growth in spending by US companies in this sub-sector, mostly due to their vastly superior size. On a more aggregate level, company data also show that the fastest growth in ICT R&D can be found among Korean and Taiwanese companies (Indian and Chinese ones do not –yet– register on the screen).

Within the EU, the distribution of ICT R&D displays a familiar pattern: it is dominated by Germany, France, the UK, Sweden and Finland. Employment data show that Germany is stronger in ICT manufacturing research, while the UK has the number one spot in ICT services research. Since ICT manufacturing research is more likely to result in patentable inventions, this contributes to the fact that Germany increasingly dominates ICT patenting within the EU, with a 50% share in 2005, up from 40% in 1990. The stories of Finland and Sweden, on the other hand, are becoming less similar. While Finland has strongly increased its ICT R&D intensity, to such an extent that ICT R&D is becoming ever more important despite a relatively shrinking ICT sector, Sweden appears to have reduced its ICT R&D intensity, in part because the absolute size of the ICT sector in its economy has been growing. Indeed, Finland has an outstanding ICT BERD intensity, while its non-ICT BERD intensity is close to the EU27 average. In the case of Sweden, high ICT sector contribution is accompanied by the highest non-ICT BERD intensity of all the Member States. For Sweden, ICT contributes to a general excellence in BERD intensity. Finland and Sweden are also clear leaders in terms of Government financing of ICT R&D (ICT GBAORD). While this shows that supporting ICT is a public policy priority, it does not necessarily mean there is strong government support to R&D in ICT companies, but rather, that this support produces a strong leverage effect. As a matter of fact, in both countries the ICT BERD financed by the government is accompanied by a much higher contribution from the private sector.

Although patent statistics are only a proxy, they provide information on inventive activities of countries or regions. A –rudimentary– analysis of the relation between ICT BERD intensity (ICT BERD/GDP) and patenting suggests that some countries - Germany more than others, but also France, the UK and Austria - transform R&D investments into ICT priority patent applications more efficiently than others.

A major shortcoming of the above figures on business R&D is that they do not take into account ICT research in other industries, the so-called embedded systems, which could be a significant share of overall ICT research. How important embedded systems really are is undoubtedly a pressing question in an analysis of ICT R&D today.

Annex 1 - Definition of the ICT sector

1. Definition of the ICT sector

The ICT sector is defined according to the Frascati Manual (OECD 2002), based on NACE classification[85] rev 1.1. in two versions: the comprehensive definition and the operational one.

We will use the operational definition, except for the sector Post and Telecommunications where we retain data on 642, Telecom Services. To the extent in which the data availability allows, we identify and use data corresponding to the following subgroups: NACE/ISIC 3210 (electronic valves and tubes and other electronic components), NACE/ISIC 3220/3230 (television and radio transmitters and apparatus for line telephony and line telegraphy, television and radio receivers, sound or video recording or reproducing apparatus, and associated goods), NACE 3320 / ISIC 3312 (Instruments and appliances for measuring, checking, testing,

85 NACE refers to Nomenclature générale des Activites économiques dans les Communautés Européennes and is the European standard used by Eurostat. It classifies the juristic persons according to the value added of their main activity or to their own declaration. Therefore the economic indicators describing them will be included in the corresponding aggregate for the industrial sector of their main activity. Within various occupational and educational classifications (ISCO-88 and ISCED) or product-based classifications (PRODCOM, HS, SITC, EBOPS) alternative definitions of ICT sectors have been proposed. The NACE based one was selected for this study given the availability of R&D investments at this level. Correspondence keys are used to construct mirror aggregates from product and employment data as it will be discussed in the corresponding subchapters of this report.

1. The NACE rev1.1 industries included in the ICT Sector (OECD, 1998 and 2002):

Manufacturing:
3000: Office, accounting and computing machinery
3130: Insulated wire cable
3210: Electronic valves and tubes and other electronic components
3220: Television and radio transmitters and apparatus for line telephony and line telegraphy
3230: Television and radio receivers, sound or video recording or reproducing apparatus and associated goods
3312: Instruments and appliances for measuring, checking, testing, navigating and other purposes except industrial process equipment
3313: Industrial process equipment

Services:
5150: Wholesale of machinery, equipment and supplies (part only, where possible)
- 5151: Wholesale of computers, computer peripheral equipment and software
- 5152: Wholesale of electronic and telecommunications parts and equipment
6420: Telecommunications
7123: Renting of office machinery and equipment (incl. computers)
72: Computer related activities

2. A more aggregated (operational) definition (NACE Rev.1.1)

Manufacturing
30: Manufacture of office, accounting and computing machinery
32: Manufacture of radio, television and communication equipment and apparatus
33: Manufacture of medical, precision and optical instruments, watches and clocks

Services
64: Post and telecommunications
72: Computer and related activities

navigating and other purposes except industrial process equipment), NACE 3330 / ISIC 3313 (Industrial process equipment).

2. Main limitations of the definition

With the conceptual and methodological standard premises described above, international organisations as well as national organisations issue R&D statistics on a regular basis.

However, the following proviso needs to be spelled out; the definition of the ICT sector as it is currently laid down sets artificial boundaries to the framework of measuring the real developments in ICT R&D. *This is because data collected on country and enterprise basis measures the R&D performed or financed by the companies registered in ICT sectors, rather than the R&D dedicated to creation and development of ICT-related products.*

When this rule is interpreted strictly, this approach generates a mismatch between product and company level data, e.g. all the BERD of a diversified enterprise will be allocated to the industrial class of its principal activity. The main PREDICT Report refers to some companies that represent boundary cases.

This is why, following the recommendations of the latest Frascati Manual, 2002, one of the aims of R&D data collection is to move closer to product field data, where this is possible. Some countries provide data that distributes the R&D figures according to secondary activity of the companies as well, by redistributing the figures. However, over the time span of our study there is no unique approach from all the countries in dealing with this issue. Some countries collect and submit product field data (*e.g.* Finland, Sweden, United Kingdom); for others, adjustments are made using product field data to reduce enterprise bias (*e.g.* Spain); finally, for a few, product field data are not available so data are reported by principal activity (*e.g.* United States) (http://www.oecd.org/dataoecd/52/23/1962156.pdf).

