

The 2010 report on R&D in ICT in the European Union

**Authors: Geomina Turlea, Daniel Nepelski, Giuditta de Prato, Sven Lindmark,
Andrea de Panizza, Lucio Picci, Paul Desruelle, David Broster**



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■ Executive Summary

Introduction

This report provides an analysis of R&D investments in the EU Information and Communication Technology sector (ICT sector²). The research and analysis was carried out by the Information Society Unit at JRC-IPTS³ in the context of PREDICT,⁴ a research project co-financed by JRC-IPTS and the Information Society & Media Directorate General of the European Commission.

This report combines in a unique way three complementary perspectives: national statistics (covering both private and public R&D expenditures), company data, and technology-based indicators. It relies on the latest available

official statistics delivered by Member States, Eurostat and the OECD.⁵ This data still contains gaps and where this is the case, rigorous cross-checking and estimating methods have been applied by JRC-IPTS to provide the study with the necessary set of data.⁶

The current analysis includes data up to 2007,⁷ and, this being the third report of a series published annually,⁸ it now covers the period of ICT sector growth that took place between two important financial events: the 'dot.com' crisis and the current financial and economic crisis.

This multiannual analysis confirms the consistency of the data over time and offers a

Important note

Official statistical data is produced on an on-going basis by the relevant international organisations (Eurostat, OECD, US National Science Foundation (NSF)). It is normal to observe minor adjustments in the available data from one year to another. US R&D data has been nevertheless subject to a major revision by the NSF which was published by OECD in late 2009 (OECD 2009a). The revision follows the decision of the NSF to change its method for classifying industrial R&D, beginning with reference year 2004. The major impact of this revision is a 40% increase in the amount of R&D allocated to the manufacturing sector (i.e. in pharmaceuticals and ICT), mainly at the expense of the wholesale trade industries. Therefore R&D data for the US presented in this report is not directly comparable with the statistical data used in previous editions of the report. The current revision does not affect the overall trends observed before, or the relevance of our previous conclusions (see Annexes 3 and 6).

2 The ICT sector includes five NACE Rev.1.1 classes, also called sub-sectors:

- Three ICT manufacturing sub-sectors (IT equipment; IT Components, Telecom and Multimedia Equipment; and Measurement Instruments)
- Two ICT services sub-sectors (Telecom Services, and Computer Services and Software). Where indicated, the Telecom Services sub-sector also includes Postal Services (for a formal definition of the ICT sector see Chapter 2).

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

4 PREDICT: "Prospective insights on R&D in ICT."

5 Namely the following sources:

- For R&D data: ANBERD 2009 (OECD), R&D Statistics (Eurostat), EU industrial R&D Investment Scoreboard (JRC-IPTS)
- For supporting data: Structural Business Statistics SBS, National Accounts, Trade, Price and GDP data (Eurostat), EU KLEMS database (Groningen University), PATSTAT (European Patent Office), Amadeus database (Bureau Van Dijk) as well as several other external or in-house resources.

6 PREDICT's methodology is summarised in the report introduction and described in detail in the annexes.

7 For most of the data, 2007 figures were the latest available in December 2009 when the report was prepared; for patent data, latest year available was 2006.

8 The 2009 report is available at <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2259> and the 2008 report at <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1879>

privileged view of the major ICT R&D trends across those years (2002 – 2007). The following main observations can be made:

- Worldwide, the ICT industry maintains its position as the leading R&D investing sector, due to its dynamism, its innovative capacity and the fact that it supplies general purpose technology to the rest of the economy (see Chapter 2).
- Europe has been, and is still, lagging behind its main competitors in terms of ICT R&D investment (see Chapter 3) and ICT R&D patenting (see Chapter 7).
- This lag is largely due to the size of European ICT companies. For example, as compared with US ICT companies, they are smaller and did not grow as fast in the last decades. This is a particular weakness in the most promising segments, for example in the Computer Services and Software ICT sub-sector, where EU Internet companies have failed so far to achieve a truly global scale. Hence, a growing part of the R&D gap can be observed in this segment (see Chapters 4 and 6).
- Europe is an important location for foreign ICT R&D investment, but international cooperation in R&D is evolving from a dominant EU-US relation to global networking where the US-Asia relation is taking a growing share. Here also, it seems that US companies are able to grasp opportunities more rapidly than EU ones (see Chapters 8 and 9).

The detailed and comprehensive analyses contained in this report are particularly relevant for policy makers since:

- The ICT industry and ICT-enabled innovation in non-ICT industries and services make an increasingly important contribution to the economic growth of advanced economies.

- The ICT sector was highlighted in the EU Lisbon Objectives, and has retained its prominence in the recently proposed Europe 2020 Strategy.⁹
- The ICT sector is a significant contributor to the ambition of achieving the target of investing 3% of GDP in R&D in the EU – a target which is reiterated in the proposed Europe 2020 Strategy.

These characteristics have provided the rationale for this research work and the ambition to gain a deeper understanding of the dynamics of research in the ICT industrial sector which, in turn, can provide important policy insights and options.

Main findings of this report

This executive summary aims to highlight the most important findings of this year's report and these are fully elaborated in the subsequent chapters. The findings are consistent and coherent with those of the two previous reports, thus demonstrating the persistence of the observed trends and also indicating the robustness of the analysis and methodologies.

The importance of the ICT sector

ICTs are highly pervasive technologies and the ICT sector underpins growth in all sectors of the economy. In the EU, the US, and Japan, **the ICT sector is by far the largest R&D-investing sector of the economy**. In 2007, while the ICT sector represented 4.8% of GDP (€540 billion) and 3% of total employment in the EU (6.1 million employees), it accounted for **25% of overall business expenditure in R&D (BERD) and employed 32.4% of all business sector researchers** (see Chapter 2).

⁹ Proposed in March 2010 by the European Commission. See: <http://ec.europa.eu/eu2020>

The time-series (2002 to 2007) show that EU ICT BERD remained stable (see blue line in Figure 1, left) with an ICT BERD intensity between 6 and 6.5% of ICT sector value added. Whilst this is far above the EU 3% target, it is well below US ICT BERD intensity (see Table 1 below). It does however demonstrate the importance of the sector in understanding R&D expenditures, dynamics and performance in the EU.

Not only does the ICT sector lead other economic sectors in terms of BERD, it also provides them with productivity-enhancing technology. Hence it contributes directly and indirectly to increasing labour productivity and overall EU competitiveness.¹⁰

Further, additional evidence of the importance of the sector is provided by the fact that 20% of all EU patents are in ICT technologies (see Section 7.2).

The importance of ICT services, and in particular of the Computer Services and Software sub-sector

In 2007, total ICT sector employment exceeded for the first time its previous peak level of 2001. It therefore took six years for total ICT sector employment to recover from the effects of the dot.com crisis, with an important redistribution of jobs from ICT manufacturing¹¹ to ICT services¹² sub-sectors (see Section 2.1).

From 1999 to 2007, employment increased by 27% in ICT services sub-sectors while it decreased by 10% in ICT manufacturing sub-sectors. **This brought the share of ICT services employment to 68% of the total ICT sector.** In 2007, the Computer Services and Software sub-sector alone accounted for half the total ICT employment in Europe.

A similar structural shift occurred for ICT value added with a steady increase of the share of the ICT services sub-sectors' value added. **ICT Services accounted for more than 75% of total ICT value added in 2007**, with the Computer Services and Software sub-sector alone producing 42% of the ICT sector value added.