However, a similar redistribution of employment, VA or sales on product or activity basis is not simultaneously available. Therefore it is not clear to what extend and how the product adjustment at the level of R&D figures impacts on the overall competitiveness analysis at detailed sectoral level.

Therefore, data collected on country or company level results in a non-accurate registration of R&D ICT. While it makes sense to assume that R&D in ICT sectors is R&D overwhelmingly dedicated to ICT products, ICTs are certainly developed in other sectors as well (e.g. embedded systems). This is a recurrent issue throughout the entire analysis and affects the relevance of results at various levels. Research on statistical registration of embedded systems is ongoing, but so far excluding the R&D ICT performed outside the ICT sector is the only operational choice for the PREDICT project.

A particularly relevant sub-issue in this respect is clarifying the statistical registration of various research bodies such as technology platforms, business incubators, R&D alliances, private R&D institutions, *pôles de competitivité* etc., most likely registered within NACE 73, Research and Development services.[86] Trying to amend the current ICT sector definition would be outside of the scope of the PREDICT study. It remains, nevertheless, interesting and useful to gain as much knowledge as possible on the issues related with the statistical treatment of entities performing ICT R&D (other than companies and public R&D institutes); to estimate the size of the potential bias on statistical estimation of overall ICT R&D, but mainly in view of appreciating their role as a part of the surrounding ICT sector innovation system.

86 In fact, through the actual methodology, figures on public support for private research bodies performing research in ICT are accounted within the total (see the chapter 2.3.), but not the figures on business funding towards the same institutions, because those research bodies are not normally registered in the ICT sectors as defined based on NACE (see the discussion below on Telefonica Spain in chapter 2.1).

Annex 2 – Description of R&D intensity indicators

The PREDICT report refers throughout to R&D intensity. Indicators of R&D intensity are conceived as ratios which measure the *relative* importance of the *absolute* R&D effort. They can be referred to individual companies, to industries/sectors, or to countries/regions, and can be computed either in monetary or in employment terms.

The R&D intensity indicators used in the PREDICT report and their specific features are discussed below in more detail.

1. R&D intensity indicators computed in monetary terms

➔ R&D Intensity at national or regional level:

$$\frac{\textit{GERD (or BERD)}}{\textit{GDP}}$$

➔ R&D Intensity at industry (or sector) level:

$$\frac{\textit{Sectoral GERD (or Sectoral BERD)}}{\textit{VA (Sectoral GDP)}}$$

➔ R&D Intensity at company level:

$$\frac{\textit{R \& D expenditure}}{\textit{Total sales}}$$

All the three ratios above describe the R&D content of the production process and are computed at current prices. There are, however, two key differences between the macro (national and industry) and the company level indicators:

(a) The R&D effort is weighted on value added (i.e. profits plus wages) for macro indicators, and on total sales for the company level indicator; this is primarily due to the higher volatility of value added at the firm level, where negative values are also quite frequent.

(b) The macro level R&D intensity indicators refer to both R&D and production activities performed within specific territorial or sectoral boundaries. For the case of companies instead, the indicator makes reference to their financial results, irrespective of the physical location of production or R&D activities.

It is also useful to recall some features of the above indicators, and differences between them:

- Knowledge intensive industries typically show a high R&D intensity, and ICT manufacturing ranks first amongst all industrial sectors, excluding NACE rev 1.1 Division 73 "Research and Development".

- R&D intensity at industry or sectoral level is a disaggregation of the R&D intensity at national level, and is meant to highlight structural features of an economy. Given the above mentioned differences in computation and coverage, the sum of company level R&D intensities does not, however, add up to sectoral and national intensities.

- The macro level R&D intensities and their dynamics reflect the relative volume of knowledge creation inside a country or within a given industry or sector, with respect to other countries or sectors and to historical values. This type of indicator is therefore of strategic importance for policymaking, also considering the wide consensus on the fact that societal benefits of R&D activities exceed the sum of private benefits. The micro level R&D intensity, instead, portrays the techno-economic position of a company, within a given industry.

- In general, a high (and rising) R&D intensity is deemed positive, as it is related to the creation of more qualified employment positions, and to the capability (or potential) of the economy to increase future value added (hence, income) per person in employment. Nevertheless, it has to be remarked that the index might grow (fall) due to a rise (fall) in R&D or to a fall (rise) in production, especially in the short run: hence, in this case, to ascertain whether a rise or fall is to be looked upon favourably or not, one has to look at the dynamics of both terms of the ratio.

2. R&D intensity indicators computed in employment terms

In the PREDICT report we make reference to R&D employment intensity indicators at the national / regional and industry / sector levels only. These indicators are all based on the same type of ratio, i.e.:

➔ $$\frac{\textit{Total R\&D personnel (or Researchers)}}{\textit{Total employment}}$$

To avoid the influence of specific national and industrial features, full-time equivalent (FTE) data are used, rather than headcounts. Employment-based indicators provide a complementary view, and have the following advantages over value-based indicators:

- Their neutrality with respect to exchange rate levels and movements constitutes a particularly useful feature for international comparisons;

- They are not affected by fluctuations in BERD value (due to investment flows irregularities) and in sales and value added, and thus tend to be relatively more stable.

Annex 3 - Methodology for BERD data

1. Definitions

According to the Frascati Manual (OECD 2002), business expenditures research & development (BERD) are defined as *"R&D activities carried out in the business sector, regardless of the origin of funding"*.

With regard to R&D, the business sector or business enterprise sector (BES) includes: "All firms, organisations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price." (OECD 2002, p. 54).

"Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications" (OECD 2002, p. 63)

2. Sources of data

- Eurostat's R&D Statistics
- OECD's Analytical Business Enterprise R&D Expenditure (ANBERD) database
- OECD's STAN Database
- Alternative sources (mostly National Statistical Offices), company level data (mainly for the telecom services sectors). These sources were used in particular to estimate data treated by Eurostat as confidential.

3. Geographical scope and time coverage for PREDICT

In addition to the above definitions, the geographical scope and the time coverage of the PREDICT study were pre-defined:

- the time span of the data series was planned to be 1998 to the most recent year available,
- the analysis would cover each separate EU Member State (27), offer an aggregate for the EU and other main economies, in particular US and Japan, but also other OECD countries as Australia and Korea.

Data scarcity forced us to concentrate to the period from 2000 to the most recent year available. The last year for which data is available in both EUROSTAT and OECD (as to mid-June 2008) is 2005, with a very limited number of countries publishing data for 2006.

None of the available sources provides complete series of data for any year, or any of the NACE ICT composite sectors.

There are several reasons for this lack of data. Some countries like Malta or Luxembourg do not provide any R&D data in ICT sectors in any of the sources mentioned above. For others as Greece, Denmark, Netherlands, Sweden, US or Japan data is not collected at the level of breakdown required. In many cases, the Statistical Offices do not publish R&D data for Telecom services sectors for confidentiality reasons.

Basically those important shortcomings impose the need to implement two methodological solutions: the simultaneous use and crosscheck of several alternative sources, and the estimation of data.

4. Main methodological notes

After crosschecking with experts from both EUROSTAT and OECD ANBERD, it appears clearly that it is not advisable to use both sources for data prior to 2005 as several inconsistencies make those datasets rather incompatible.

Until 2003, EUROSTAT data on R&D (including BERD) were collected under a gentleman's agreement. From the reference year 2003 onwards the data collection is based on the Commission Regulation No 753/2004 on statistics on science and technology (OJ L 118, page 23 from 23 April 2004). From December 2005 onwards, R&D data are collected in co-operation with OECD using a common core questionnaire and two separate modules which cover each organisations specific statistical need. The data compatible with EUROSTAT is to be found in OECD in the section dedicated to STI indicators. Whenever available, we employed the EUROSTAT data.

Nevertheless, ANBERD remained, at least for the data 2004, a source of last resort in few cases, among which the most notable is the US. In the case of ICT sectors, the use of ANBERD data is very likely to lead to an overvaluation of the ICT R&D because the ANBERD reallocate secondary activities of the companies to their theoretically corresponding ISIC (or NACE) code. ANBERD is also used to breakdown on NACE codes aggregates provided by national statistical offices in special cases as Sweden, who publish BERD data for NACE 30-33 together. Is worth highlighting the fact that the use of corrected Swedish data induce significant changes in the EU27 totals for NACE 30 and NACE 32, as compared with the total EU25 figures provided by EUROSTAT.

There are very few alternative sources of data available. Moreover, the use of alternative sources for data collection, including National Statistics Institutes, might lead to some distortions of the data.

Within the earlier stages of the REDICT project, some data originating from alternative sources have been used. According to the Methodological Report provided with the data submitted, the result of the exercise led to rather limited results. This is mainly due to objective reasons as legal intervals of data collection being in some cases higher than one or even two years87 or the data not being collected on the level of details required.

Moreover, it is not always clear if the data provided through this alternative data source respects the OECD/EUROSTAT practices, and nor is it clear, therefore, if the compatibility with the rest of the dataset is fully ensured.

Nevertheless, a particular case regards data collection in countries/sectors when data is not published for confidentiality reasons. To an overwhelming extent, this is the case of telecoms. These are assimilated in this report to the alternative BERD data collection, as access to company level data might supply the needed information. However, this approach needs particular attention, given the different definition and coverage of company level data and BERD data.88

The second goal of alternative data collection is to allow provision of timely estimations of EU27

87 Several countries - Denmark, Germany, Ireland and Sweden – did not run so far annual R&D surveys so the missing points need interpolation. These are performed mostly by the statistical sources referred.

88 The transition from company level data (R&D financed by the companies registered in a certain NACE sector irrespective of where is performed) to BERD data (R&D performed within a certain NACE sector, irrespective of the source of funds is another key methodological challenge within this Report. Some of its main implications, including on evaluation of international flows of R&D are mentioned as well in the chapter 2.3.

aggregates. Data provided by EUROSTAT/OECD is published with a delay of at least 2 years, and this reduces their relevance for European policy making. For this purpose, data obtained in advance from the statistical offices has high relevance.

The above mentioned limitations call for estimations of EU27 total and country/sector subcomponents to fill in various remaining gaps in the datasets. Some more sophisticated methods of estimations have been run in previous stages of the project with unsatisfactory results. Currently we employ a straightforward estimation of sectoral BERD data based on accounting for trends in total economy BERD and sectoral value added, crosschecked with employment and productivity trends estimated independently. These estimations are applied only for filling in the gaps, as the methods are not reliable enough for forecasting.

Technical Report Series

90

Annex 4 - Methodology for value added data

> *"Gross value added for a particular industry represents its contribution to national GDP*. It is sometimes referred to as GDP by industry. It is not directly measured. In general, it is calculated as the difference between Production and Intermediate inputs. Value added comprises Labour costs (compensation of employees […]), Consumption of fixed capital, taxes less subsidies (the nature of which depends on the valuation used […]) and Net operating surplus and mixed income […]."

Source: The OECD STAN database for Industrial Analysis, methodological note www.oecd.org/dataoecd/53/21/34464010.doc

Data for value added (VA) used to calculate the R&D intensities is taken, when possible from the EU KLEMS project. The methodology for data collection in the case of the EU KLEMS project is described in Marcel Timmer, Mary O'Mahony and Bart van Ark, The EU KLEMS Growth and Productivity Accounts: An Overview, The University of Groningen and the University of Birmingham, March 2007, or at www.euklems.net.

There are two reasons for choosing the EU KLEMS data. Firstly, the EU KLEMS project estimates the value added according to the NACE classification for EU25 countries (i.e., not including Bulgaria and Romania) as well as for the US, Japan and Korea, ensuring comparability between those countries, that do not normally use industrial classifications compatible with the NACE. Secondly, the VA is expressed in market prices, a measure more appropriate for our purpose.

In fact, this is the main difference between the data published by EU KLEMS and data provided by EUROSTAT in the SBS database, as the figures on value added from SBS are in basic prices.