The Computer Services and Software sub-sector is also the only EU ICT sub-sector with a strong and sustained increase in both BERD and employment of researchers: from 2002 to 2007, BERD increased by 40% (see orange line in Figure 1, left) and employment of researchers by 56%. In 2007, the Computer Services and Software sub-sector became for the first time the leading ICT sub-sector in terms of employment of researchers (see orange line in Figure 1, right).

International comparisons

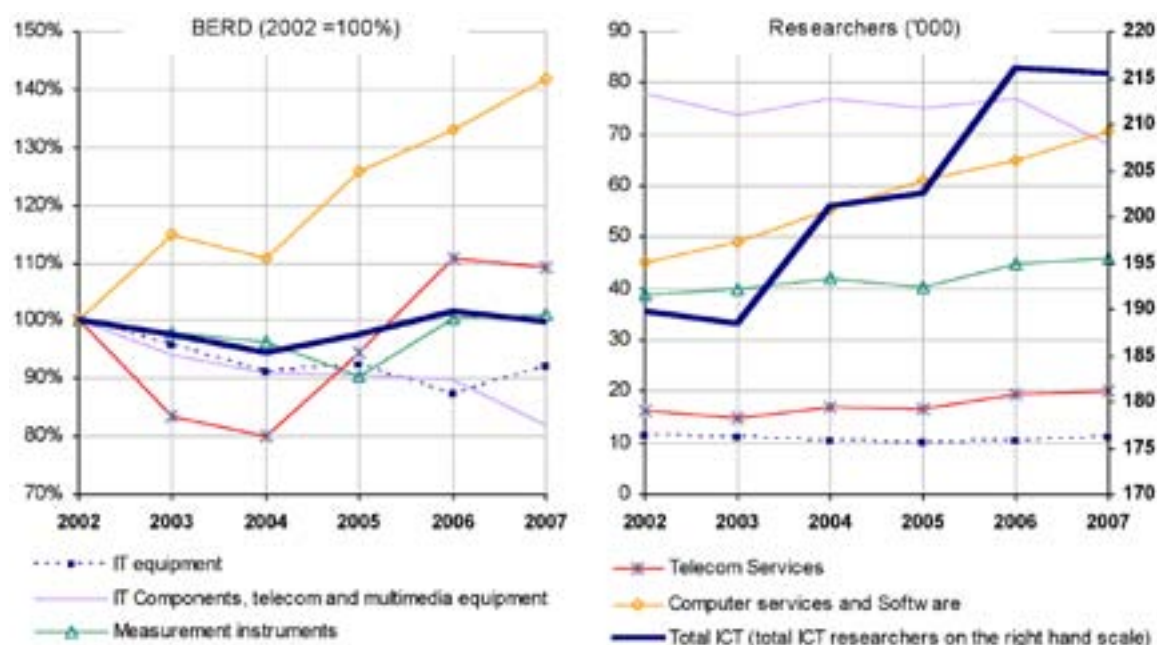
The US, Japan, Taiwan and Korea are investing significantly more in ICT R&D than the EU (when comparing ICT R&D over GDP ratios). Although the EU and the US have roughly

10 See the March 2009 European Commission Communication: "A Strategy for ICT R&D and Innovation in Europe: Raising the Game", COM(2009)116, available at: http://ec.europa.eu/information_society/tl/research/documents/ict-rdi-strategy.pdf

11 ICT manufacturing includes three sub-sectors: IT Equipment; IT Components, Telecom and Multimedia Equipment; and Measurement Instruments.

12 ICT services include two sub-sectors: Telecom Services, and Computer Services and Software (where indicated, the Telecom Services sub-sector also includes Postal Services).

Figure 1: BERD growth (%) and number of researchers (thousands) by ICT sub-sector and for the ICT sector, 2002-2007¹³



equivalent GDPs, the US levels of both business ICT R&D expenditure (ICT BERD) and public ICT R&D funding (ICT GBAORD¹⁴) are double those of the EU. These points are further elaborated below from three perspectives:

- In 2007, ICT BERD was €36.6 billion in the EU, and €83.8 billion in the US.¹⁵ This represents a contribution in relation to GDP of 0.30% for the EU, versus 0.72% for the US. As can be seen in Table 1, this difference can be attributed to both a smaller relative size of the ICT sector in the economy and to a lower R&D intensity of the ICT sector. This difference is even bigger when comparing the EU to Japan, Korea and Taiwan. Analysis of global R&D investments made by *ICT Scoreboard* companies¹⁶ produces correlated results. In 2007, top R&D-investing EU ICT companies invested about half the total amount invested by their US counterparts (€27.6 billion vs. €58.8 billion) (see Section 6.1).
- Public funding figures also indicate that, compared to the US, EU governments fund a smaller share of ICT R&D in relation to total public funding for R&D. In 2007, EU ICT GBOARD represented 6% of total public funding for R&D in the EU (€5.3 billion), while it was close to 9% in the US (€10.4 billion) (see Section 3.2).
- Patenting activity also appears to be notably more specialised in ICT in the US than it is in the EU. In 2006, 50% of all patents

¹³ Source: IPTS estimates, based on data from Eurostat, OECD, EU KLEMS and national statistics.

¹⁴ ICT GBAORD: An estimation of Government Budget Appropriations or Outlays for R&D by Socio-economic Objectives (GBOARD) targeting ICT R&D.

¹⁵ Using Purchasing Power Parity (PPP) exchange rates.

¹⁶ The *ICT Scoreboard* includes the 453 ICT companies with the largest R&D budgets globally. It is extracted from the *EU industrial R&D Investment Scoreboard*, available

at http://iri.jrc.ec.europa.eu/research/scoreboard_2008.htm. In the *Scoreboard*, the term 'EU company' concerns companies whose ultimate parent has its registered office in a Member State of the EU. Likewise, 'non-EU company' applies when the ultimate parent company is registered outside of the EU.

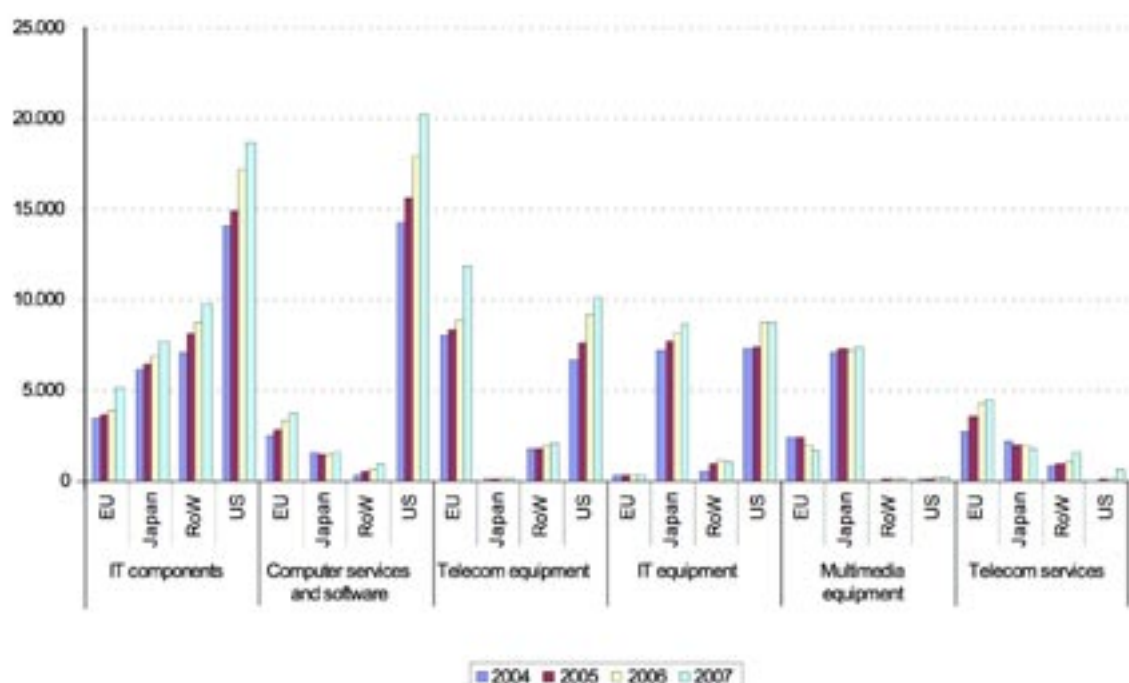
Table 1: ICT BERD in relation to GDP broken down into ICT sector size and R&D intensity factors, 2007¹⁷