Data for Romania and Bulgaria is extracted from EUROSTAT SBS and for Australia and Canada from OECD STAT. VA from those countries would be expressed at factor costs or basic prices. When possible, these data were corrected with a coefficient calculated as GDP/Total economy VA which accounts to a large extent for the differences in valuation. This methodological detail explains the differences that might appear in VA numbers throughout the text

Figure 1. Valuation of value added

Value added at **Factor costs**

+ *other* taxes, less subsidies, *on production*[2]

= Value added at **Basic prices**

+ taxes less subsidies, *on products*[3] *(not including imports and VAT)*

= Value added at **Producer's prices**

+ taxes, less subsidies, *on imports*

+ Trade and transport costs

+ Non-deductible VAT

= Value added at **Market prices**[4]

1. This table draws on concepts outlined in both the 1968 and 1993 version of a System of National Accounts (SNA68 and SNA93). Until the late 1990s, most countries adhered to recommendations in SNA68 (where the notions of Factor Costs, Producer's Prices and Market Prices were predominant). However, many OECD Member countries have now implemented SNA93 (or the EU equivalent, ESA95) which recommends the use of Basic Prices and Producer's prices (as well as Purchaser's Prices for Input-Output tables).
2. These consist mostly of current taxes (and subsidies) on the labour or capital employed, such as payroll taxes or current taxes on vehicles and buildings.
3. These consist of taxes (and subsidies) payable per unit of some good or service produced, such as turnover taxes and excise duties.
4. Market prices are those which purchasers pay for the goods and services they acquire or use, excluding deductible VAT. The term is usually used in the context of aggregates such as GDP, whereas Purchaser Prices refer to the individual transactions.

Source: The OECD STAN database for Industrial Analysis, methodological note www.oecd.org/dataoecd/53/21/34464010.doc

Technical Report Series

92

Annex 5 - Methodology for R&D employment data

Researchers are defined as "professionals engaged in the conception or creation of new knowledge, products processes, methods, and systems, and in the management of the projects concerned." Researchers are all people in the International Standard Classification of Occupations-88 (ISCO-88) Major Group 2 "Professional Occupations" plus "Research and Development Department Managers" (ISCO- 88 1237). By convention, any members of the Armed Forces with similar skills performing R&D should also be included in this category." (OECD 2002, p. 93).

R&D employment "includes all people employed directly on research and development [activities], as well as those providing direct services such as research and development managers, administrators and clerical staff. Those providing an indirect service, such as canteen and security staff, should be excluded, even though their wages and salaries are included as an overhead cost when measuring expenditure". (OECD 2002, paras. 294-295, p. 92).

Similarly to the work done on expenditure, and partly based on it, gaps in official sources for ICT employment industries were filled, producing an estimate of EU27 R&D employment (total and researchers) for each of the ICT sub-sectors at NACE two digits level for the years 2001 to 2005. The filling of gaps was based wherever possible on simple statistical routines (averages, trended averages, etc.). In some cases, however, it demanded relatively complex operations of checking and introducing a set of assumptions. These included relying on base years and conjecturing on the dynamics of sub-sector composition, the attribution of labour costs based on ratios for similar ("donor") economies and/or sectors, starting from expenditure data which, at times, had to be inferred from key primary sources. These techniques were necessary, for example, in Telecom Services for countries where data are not disclosed on grounds of confidentiality, and cases where the information available was at too aggregate a level, including other non ICT industries (e.g. electric appliances in manufacturing, or logistics and post in services) or, even where the information was clearly misleading, with odd and wide year on year changes, and suspicious movements across industries. The figures obtained were coherent with the IPTS series for expenditure at country and industry cell level.

Technical Report Series
94

Annex 6 - Methodology for GERD and GBAORD data

1. Definitions

Government Budget Appropriations or Outlays for R&D by Socio-economic Objectives (GBAORD) are estimated as the sum of all the budget items involving R&D and measuring or estimating their R&D content in terms of funding. These estimates are less accurate than performance-based data but, as they are derived from the budget, they can be linked to policy through classification by "objectives" or "goals". (OECD 2002, p. 138). When the objective of a funding scheme is ICT-related, this data offer a measure of ICT GBAORD.

According to the Frascati Manual (OECD 2002, p. 121), ***gross domestic expenditure on R&D (GERD)*** is defined as ***"total intramural expenditure on R&D performed on the national territory during a given period".*** "Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications" (OECD 2002, p. 63).

2. Sources of data

- Eurostat's R&D Statistics
- OECD's Analytical Business Enterprise R&D Expenditure (ANBERD) database
- OECD's STAN database
- Alternative sources (mostly National Statistical Offices, experts estimates)
- IPTS forthcoming Technical Report on "Public Expenditures in ICT R&D" (European Commission, 2009)

3. Geographical scope and time coverage for PREDICT

Due to serious shortcomings on availability of GBAORD data, time coverage for this calculation is restricted to 2005. Geographical coverage is EU27 Member States and the USA for GBAORD. Methodological constraints would make any attempt to calculate ICT GERD at country level unreliable, hence the data for the EU aggregate is presented for GERD only.

4. Methodological notes

4.1. Financing vs. Performing

R&D data can be further broken down 1) by performing sectors (that is the value of their intramural R&D activities) and 2) by financing sectors (that is on sectors financing the R&D activities worldwide). In concordance with the international standards and the SNA93 (OECD 2002, page 63) distinguishes five economic sectors: 1) business enterprise sector, 2) government sector, 3) higher education sector, 4) private non-profit enterprise sector and 5) abroad. The definition of those sectors is presented in Box 1.

The full relationship R&D performed/R&D financed is often displayed as a matrix of funding and performing sectors:

Funding sector	Sector of performance				Total
	Business enterprise	Government	Private non-profit	Higher education	
Business enterprise					Total domestic performance financed by the business enterprise sector
Government (incl. public general university funds)					Total domestic performance financed by the government sector
Higher education					Total domestic performance financed by the higher education sector
Private non-profit					Total domestic performance financed by private non-profit enterprises
Abroad: • Foreign enterprises - within the same group - other • Foreign government • European Union • International organisations • Other					Total domestic performance financed by abroad
Total	Total performed in the business enterprise sector (BERD)	Total performed in the government sector (GOVERD)	Total performed in the private non-profit sector	Total performed in the higher education sector	**GERD**

Box.1. Definition of the five economic sectors in the R&D statistics

With regard to R&D, the ***business sector or business enterprise sector (BES)*** includes: "All firms, organisations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price." (OECD 2002, p.54).

The ***government sector (GOV)*** is composed of:

- All departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. (Public enterprises are included in the business enterprise sector.)
- Non-profit institutions (NPIs) controlled and mainly financed by government, but not administered by the higher education sector" (OECD 2002, p.62).

With regard to R&D, the ***private non-profit sector (PNP)*** includes non-market, private non-profit institutions serving households (*i.e.* the general public) and private individuals or households.

For the purpose of collecting R&D data, the ***higher education sector (HES)*** is defined as "All universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of or administered by or associated with higher education institutions." (OECD 2002, p.54).

The ***abroad sector (ABR)*** consists of "All institutions and individuals located outside the political borders of a country, except vehicles, ships, aircraft and space satellites operated by domestic entities and testing grounds acquired by such entities as well as all international organisations (except business enterprises), including facilities and operations within the country's borders." ABR occurs in R&D surveys only as a source of funds for R&D performed by statistical units already classified in one of the four national sectors or as a destination for their extramural R&D expenditures. Thus, as it occurs only as a sub-item of the R&D resources of a statistical unit, the choice of a standard sub-classification does not arise. (OECD 2002, p.72).

Source: adapted by IPTS from Frascati Manual (OECD 2002)

GERD is constructed by adding together the intramural expenditures of four first performing sectors, excluding Abroad (ABR). GERD includes R&D performed within a country and funded from abroad but excludes payments for R&D performed abroad.

A series of further assumptions is made in order to account for the fact that data on R&D performed in the Governmental sector (GOVERD) is not available at a level of detail that would allow us to isolate the ICT-related activities.

4. 2. First set of assumptions: combining data from financing and performing sectors

In this report, a redefinition of economic sectors is employed. The business sector is considered to include the private non-profit sector and the government sector is considered to include the higher education sector. Funds from abroad are included either among the business sector funds or among the public sectors funds according to their concrete origin. Consequently, the working definition of the economic sectors for this report is restricted to two such sectors: business (or private) and government (or public). Hence, in this definition, GERD will be the sum of intramural expenditures of the business (assumed as equal with BERD) and government sector. The breakdown on performing and financing sectors can be presented as follows:

The equation introduces further assumptions used in this calculation. The R&D performed in the government sector but financed by the business sector and the R&D performed abroad but financed by the national government are assumed to be limited, hence ignored. This allows us to calculate indirectly the government intramural R&D (GOVERD) using the data collected on the total R&D financed by the Government (GBAORD). This methodology follows the general approach in the GFII (2006), with some adjustments.

There are nevertheless several relatively important shortcomings in corroborating the data on R&D collected from the funding bodies and data collected from the performers.(OECD 2002, p. 150). Below are highlighted those considered as particularly relevant for this exercise.

GBAORD is a variable of funding and covers not only government-financed R&D performed in government establishments but also government-financed R&D in the other three national sectors (business enterprise, private non-profit, higher education) as well as abroad (including international organisations). In principle, GBAORD- and GERD-based data are collected on the basis of the same definition of R&D and cover both current and capital expenditures. The GERD-based series, though, cover only R&D performed on national territory, whereas

$$GERD = \overbrace{BERD_{\substack{\text{Financed by Businesses}\\ \text{Performed by Businesses}}} + \rlap{$\displaystyle\underbrace{\phantom{BERD_{\substack{\text{Financed by Government}\\ \text{Performed by Businesses}}} + GOVERD_{\substack{\text{Financed by Government}\\ \text{Performed by Government}}}}}_{GBAORD}$}BERD_{\substack{\text{Financed by Government}\\ \text{Performed by Businesses}}}}^{BERD} + GOVERD_{\substack{\text{Financed by Government}\\ \text{Performed by Government}}}$$

GBAORD also includes payments to foreign performers, including international organisations.

At the same time, GBAORD covers only R&D financed by government (including abroad), whereas GOVERD (which in our approach includes higher education sector) covers all sources of funds on national territory. This is a particularly important issue for the treatment of the EU funds, which will need to be identified separately in the future.

4.3. Second set of assumptions: isolating the ICT sector GERD from total GERD

A second set of assumptions is needed to isolate the ICT slice corresponding to the redefined business and government sectors.

With a number of shortcomings (see Annex 3 on BERD), BERD data is available by industries, and by sources of funds, allowing us to identify directly the ICT sector following the NACE classification presented in Annex 1. GBAORD is however collected by socio-economic objectives following the NABS classification. The NABS classification (Nomenclature for the analysis and comparison of scientific programmes and budgets) was defined in 1992, based on previous OECD definitions originally established in 1969. A new classification was adopted in 2007, and was applied first for data collection in June 2008. A key modification is that no effort is made any longer to collect 4 digits data, as was the case for the 1992 definition. The decision has been made due to the scarcity of data at 4 digits level. 14 objectives are now considered, the only one new objective being "general advancement of knowledge". Most of the data are collected now at one digit level.

Moreover, NABS groups provide limited scope for international comparability, as they are intentionally broad and the series are constructed to show the amount of resources devoted to each primary purpose (defence, industrial development, etc.), therefore to reflect the policy intentions of a given programme rather than its precise content. (OECD 2002).

Nevertheless, the Frascati Manual (OECD 2002) supports the identification of the ICT sector through the NABS groups, with the argument that despite issues like lack of availability of data for all the countries, "the classification by socio-economic objective may also be used to distinguish ICT-related R&D. Relevant sub-classes are included at the 2-digit level of the present NABS" (OECD 2002, p. 189).

In a first step, the NABS categories which include ICT-sector R&D need to be identified. Estimations provided here are based on four such categories at 1-digits NABS, namely:

Exploration and exploitation of the earth (objective 01)

Industrial production and technology (objective 07),

Research financed from general university funds (GUF) (objective 10)

Defence (objective 13).

ICT is, however, obviously present in several other sub-categories of governmental spending. For instance, research on *Telecommunication systems* (NABS 0205) is included in NABS 02 (Infrastructure and general planning of land-use), and research into *Photovoltaic energy* (NABS 0501) into NABS 05 (Production, distribution and rational utilisation of energy). ICT will be naturally an important part of the Protection and improvement of human health (NABS 04), or Control and care of the environment (NABS 02), as well as of Exploration and exploitation of space (NABS 09) etc. Unfortunately, the non-availability of data substantially limits possibilities for refining the analysis. The shares of ICT in each of these categories are estimated for each country using a variety of methods and instruments. Complete methodological description of these estimates will be given in a forthcoming IPTS Technical Report on "Public Expenditures in ICT R&D" (European Commission, 2009 – forthcoming).