	ICT BERD in the economy (ICT BERD/GDP)	Size of ICT sector in the economy (ICT VA/GDP)	ICT sector R&D intensity (ICT BERD/ ICT VA)
EU	0.30%	4.8%	6.2%
US	0.72%	6.4%	11.2%
Japan	0.87%	6.8%	12.8%
Korea	1.30%	7.9%	16.5%
Taiwan	1.31%	10.6%	12.3%

applied for by US-based inventors¹⁸ were in ICT technologies vs. only 20% of all patents applied for by EU-based inventors (see Section 7.2).

In terms of R&D invested in ICT sub-sectors for the period 2004 to 2007, analysis of *ICT Scoreboard* companies shows that **R&D investments by EU companies have been growing** –in some case strongly- in all ICT sub-sectors.¹⁹

However, at the same time, the *ICT Scoreboard* also shows that US companies clearly outperform EU companies in several ICT sub-sectors that are key to the competitiveness of the EU industry, notably Computer Services and Software (see Figure 2). A further example of EU weaknesses in growing markets is that in the Internet industry, where companies like Google or Yahoo are dominant, no EU company had invested sufficiently in R&D in 2007 in order to make it to the *ICT Scoreboard* listing! (see Section 6.5).

Figure 2: R&D investments in the ICT sub-sectors by EU, Japanese, US and Rest of the World (RoW) *ICT Scoreboard* companies, 2004-2007 (€ million)²⁰

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

18 Patent priority applications by inventors physically based (residing) in the US.

19 Except Multimedia Equipment.

20 Nominal terms, not adjusted for inflation.

Internationalisation of ICT R&D

ICT R&D is an international endeavour that is increasingly widely distributed globally. Analyses of a combination of indicators (global distribution of corporate R&D sites of major ICT companies,²¹ and international patents in ICT technologies²² - see Chapter 9) indicate that the **EU remains an important location for ICT R&D** – for both EU and non-EU companies - but it is also noted that **Asia is gaining importance** in this respect.

International patent analysis also indicates that **US companies have taken a ‘first mover’ advantage in developing ICT R&D collaborations with Asia**. For example the share of the ICT inventions developed in Asia owned by US patent applicants grew from almost zero in the early 1990’s to 1.5% in 2006, while the share owned by EU patent applicants merely started growing in the late 1990’s and reached only 0.5% in 2006 (see Section 9.2).²³

ICT R&D distribution across EU Member States

There are very large differences in ICT R&D activity between the 27 EU Member States. The EU’s three largest economies (Germany, France and the UK), and to some extent the next two (Italy and Spain), dominate and set the average EU trend. When the size of the respective economies is taken into account, the best performers are Nordic countries. The Member States that have experienced the largest increases in ICT BERD in recent years are the new EU Member States along

with Portugal and Spain (see Chapter 5). More specifically:

- In 2007, **Germany, France, the UK, Italy and Spain** accounted for more than 70% of total ICT sector value added and 2/3 of its employment. In ICT manufacturing, Germany alone contributed 27% of EU employment and 30% of value added. In ICT services, the UK remains the leading country for employment (19% of EU employment) and a clear leader in value added terms (25% of EU value added). These five countries together contribute more than 2/3 of EU ICT BERD, and they generate more than 75% of all ICT patents (Germany generates almost 45% of these).
- **Finland and Sweden** invest the largest amount in ICT BERD in relation to their GDP (and above the US level). In 2007, Finland and Sweden were also (with Spain) the countries with highest levels of ICT public funding²⁴ in relation to their GDP (comparable to US level). **Finland, Germany, the Netherlands and Sweden** are the only four Member States with ratios of ICT patent applications in relation to GDP either above or close to the US ratio (although the ratios of Sweden and the Netherlands have dipped in recent years). **Finland and the Netherlands** have the highest degree of specialisation in ICT patenting (i.e. their share of ICT patent applications amongst total patent applications).
- In spite of strong ICT BERD increase, however, the new EU Member States still have very low ICT BERD in relation to their GDP. They also have very low ICT GBAORD in GDP. Although several new Member States, such as **Hungary, the Czech Republic and Poland** recorded spectacular increases in ICT manufacturing employment, deeper analysis shows that these countries are still hosting rather low value added activities.

21 Based on the *IPTS ICT R&D Location Database*. This dataset includes location information for over 1,800 R&D sites that, in 2007 and 2008, belonged to 80 multinational companies that are considered to be major semiconductor influencers. Among the companies included in the sample are, for example, Microsoft, IBM, Sony and Siemens. The full list of companies included in the database is provided in Annex 9.

22 This report calls ‘International patents’ those patents which have inventors or applicants from different regions of the world (e.g., from the US and the EU), but not intra-EU patents with only inventors or applicants from different EU Member States.

23 Estimated by analysing priority patents applications filed in 2006 to all European national patent offices, the EPO and the USPTO - see Section 9.2.5.

24 Measures based on an estimate of ICT GBAORD.

Broader observations

Our analyses show that EU ICT R&D investment is less than half of that in the US. Moreover, due to its prominence in overall R&D investments, the ICT investment 'gap' accounts for a substantial part of the difference between EU and US R&D investment. A number of possible contributory factors are elaborated in the paragraphs below.

Issues of economic and industrial composition

As this series of reports have indicated, the economic structure (size of the ICT sector in the total economy), the composition of the industry (share of each ICT sub-sector), and the overall size and number of ICT companies (and particularly the scarcity of large, globally operating EU companies - with the exception of Telecom Services sector companies) largely explain the investment differences. However, our analysis also shows that EU ICT companies' R&D investments are roughly equivalent to those made by comparable US firms in comparable sub-sectors.²⁵ These investments are driven by an industrial logic where, in order to remain competitive, the companies have to make an equivalent investment in R&D.

Issues of growth

Company data analysis indicates that the EU does not generate as many large new and innovative ICT companies as the US (and may additionally be threatened by emerging competitors from China and India). This appears particularly true in a key growth segment: Computer Services and Software. The US R&D investments have grown from virtually nothing to about €2.5 billion/year in Internet-related businesses, and, moreover, this growth can largely be attributed to only two relatively recently created companies: Google and Yahoo. The lack of large innovation clusters

in the EU may partly explain these difficulties, but market fragmentation, difficult access to financial capital, and other market rigidities are often cited²⁶ as other possible causes. The lack of large ICT companies in high growth sectors and slower industrial growth clearly have a negative impact on the R&D investment indicators.