The main methodological shortcoming of these calculations is that they estimate ICT GERD by adding together data on R&D developed intramurally by the ICT industry and data of governmental financing of R&D for ICT applications irrespective of the industry where they are developed. As ICT R&D is actually performed in a variety of other sectors than the ICT, this will result in an overestimation of the government sector.

Annex 7 - Methodology for company data

The company data set is primarily based on the 2007 EU industrial R&D scoreboard (European Commission, 2007 - http://iri.jrc.es/research/scoreboard_2007.htm) (henceforth the *Scoreboard*) in which R&D investment data, and economic and financial data from the last four financial years are presented for the 1,000 largest EU and 1,000 largest non-EU R&D investors of 2006.[89]

Data for the *Scoreboard* are taken from companies' publicly available audited accounts. Most often, these accounts do not include information on the place where R&D is actually performed therefore, the approach of the *Scoreboard* is to attribute each company's total R&D investment to the country in which the company has its registered head quarters. In addition, all R&D is attributed to one single sub-sector (NACE and ICB class), regardless of whether the performed R&D concerns products or services related to other sectors. For example, this means that all the R&D of Philips will be attributed to the Netherlands and to NACE 3230 (here labelled *Multimedia equipment*) and to ICB 247 (*Leisure goods*) in spite of the fact that Philips invests in R&D in other countries and in other sectors as well (primarily in medical/health and lighting equipment).

R&D investment in the *Scoreboard* is the cash investment funded by the companies themselves, and is subject to accounting definitions of R&D. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes the companies' share in R&D investment by any associated company or joint venture. It follows that another difference with respect to macro-economic BERD data is that, while BERD considers all R&D expenditure which is performed by companies in a given sector and country regardless of the source of funding, company data concerns R&D expenditure of that company regardless of what entity actually performs the R&D.

Scoreboard figures are nominal and expressed in €, and all foreign currencies have been converted at the exchange rate of 31 December 2006. This has an impact on firms' relative positions in the world rankings based on these indicators. This needs to be considered when interpreting the data, as well as for the collection of longer-term trend data. Therefore one should consider recalculating *Scoreboard* data based on some purchasing power parity model at a later stage. At this stage, no such recalculation has been made.

R&D intensity is calculated as the ratio between R&D investment and sales of a given company or group of companies. Thus, the calculation of R&D intensity of company data is different from that in official statistics, where R&D intensity is usually based on value added, not sales. *Sales* are in turn defined following usual accounting definitions of sales, excluding sales taxes and shares of sales of joint ventures and associates.

In the *Scoreboard*, the EU and non-EU groups include companies with different volumes of R&D investment. In 2006, the R&D investment threshold for the EU group was about €3.3 and that for the non-EU group about €23 . In order to compare EU and non-EU companies on a similar basis, it is preferable to consider only EU companies with R&D above the non-EU

89 Parts of this chapter draw heavily on the methodological note as provided with the Scoreboard. See http://iri.jrc.es/research/docs/2007/methodology.pdf .

threshold. This comprises a group of 391 EU companies (the *Scoreboard* uses a number of 400 companies, however the exact figure should be 391), representing approximately 95% of total R&D-investment by the EU 1,000 group.

In order to create a comparable data set of ICT companies (which we may label the *ICT Scoreboard*) from the *Scoreboard,* the following actions have been carried out: First, only the companies belonging to the following NACE classes have been extracted from the *Scoreboard*: 30 (IT Equipment), 321 (IT Components), 322 (Telecom Equipment) 323 (Multimedia Equipment), 332-333 (Electronic Measurement Instruments), 642 (Telecom Services) and 72 (Computer Services and Software). In the Scoreboard, these companies are classified in the following NACE classes: 3001, 3002, 3210, 3220, 3230, 3210, 3220, 3230, 6420, 7221 and 7260. There are no companies classified under 3320-3330. The reasons for this need to be further investigated with the data provider. Extracting the relevant ICT companies generated a sub-set of 472 ICT companies (out of 1,391).

Due to strict application of cut-off deadlines for when companies have to publish their accounts in order to be included in the *Scoreboard*, some companies, which otherwise should have been in the *Scoreboard*, have been excluded. One such company is NEC of Japan. Since NEC is one of the major players in the ICT sector, with R&D investments of more than €2 billion in 2006, and has actually published their accounts after the deadline, the company has been included in the *ICT Scoreboard*.

Also, US telecom operators, for some not yet fully understood reason, report comparably low R&D investments (e.g. AT&T) or none at all (e.g. Verizon and Sprint Nextel). Since comparing the structure of the ICT sector (in terms of net sales for sub-sectors as a share of total ICT sector net sales) is an important element of the analysis, these companies need to be included into the *ICT Scoreboard*. Currently, they are Verizon, Sprint Nextel, as well as a fictitious company labelled "AT&T rest", which includes the parts of merged AT&T (e.g. Cingular) whose financials are not included in AT&T's latest annual report. These inclusions are motivated also by the sheer size of these companies, which all are among the top 20 ICT companies in terms of net sales, and should represent a very large share of the total revenues of US companies in the Telecom services sub-sector. Including them allows for a more accurate comparison with the US. Still, we have not systematically searched other companies excluded from the Scoreboard, and our data should therefore be interpreted with some caution.

The result of these additions led to a database of 476 (472+4) companies. For the purposes of the report (which does not include any calculations related to sales, such as R&D intensities), only 473 companies (i.e. 472 plus NEC) are considered. Among these companies, we estimated some missing data points for R&D investments and for net sales for 2003-2006, in order to be able make comparable growth comparisons. Missing data points for other variables may be estimated later.