Issues in international R&D cooperation

Europe is an important place for ICT R&D, but as shown in this report, globalisation leads to internationalisation of R&D activities embedded into emerging economies. In the ICT sector, US companies have opted for a more rapid internationalisation of their R&D activities than their EU counterparts and have progressively targeted Asian countries, benefiting from a first-mover advantage in the respective markets (see Chapter 9).

Issues of ICT R&D in non-ICT sectors of the economy

Substantial ICT R&D is carried out in other sectors of the economy (for example, automotive or aeronautics). The size of this additional ICT R&D expenditure cannot be readily measured with current statistics. However, OECD has estimated that the magnitude of ICT R&D carried out outside of the ICT sector could be as large as 1/3 the R&D carried out in the ICT sector itself.²⁷ After further statistical analysis and estimation, taking this additional R&D into account may eventually deepen our understanding of the nature of the EU-US gap in R&D investment. More importantly, it may also provide further evidence of the pervasive impact of ICT and ICT R&D investment on the overall economy.²⁸

²⁵ See also the JRC-IPTS Reference Report "Mapping R&D Investment by the European ICT Sector" (Lindmark et al. 2008).

²⁶ See also: Information and Communication Technologies, Market Rigidities and Growth: Implications for EU Policies at <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1508>.

²⁷ Estimated in a sample of countries: Czech Republic, Denmark, Norway, Finland, Japan (OECD, 2008 b).

²⁸ JRC-IPTS is currently investigating this issue further.

Issues of publicly-funded ICT R&D

It is inherently difficult to access data on public funding of ICT R&D. However, available (incomplete) data indicates a substantial 'gap' where, again, the EU is a long way behind the US in terms of R&D public procurement²⁹ and did not fully adopt dual-use research.³⁰

Issues of statistics

As stated elsewhere in this report, official statistical data is produced on an on-going basis by the relevant international organisations with a view to improving data quality and comparability at international level. The recently revised data for the US raises their annual business ICT R&D investment by some 20%. Notwithstanding these changes, our analysis helps to develop an understanding of the main trends.

Issues of policy

The pervasive impact of ICT, its inherent R&D magnitude and intensity, its innovation performance and global dynamics, confirm the central role ICT plays in the world economy, the EU economy and the EU's economic recovery. This report further indicates that the current under-investment in ICT R&D is a complex issue that has a multitude of contributory factors, including Europe's economic and industrial structure. New measures will therefore require a coordinated policy mix that includes, but also goes beyond, ICT R&D and innovation policies. In particular, a policy mix needs to favour industrial restructuring to high-tech, high-growth, high added-value sectors fuelled by ICT-enabled innovations. The report also points to potentially important trends (threats and opportunities) in terms of internationalisation of ICT R&D.

29 See December 2007 EC Communication on pre-commercial procurement, COM(2007) 799, available at: http://ec.europa.eu/information_society/tl/research/priv_invest/pcp/documents/pcp_brochure_en.pdf

30 Dual-use research refers to tools or techniques, developed originally for military or related purposes, which are commercially viable enough to support adaptation and production for industrial or consumer uses. The United States Department of Defence (DOD) has an important dual-use research program. Adapted from: <http://www.answers.com/topic/dual-use-technology>

■ 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 (JRC-IPTS)³¹ under PREDICT,³² a research project analysing Research and Development (R&D) in ICT in Europe. PREDICT is being run by JRC-IPTS for the Directorate General Information Society & Media of the European Commission.

This is the third report of a series which is published annually.³³ Each annual report consists of two parts: Part I provides an analysis of available data as part of a regular reporting on ICT R&D, and Part II focuses on a particular topic. This year's report focuses on internationalisation of ICT R&D. It provides data up to 2007,³⁴ and therefore covers a period of ICT sector growth that took place between two important crises: the 'dot.com' crisis and the current financial and economic crisis.

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 EU in an international perspective, looking in particular at the US as a benchmark (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*,³⁵ which tracks R&D spending by the biggest EU and non-EU R&D spenders. Chapter 7 provides an overview of ICT patenting in the European Union and a comparison of ICT patenting performance, by Member State and with the US.

Part II includes a thematic analysis on internationalisation of ICT R&D, on which there is still scarce evidence available, particularly with regard to ICT R&D internationalisation with emerging Asian economies. This scarcity creates a challenge for informed policy making. For this reason, PREDICT aims to assess the size and importance of the internationalisation of ICT inventive activity. Chapter 8 discusses the concept of R&D internationalisation and aspects such as drivers and barriers to this process. This discussion serves as a framework and a starting point for a set of empirical analyses of R&D internationalisation in the ICT sector in Chapter 9.

Finally, Chapter 10 provides the conclusions of the report. Several methodological annexes can be found at the end of the report.

31 The Institute for Prospective Technological Studies (JRC-IPTS) is one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC).

32 PREDICT: *Prospective Insights on R&D in ICT*.

33 The 2009 report is available at <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2259> and the 2008 report at <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1879>

34 For most of the data, 2007 figures were the latest available in December 2009 when the report was prepared; for patent data, latest year available was 2006.

35 http://iri.jrc.ec.europa.eu/research/scoreboard_2008.htm

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 industry. JRC-IPTS has articulated official data from different repositories, namely ANBERD 2009 (OECD), R&D Statistics (Eurostat), and the EU Industrial R&D Investment Scoreboard (JRC-IPTS) for R&D data, and Structural Business Statistics (SBS), National Accounts, Trade, Price and GDP data (Eurostat), EU KLEMS database (Groningen University), PATSTAT (European Patent Office), Amadeus database (Bureau Van Dijk) and several external and in-house resources for supporting data. JRC-IPTS has used this data to fill a number of gaps, and correct for incoherencies and 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 robust.

To address public R&D expenditures data (GBAORD³⁶), 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 these lines by the GFII.³⁷ PREDICT further improved and deepened some of the methodological aspects, investigating the concrete way data were collected in each country, thus making major improvements in terms of both scope and quality. To fine tune estimations, the PREDICT team also performed extended expert consultations and interviews.³⁸

The initial basis for assessing company data was the JRC-IPTS annual *EU Industrial R&D Investment Scoreboard*.³⁹ The underlying information was integrated and reclassified to isolate the ICT sector. Demographic data (age) were added, to better capture dynamics. Some additional descriptive dimensions have also 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 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 detailed level.

PREDICT is unique in analysing patent statistics using the information produced by all the national European patent offices, the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO) collected in the PATSTAT database of the EPO.⁴⁰ This coverage makes possible a valid comparison of respective EU and US inventive prowess, which would otherwise be affected by a serious country bias. It also enables PREDICT to draw a more complete picture of the ICT R&D and innovation activity of the EU and its Member States.

The analysis of the internationalisation of ICT R&D focuses on two aspects:

- Input in ICT R&D was analysed by using the *JRC-IPTS ICT R&D Location Database* and looking at the global distribution of over 1,800 R&D sites of a group of 80 multinational companies that are considered to be essential industrial actors in the ICT value chain.
- For output of ICT R&D, an extensive analysis of international patent applications in the PATSTAT database was performed.

36 GBAORD – Government Budget Appropriations or Outlays on R&D.

37 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.

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

39 The *EU Industrial R&D Investment Scoreboard* is available at: http://iri.jrc.ec.europa.eu/research/scoreboard_2008.htm

40 PATSTAT is the name under which the EPO Worldwide Patent Statistical Database is known. It is a database containing worldwide coverage of information on patent applications. Detailed information on PATSTAT is available online at the EPO website: <http://www.epo.org/patents/patent-information/raw-data/test/product-14-24.html>.

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 provides a substantial contribution to the development of the EU knowledge economy: it is the leading sector in R&D expenditure, and its labour productivity is almost twice as big as the whole economy average.⁴²

Definition of the ICT sector⁴¹

The ICT sector, as defined in this report, includes all firms, whose principal activity is in the following NACE rev.1.1. classes:

Manufacturing:

- NACE 30 (IT Equipment): computers, printers, scanners, photocopiers
- NACE 32 (Components, Telecom and Multimedia Equipment): semiconductors, printed circuits, LCDs, TV tubes, diodes, TV, VCR, cameras, cassette players, CD and DVD players, telephones, faxes, switches, routers, TV and radio emitters
- NACE 33 (Measurement Instruments): measurement instruments (sensors, readers), industrial process control equipment.

Services:

- NACE 642: Telecommunication services (or NACE 64 for international comparisons due to data availability)
- NACE 72 (Computer Services and Software): hardware consultancy, software consultancy and supply, database activities, Internet, maintenance and repair.

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 therefore not cover ICT-related activities embedded in other sectors of the economy, such as those in IT departments of firms not belonging to the ICT sector (e.g., in the automotive or aeronautics industries). This definition covers the business ICT sector. ICT R&D performed by the government sector can take place in any NACE class and it is presented in Section 3.2 of the Report.

⁴¹ See Annex 1 for more details on the definition of the ICT sector.

⁴² 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.

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

In 2006, ICT industries in the EU followed the trend set in previous years, with a relative decline in manufacturing industries and an expansion of services, while in 2007 there was a slight recovery of ICT manufacturing value added at current prices and employment, due to favourable macroeconomic conditions (see Figure 2.1). During this period, manufacturing increasingly moved towards Eastern EU Member States. In services, value added continued to grow in 2006 and 2007 in both Telecom and Computer Services and Software industries. This latter industry witnessed a spectacular growth in employment, especially in Eastern EU Member States. In the EU, the number of people employed in the Computer Services and Software industry was over 51% higher in 2007 than it was in 1999, i.e. an increase double that of the whole non-financial market services sector and almost four times that of the aggregate of the non-financial business economy (NFBE).⁴³ Computer Services and Software was thus confirmed as the leading ICT sub-sector, with 2.3% of non-financial business employment and about 1.5% of total employment in the EU.

In 2007, there were about 716,000 enterprises in the EU whose main activity was in ICT manufacturing and services. These employed 6.1 million people, and had a turnover of €1,288 billion and a value added of almost €540 billion.⁴⁴ These figures stand for 3.4% of enterprises, 4.6% of employment, 5.4% of turnover and 8.5% of value added of the EU NFBE, corresponding approximately to little less than 3% of EU total employment and to 4.8% of value added. The

above figures suggest that the average ICT sector enterprise has a relatively larger employment size and a considerably more productive workforce than the average enterprise operating in the rest of the NFBE in the EU.

The number of ICT enterprises in the EU increased 4.3% in 2006, and only 0.4% in 2007 (against 2.6% and 3.7% for the whole NFBE), while the ICT sector value added at current prices increased 5.5% and 5.1% (against 5% and 7.7% for the NFBE), and employment growth accelerated from 0.5% in 2006 to 3.7% in 2007 (against 2.4% and 3.1%). These figures reflect both cyclical dynamics – with a steadier overall economic growth in 2007 – and a longer-term trend, with a general tendency towards the development of service activities in advanced economies, and distinct patterns among ICT sub-sectors (See Figure 2-1).

Employment in the ICT sector in 2007 was 12.3% higher than in 1999, against an increase of 13.7% for the whole of the NFBE. In 2007, total ICT sector employment exceeded for the first time the peak reached in 2001 (see Figure 2-1, left). It took therefore six years for total ICT sector employment to recover from the effects of the dot.com crisis, with an important redistribution of jobs from manufacturing to services.

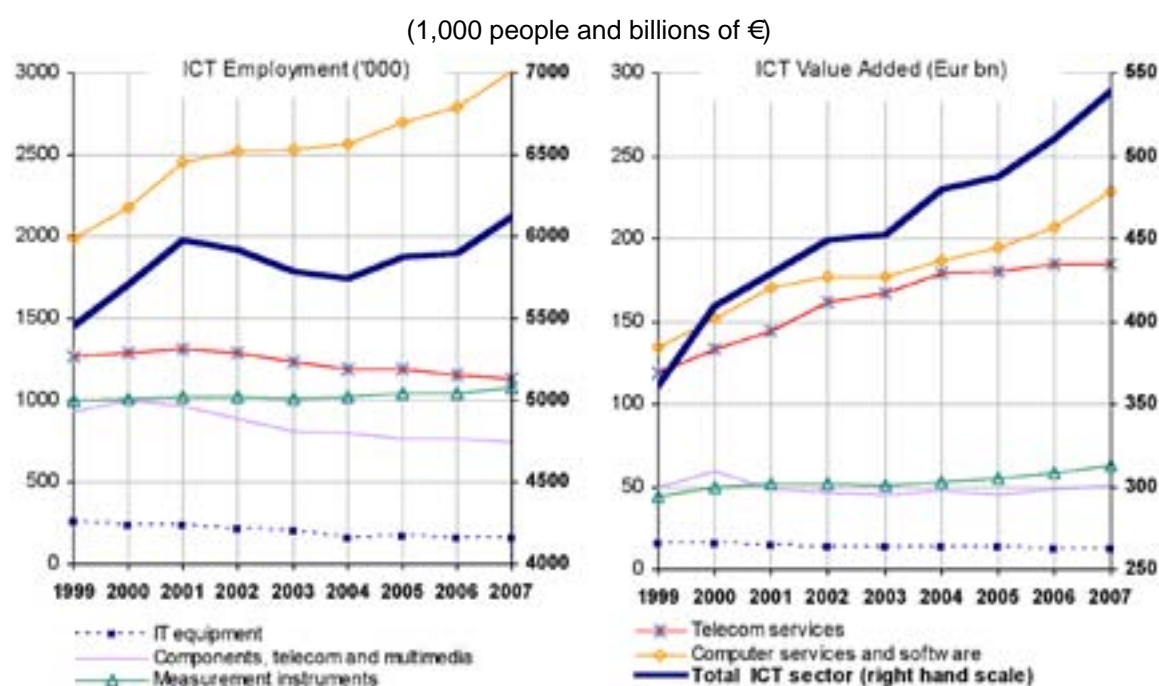
In 2007, employment in ICT manufacturing showed a slight recovery from the previous year, but its level was still just below the threshold of 2 million workers. With 213,000 jobs less than in 1999, ICT manufacturing employment decreased by about 10% from 1999 to 2007, vs. 7% for the whole manufacturing sector. On the other hand, employment in ICT services, gained about 900,000 jobs from 1999 to 2007, to more than 4.1 million, an overall increase of 27% (slightly higher than the whole of non-financial business services), which brings the share of services from 60% to nearly 68% of the ICT sector total.

In manufacturing, in the eight years from 1999 to 2007 there were 190,000 jobs lost in the

43 The non-financial business economy is commonly used as a reference, as it encompasses the *real* part of the 'modern' private economy (and in the European Statistical System undergoes a common framework of data collection within structural business statistics, covering NACE sections C to I and K). It excludes agriculture, public administration and other non-market services, as well as the financial services sector.