Glossary

ANBERD –Analytical Business Enterprise R&D Expenditure OECD database

BERD – Business Expenditure on Research and Development

CAGR – Compound Annual Growth Rate

CIS – Community Innovation Survey

CSS – Computer Services and Software ICT sub-sector

EPO – European Patent Office

EU – European Union

EU27 – The 27 Member States that were part of the EU when this report was published

EU12 – The 12 Member States which joined the EU in 2004 (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia) and in 2007 (Bulgaria and Romania)

GBAORD – Government Budget Appropriations or Outlays on R&D

GDP – Gross Domestic Product

GERD – Gross Expenditure on R&D

GOVERD– Government Intramural Expenditure on R&D

ICT – Information and Communication Technology

DG INFSO – Directorate General Information Society and Media, European Commission

ICB – Industry Classification Benchmark

IPC – International Patent Classification

IPTS – Institute for Prospective Technological Studies, part of the European Commission's Joint Research Centre

ISCO – International Standard Classification of Occupations

ISIC – International Standard Industrial Classification

IT – Information Technology

JRC – Joint Research Centre, European Commission

NABS – Nomenclature for the analysis and comparison of scientific programmes and budgets

NACE – Nomenclature générale des Activites économiques dans les Communautés Européennes

OECD – Organisation for Economic Cooperation and Development

PATSTAT – EPO Worldwide Patent Statistical Database

PPP – Purchasing Power Parity exchange rate

PREDICT – Prospective Insights on R&D in ICT project

R&D – Research and Development

RoW – Countries from the rest of the World

VA – Value Added

Technical Report Series

104

References

- Archontopoulos, Eugenio; Guellec, Dominique; Stevnsborg, Niels; van Pottelsberghe de la Potterie, Bruno and van Zeebroeck, Nicolas (2007), "When small is beautiful: Measuring the evolution and consequences of the voluminosity of patent applications at the EPO", *Information Economics and Policy*, Vol 19, Issue 2, pp. 103-132.
- Azagra Caro, J. M. and Grablowitz, A. (2008), "Data on Business R&D: Comparing BERD and the Scoreboard", EUR Number: 23364 EN, – Joint Research Centre, Institute for Prospective Technological Studies, available online at: ftp://ftp.jrc.es/pub/EURdoc/JRC44585.pdf
- Baumol, William J. (1967), "Macroeconomics of Unbalanced Growth: the Anatomy of the Urban Crisis", *American Economic Review*, vol. 57.
- Baumol, William J. (2002), *The Free Market Innovation Machine*, Princeton University Press
- Boldrin, Michele and Levine, David K. (2008), *Against Intellectual Monopoly*, Cambridge University Press, Cambridge, UK
- Bontempi, Maria Elena, and Jaques Mairesse (2008), "Intangible Capital and Productivity: An Exploration on a Panel of Italian Manufacturing Firms", *NBER Working Papers*, 14108
- Carlsson, Bo (2006) Internationalisation of innovation systems: A survey of the literature. *Research Policy* 35, pp. 56-67
- Coelli, Timothy J., Rao, Prasada D.S., O'Donnell, Christopher J. and Battese, George E. (2005), *An Introduction to Efficiency and Productivity Analysis*, Springer, New York. Second Edition
- Cohen, Wesley M. and Levinthal, Daniel A. (1989), "Innovation and learning: The two faces of R&D" *The Economic Journal*, Vol. 99, N. 397, pp. 569-596.
- Crepon, Bruno; Duguet, Emmanuel and Mairesse, Jacques (1998), Research, Innovation and Productivity: An Econometric Analysis at the Firm Level, *Economics of Innovation and New Technology*, 7:2, pp. 115-158.
- de Panizza, Andrea, and Mauro Visaggio (2007), "Key Indicators for the New Economy", *Measuring the New Economy Statistics Between Hard-Boiled Indicators and Intangible Phenomena*, T. Wolters (ed.), Elsevier Science, London, pp. 29-52.
- De Rassenfosse, Gaétan; Dernis, Helene; Guellec, Dominique; Picci, Lucio and van Pottlesberghe de la Potterie, Bruno (2009), "Patent statistics without the home bias: a corrected count of priority filings using PATSTAT", mimeo
- De Rassenfosse, Gaétan, and van Pottlesberghe de la Potterie, Bruno (2001), "The internationalization of technology analysed with patent data", *Research Policy* 30, pp. 1253-1266
- De Rassenfosse, Gaétan, and van Pottlesberghe de la Potterie, Bruno (2007), "Per un pugno di dollari: A first look at the price elasticity of patents" *Oxford Review of Economic Policy*, 23(4), pp. 588-604
- De Rassenfosse, Gaétan, and van Pottlesberghe de la Potterie, Bruno (2008), "A policy insight into the R&D-patent relationship", *CEPR Discussion Paper* n. 6718, February
- Dernis, Helene; Guellec Dominique and van Pottelsberghe de la Potterie, Bruno (2001), "Using patent counts for cross-country comparisons of technology output", STI Review, 27, OECD, pp. 129-146.
- Dernis, Helene and Khan, Mosahid (2004), "Triadic patent families methodology", OECD, Directorate for Science, Technology and Industry, DSTI/DOC(2004)2
- Ergas, Henry (1987) 'Does Technology Policy Matter?', *Technology and Global Industry: Companies and Nations in the World Economy*, National Academy of Engineering of the United States, National Academies Press, Washington DC. Reprinted in Stephan, Paula E.and David B. Audretsch, (eds.), *The*