44 For information on Methodology for value added data, see the Annex 4.

Figure 2-1: Employment and value added in the EU 27 ICT sector, 1999-2007*



(*) Latest available year to date

Source: JRC-IPTS estimates based on Eurostat Structural Business Statistics (SBS) and, for value added, on EU-KLEMS and SBS data. Note that SBS data might underestimate Computer Services employment with respect to National Accounts (EU KLEMS) data.

Component, Telecom and Multimedia industry (20% of its employment base) and 90,000 in IT Equipment (37% of its employment base), against an increase of 70,000 jobs in Measurement Instruments (7%) (see Figure 2-1, left). Hence, this latter industry increased its weight from 46% to 54% of ICT manufacturing employment, while losing importance slightly in total ICT employment, reaching less than 18%. Within services, workforce numbers fell from 1.3 to 1.1 million in Telecom Services, while they increased by 1 million in Computer Services and Software, reaching 3 million people employed. In 2007, this latter industry alone represented 49% of total ICT employment, with an increase of almost 13 percentage points with respect to the end of the 90s.

Value added at current prices grew steadily in ICT services, while it showed prolonged stagnation in ICT manufacturing (see Figure 2-1, right). Value added in Computer Services and Software increased 71% from 1999 to 2007 and in 2007 represented 42% of ICT sector value

added. The share of services in total ICT value-added reached 77% in 2007.

As stated above, ICT enterprises have a much higher than average labour productivity. This holds for both manufacturing (€64,600 in 2007, against €52,500 for overall manufacturing in the EU) and service industries (€66,200 in Computer Services and Software and €172,900 in Telecom services, against €42,200 for the aggregate of non financial business services in EU).⁴⁵ With respect to the 1999-2000 levels, in 2007 labour productivity at current prices in the ICT sector grew about 31%, against a NFBE average of 23%. In this period, productivity increased a lot (in nominal terms⁴⁶) in telecom services (+75%), and appeared to be sluggish and negative overall in IT Equipment (-6%), though this was due entirely to the effect of quickly falling unit prices, while physical output was still growing.

45 As measured by value added per person employed, using Eurostat SBS data (enterprise accounts).

46 Nominal value is the value not adjusted for inflation.

At the EU Member States level, the five largest EU economies (Germany, the UK, France, Italy, and Spain) accounted for more than 70% of total ICT value added and for 2/3 of employment in 2007 (see Figure 2-2). As in previous years, the UK led in value added, while Germany had the highest share in employment.⁴⁷

In ICT manufacturing, where Germany alone represented more than a quarter of EU employment and 30% of value added, France and the UK were most affected by the employment fall in IT Equipment. From 1999 to 2007, the UK also lost the most employment in Components, Multimedia and Telecom Equipment and, overall, about 40% of its employment base in ICT manufacturing (a loss of 140,000 jobs out of 200,000 for the whole EU), falling behind France and Italy. The UK's share of ICT manufacturing value added also decreased substantially (from 19% to 12% of the EU total), although employment in the UK continued to be comparatively more productive, as it can be seen by comparing the UK shares in value added and employment in Figure 2-2. However, Hungary, the Czech Republic and lately, Poland, recorded spectacular increases in ICT manufacturing employment. This brought them just behind the four largest EU economies and, in the case of Poland, to a share of 4.2% of EU total ICT sector employment, above Sweden and the Netherlands (See Fig 2.2, upper panel). Comparing this ranking with the ranking for value added, though, reveals that the above-mentioned emerging countries in manufacturing employment typically host mainly lower-end activities, and that value added does not stay in the country. Indeed, the cumulative shares of Poland, the Czech Republic, Hungary, Romania, the Slovak Republic and Bulgaria in EU ICT manufacturing add up to 17% for employment but only to 4.6% for value added. Those of Netherlands,

Sweden, Finland and Ireland, however, add up to 10% of employment and to almost 21% of value added in ICT manufacturing, i.e. nearly as much as those of France and Italy together (see Figure 2-2).

In ICT services, the UK remains the leading country for employment and, by far, for value added, with shares of EU totals of 19.4% and 24.8% respectively in 2007 (see Figure 2-2). With respect to the peak in 2000-2001, nearly all countries (except Germany) lost employment in Telecom Services, whereas employment grew everywhere in the Computer Services and Software industry.

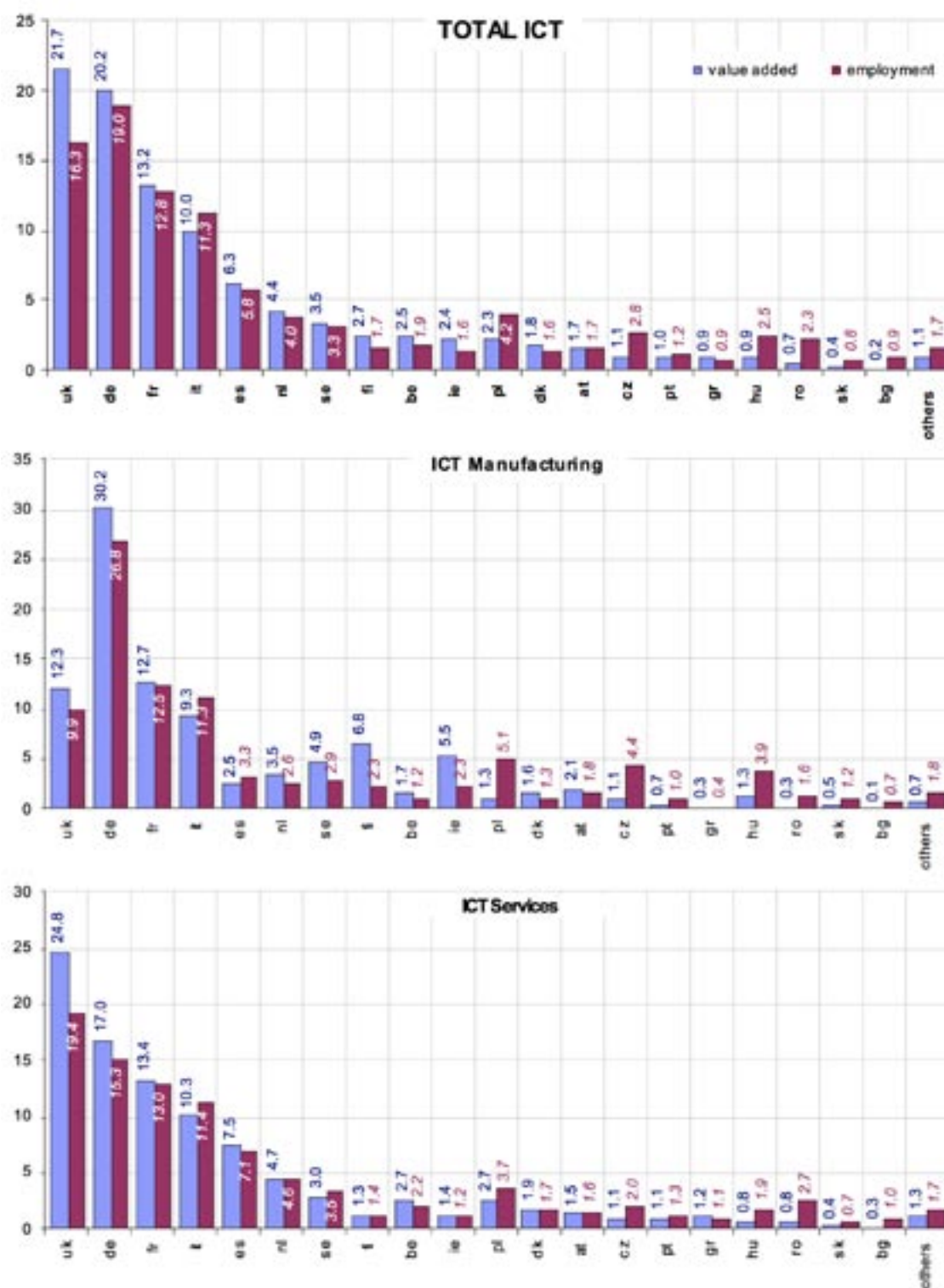
Overall, the relevance of ICT for total employment in the non-financial business economy varies widely among the EU countries, from less than 3% in Portugal, Greece, Spain, Latvia, Cyprus and Lithuania, to more than 6% in Hungary, 7% in Sweden, and 8% in Finland and Ireland.

When comparing the EU with the US, ICT sector employment is higher in the EU. Total ICT employment stood at nearly 6 million and 3% of total economy employment in the EU, vs. about 4.2 million and 2% in the US (in 2006). Employment dynamics in the US ICT sector between 2000 and 2006 were worse than in the EU across all ICT sub-sectors, with a strikingly diverging trend in Computer Services and Software (see Figure 2-3, blue columns). In terms of value added at current prices, growth in the US was also sluggish with respect to the EU, except in Measurement Instruments (see Figure 2-3, blue lines). Employment contraction in the US, though, resulted in a comparatively higher growth of apparent labour productivity (see Figure 2-3, red columns): for example, contrasted trends in Computer Services and Software can be observed, comparing the US and the EU. These dynamics are presented in Figure 2-3, where the % change in value added is decomposed into the contributions of employment and labour productivity.⁴⁸

⁴⁷ IPTS estimates based on SBS industry level national data. It is important to note that for value added, these are adjusted to EU KLEMS (National Accounts) data, which results in a slightly higher overall value and some differences in relative industry shares, due to an upward correction for IT Equipment and Computer services, and a downward correction for the remaining industries.

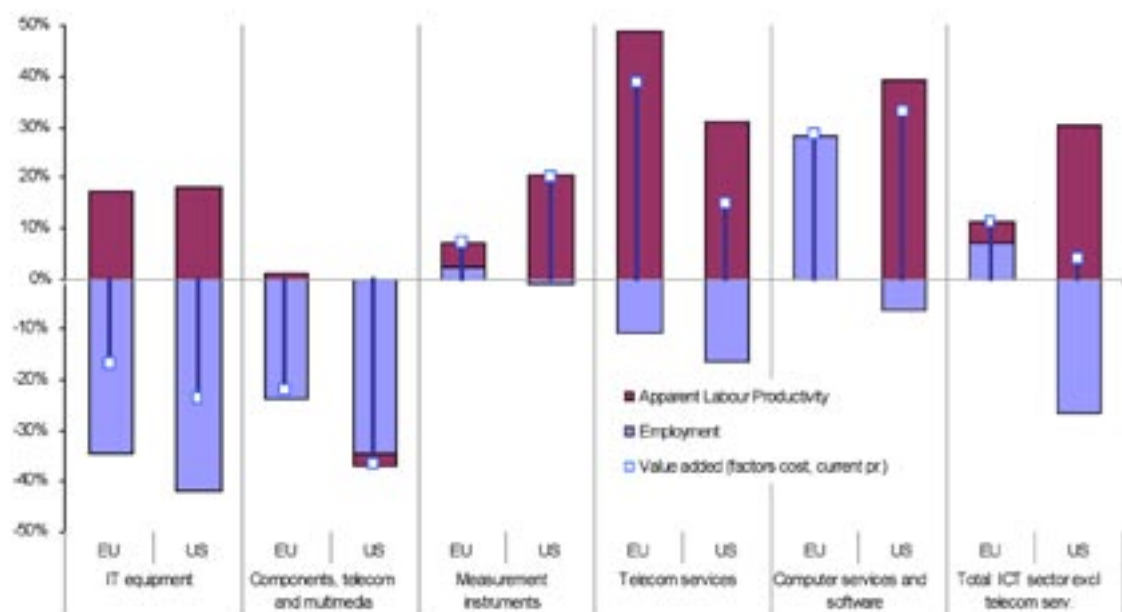
⁴⁸ By definition, % change in value added is equivalent to % change in employment + % change in apparent labour productivity (value added per person employed).

Figure 2-2: Country shares (%) in the EU ICT sector value added and employment: Manufacturing, Services and Total, year 2007



Source: JRC-IPTS estimates based on Eurostat SBS. The group 'Others' includes si, lt, lv, mt, ee, cy, lu

Figure 2-3: The dynamics of employment, value added and apparent labour productivity in EU and US ICT sector: % change from 2000 to 2006



Note: Because Telecom Services data for the US include Postal Services the Total ICT Sector EU-US comparison excludes Telecom Services.

Source: JRC-IPTS estimates based on Eurostat (SBS), OECD (STAN), and national statistics.

2.2 Recent global trends in ICT industries

Preliminary information collected by the OECD (2009b, c) shows the severe effects of the recent financial and economic crisis on the ICT sector, although these have been comparatively milder than those of the past dot.com crisis, with recovery already underway in some countries and industries. In broad terms, ICT services performed better than manufacturing and responded more slowly to the global downturn, but there are relevant differences across both industries and regions.

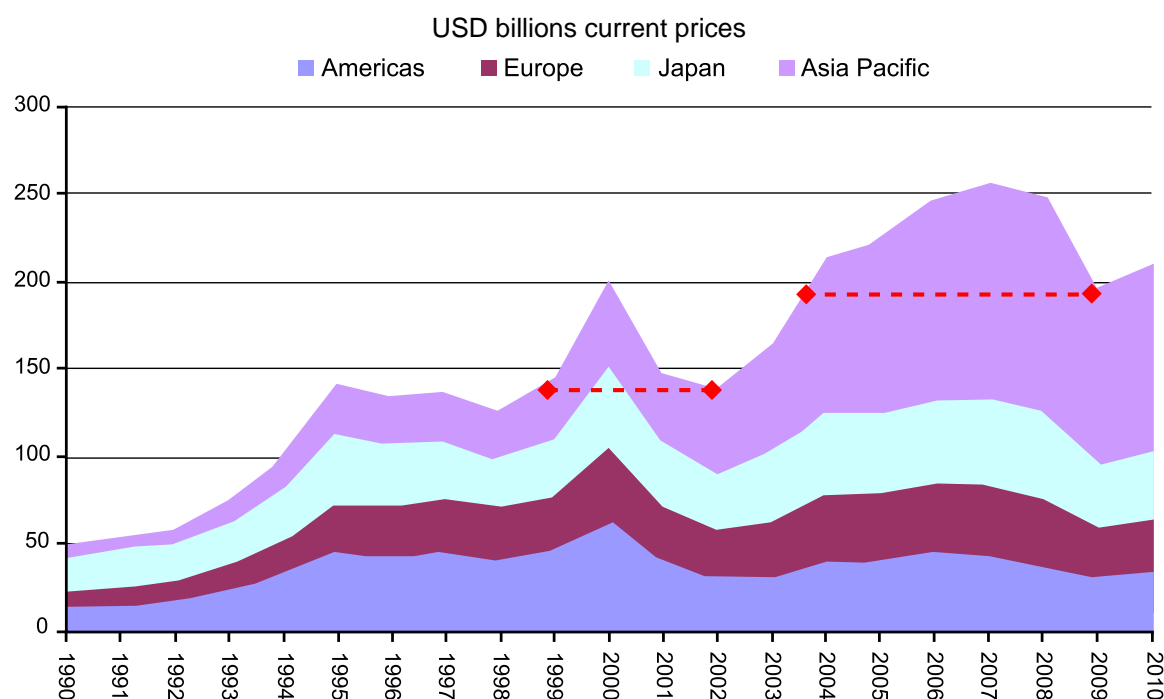
Figure 2-4 shows the evolution of the worldwide semiconductor market since 1990. Production of semiconductors often anticipates and amplifies global turns: already flat over some quarters since 2006, it dropped sharply from the end of 2008, bringing a drastic reduction to inventories. Sales recuperated in the second and third quarters of 2009. On