economics of science and innovation, vol. 2, pp. 438–492, Elgar Reference Collection, International Library of Critical Writings in Economics, vol. 117, Cheltenham, U.K. and Northampton, Mass. 200
- European Commission (1995), "Green Paper on Innovation", COM (1995) 688, December
- European Commission (2007), "The 2007 EU Industrial R&D Investment Scoreboard", EUR 22928 EN– DG Research – Joint Research Centre, Institute for Prospective Technological Studies: http://iri.jrc.ec.europa.eu/research/docs/2007/eur22928en.pdf
- European Commission (2008a), "Government budget appropriations or outlays on R&D – GBAORD", Science and Technology, Statistics in Focus 29/2008, Eurostat (Author: Hakan Wilen), ISSN 1977-0316
- European Commission (2008b), "Study on the Trends in European Public and Private Investments in ICT R&D and on the Globalisation of R&D and the Competitiveness of the European Innovation System in ICT: Country Report Finland", ETEPS AISBL and ARC Research Austria, Research Report
- European Commission (2008c), "Study on the Trends in European Public and Private Investments in ICT R&D and on the Globalisation of R&D and the Competitiveness of the European Innovation System in ICT: Country Report Sweden", ETEPS AISBL and ARC Research Austria, Research Report
- European Commission (2009 - forthcoming), IPTS Technical Report on "Public Expenditures in ICT R&D"
- European Patent Office (2008a), PATSTAT database, April 2008 Edition
- European Patent Office (2008b), Data catalogue for the EPO Worldwide Patent Statistical Database, April 2008 Edition
- Eurostat (2008), Patent applications to the EPO in the ICT sector 1993 to 2003, Statistics in Focus, 22/2008
- GFII (2006), "Recherche et développement en sciences et technologies de l'information dans les grands pays industriels. Analyse statistique des investissements en R&D», French Association of Electronic Information Industry, GFII Research Report, 2006.
- Griliches, Zvi (1957), "Hybrid Corn: An Exploration in the Economics of Technological Change", *Econometrica*, 25
- Griliches, Zvi (1990), "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature*, Vol. 28, pp. 1661-1707
- Guadamuz González, Andrés (2006), "The software debate, Journal of Intellectual Property", *Law & Practice*, Vol. 1: pp. 196-206
- Guellec, Dominique, and van Pottelsberghe de la Potterie (2001), "The internationalization of technology analyzed with patent data" *Research Policy* 30, pp. 1253-1266
- Heckman, J. J. (1979), Sample Selection Bias as a Specification Error", *Econometrica* 47, pp. 153-161
- IBFD (2004), *Tax Treatment of Research and Development Expenses*, International Bureau of Fiscal Documentation, Amsterdam
- Jaffe, Adam B. and Lerner, Josh (2004), "Innovation and its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do about It" Princeton University Press, Princeton, PA.
- Johnson, Daniel K.N (2002), The OECD technology concordance (OTC): Patents by industry of manufacture and sector of use. OECD, STI Working Papers 2002/5
- Kline, S.J., and Rosenberg, N. (1986), "An Overview of Innovation", *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, Landau R., and Rosenberg, N. (eds.)
- Koch, Stefan and Gonzales-Barahona, Jesus M. (2005), Open Source software engineering – The state of research, First Monday, Special issue No. 2: *Open Source* (October), available on-line at

(last checked on 25 March 2009): http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/issue/view/212

- Krogh Graversen, E. and Mark, M. (2005), "The Effect of R&D Capital on Firm Productivity", *The Danish Centre for Studies in Research and Research Policy Working Papers* (3/2005).
- Leonard-Barton, D. (1988), "Implementation as mutual adaptation of technology and organization", *Research Policy* 17: pp. 251-267
- Lerner, Josh and Jean Tirole (2005), "The Economics of Technology Sharing: Open Source and Beyond", *Journal of Economic Perspectives*, Vol. 19, N. 2, Spring 2005, pp. 99-120.
- Lindmark, Sven; Turlea, Geomina and Martin, Ulbrich (2008), "Mapping R&D Investment by the European ICT Sector", IPTS, *JRC Reference Report* EUR 23518 EN.
- http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1879
- OECD (1994), *The Measurement of Scientific and Technological Activities: Using Patent Data as Science and Technology Indicators – Patent Manual* OCDE/GD(94)114
- OECD (2002), *Frascati Manual: Proposed standard Practice for Surveys on Research and Experimental Development*. Sixth edition; Paris
- OECD (2006), *Government R&D Funding and Company Behaviour: measuring behavioural additionality*, Paris
- OECD (2008a), Compendium of Patent Statistics 2007, available online: http://www.oecd.org/dataoecd/5/19/37569377.pdf
- OECD (2008b), OECD Information Technology Outlook, available online: http://www.oecd.org/document/20/0,3343,en_2649_33757_41892820_1_1_1_1,00.html#HTO
- OECD - Eurostat (1995), *Canberra Manual: The Measurement of Human Resources Devoted to S&T* – OECD/EC/Eurostat, OCDE/GD(95)77, Paris.
- OECD - Eurostat (2005), *The Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*. Third edition; Paris
- Pakes A. and Griliches, Zvi (1984), "Patents and R&D at the Firm Level in French Manufacturing: A First Look", Zvi Griliches, ed., *Research and Development, Patents and Productivity*, Chicago: The University Press of Chicago, pp. 55-72.
- Patel, Pari and Pavitt, Keith (1991), "Large firms in the production of the world technology: An important case of 'non-globalization'", *Journal of International Business Studies* 22 (1), pp. 1-21
- Picci, Lucio (2006), "Bad design by design: economics meets other types of interactions," in Sebastiano Bagnara and Gillian Crampton Smith (editors), *Foundations of Interaction Design*, Lawrence Erlbaum Associates, New York
- Picci, Lucio (2009), "A methodology for developing patent statistics on European inventive activity using the PATSTAT database", Forthcoming JRC-IPTS Technical Note
- Shy, Oz (2001), *The Economics of Network Industries*, Cambridge University Press
- Smith, Keith (2005), "Measuring Innovation", in Fagerberg, Jan; Mowery, David C. and Nelson, Richard R. (ed.), *The Oxford Handbook of Innovation*, Oxford University Press, Oxford, U.K.
- van Zeebroeck, N., N. Stevnsborg, B. van Pottelsberghe de la Potterie, D. Guellec and E. Archontopoulos (2007), "Patent inflation in Europe", *World Patent Information*, Vol 30, n. 1, pp. 43-52
- Véron, Nicolas (2008) "The demographics of global corporate champions", *Bruegel Working Paper* n. 2008/3
- Von Hippel, Eric (2005), *Democratizing Innovation*, MIT Press, Cambridge, MA

European Commission

EUR 23832 EN — Joint Research Centre — Institute for Prospective Technological Studies

Title: The 2009 Report on R&D in ICT in the European Union

Authors: Geomina Turlea, Sven Lindmark, Lucio Picci, Andrea De Panizza, Martin Ulbrich, Paul Desruelle, Marc Bogdanowicz and David Broster

Luxembourg: Office for Official Publications of the European Communities
2009

EUR — Scientific and Technical Research series — ISSN 1018-5593
ISBN 978-92-79-12433-4
DOI 10.2791/10608

Abstract

This report is the IPTS annual "PREDICT" report, which presents all the data available on ICT R&D private and public expenditures in Europe, at sector level, at country level, in an international perspective (benchmarking), and at company level. It covers data for the period 2001 – 2005 (and also 2006 for company data). The report includes in its second part a thematic analysis on R&D output in ICT and provides a detailed investigation of ICT R&D output based on the analysis of patent data.

The mission of the Joint Research Centre is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of European Union policies. As a service of the European Commission, the Joint Research Centre functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LF-NA-23832-EN-C

JRC
EUROPEAN COMISSION

Publications Office
Publications.europa.eu

ISBN 978-92-79-12433-4