a yearly basis, though, for 2009 the OECD estimates a shrinkage of at least 20%, which would bring the market value in current US dollars to the year 2000 level, with recovery only visible in 2010 (note that 2009 and 2010 are forecasts at the time of publication).

Sales of IT equipment also dropped in quantity in the last quarter of 2008 (for the first time since 2002) and at the beginning of 2009. Recovery in this area went with a shift towards cheaper products (e.g., netbooks), which, in turn, also brought on a shrinkage in value in the mid term.

Production of communications equipment decelerated towards null growth, while sales values went down for most producers. Mature markets (notably, Western Europe) seem to have suffered more than those in emerging economies, in both the networks and consumer segments (e.g., mobile phones). In this latter area, recovery started in the third quarter of 2009, but at the same time, EU-based companies lost market

Figure 2-4: Worldwide semiconductor market by region, 1990–2010



Note: 2009 and 2010 are forecasts.

Source: elaborated on OECD (2009b), Fig. 25, based on World Semiconductor Trade Statistics, July 2009.

shares to their Asian and US-based competitors.⁴⁹ The production of measurement and precision instruments, mostly tied to industrial demand, went down, but only after the downturn of investment. ICT services, instead, have still retained positive growth, due to Computer Services and Software.

In the second quarter of 2009, employment in ICT manufacturing was about 6-7% lower year-on-year, while in ICT services it kept still or increased slightly in most of the countries surveyed by the OECD, with Computer Services and Software performing better than Telecoms. The US have been particularly affected, with a 10% year-on-year decrease for ICT manufacturing employment in September 2009, and a 2% decrease for ICT services. China's employment performance in ICT equipment was also worse than its manufacturing average, while IT services

continued to be amongst the fastest growing activities.⁵⁰

2.3 R&D expenditure in the ICT sector in the EU

In the EU in 2007, gross expenditure in ICT R&D (ICT GERD) was €36.7 billion PPP, which represents 17% of the total R&D expenditure of €219.2 billion PPP. The bulk of ICT GERD consists of business expenditure in R&D (ICT BERD).⁵¹ In 2007, the ICT BERD totalled €34.1 billion PPP, or 93% of ICT GERD. The remaining 7%, i.e. €2.6 billion PPP, consist of government-funded ICT R&D executed outside of the private sector.⁵² Within the ICT sector, almost two thirds of BERD are accounted for by manufacturing and

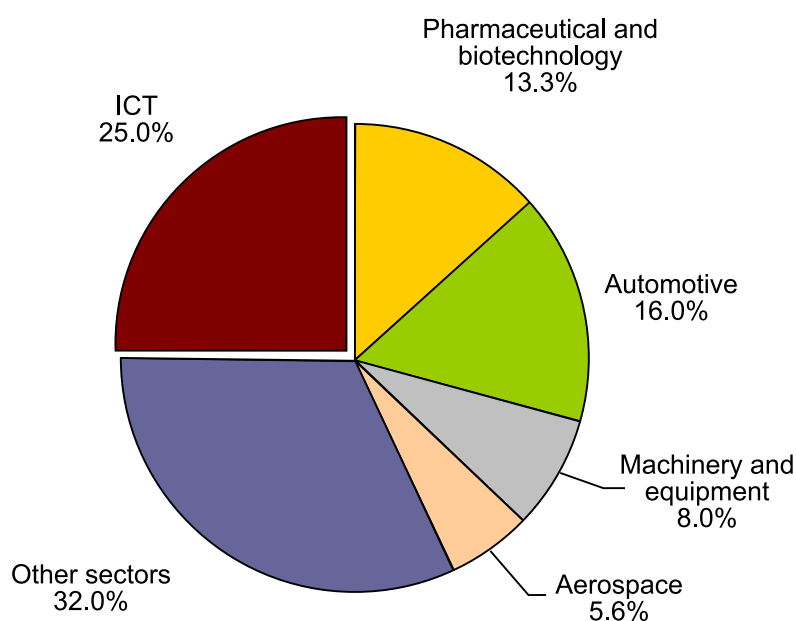
49 See, inter alia, the Quarterly *European Mobile Phone Tracker* by IDC.

50 For a more thorough analysis, see OECD (2009 b, c).

51 Data on BERD used this report are based on figures published by Eurostat and OECD as from December 2009 (Eurostat) and February 2010 (OECD).

52 See Section 3.3 on GERD.

■ Figure 2-5: Share of ICT in EU total BERD, Year 2007



Source: JRC-IPTS estimations based on Eurostat data.

one third by services industries. Services sectors are more prone to non-technological innovation than to R&D, on which this report is focused. It is worth highlighting that the ICT services stand out as a notable exception of innovation intensive services.⁵³ Furthermore, continuous progress in innovation statistics makes the role of the services in knowledge creation, on top of their recognised contribution to value added and jobs creation, increasingly clear.

The €34.1 billion PPP of ICT BERD represent a share of 25% of total BERD in the EU economy in 2007⁵⁴ (see Figure 2-5). 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 BERD share.

In addition, R&D expenditure in other economic sectors often concerns ICT as well, – i.e. in ‘embedded systems’. 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.⁵⁵ Therefore, 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 itself. Although a thorough literature review shows that nobody has quantified this embedded research yet,⁵⁶ according to OECD (2008b), a sizeable share of the R&D in non-ICT industries (equivalent of about one-quarter of ICT R&D or about 6% of the total economy BERD) leads to ICT products. This report focuses on the R&D expenditures in the ICT sector, but acknowledges

⁵³ For more analysis see EC(2010), http://ec.europa.eu/enterprise/policies/innovation/policy/innovation-services/index_en.htm

⁵⁴ 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.

⁵⁵ 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.

⁵⁶ The IPTS is currently running a pilot project on behalf of DG INFSO to study “embedded systems.”

the importance of ICT-related R&D performed in other sectors and especially the role of this type of R&D in defining the demand for ICT products from sectors such as Automotive or Machinery and Equipment.

2.4 R&D employment in the ICT sector in the EU

In 2007, the total number of R&D personnel in the ICT sector in the EU consisted of about 336,000 full time equivalent units (FTE), according to JRC-IPTS estimates,⁵⁷ out of which 216,000 were researchers. The EU ICT sector provided 27% of the total business employment in R&D and employed 32.4% of all researchers in the total economy (see Figure 2-6), confirming

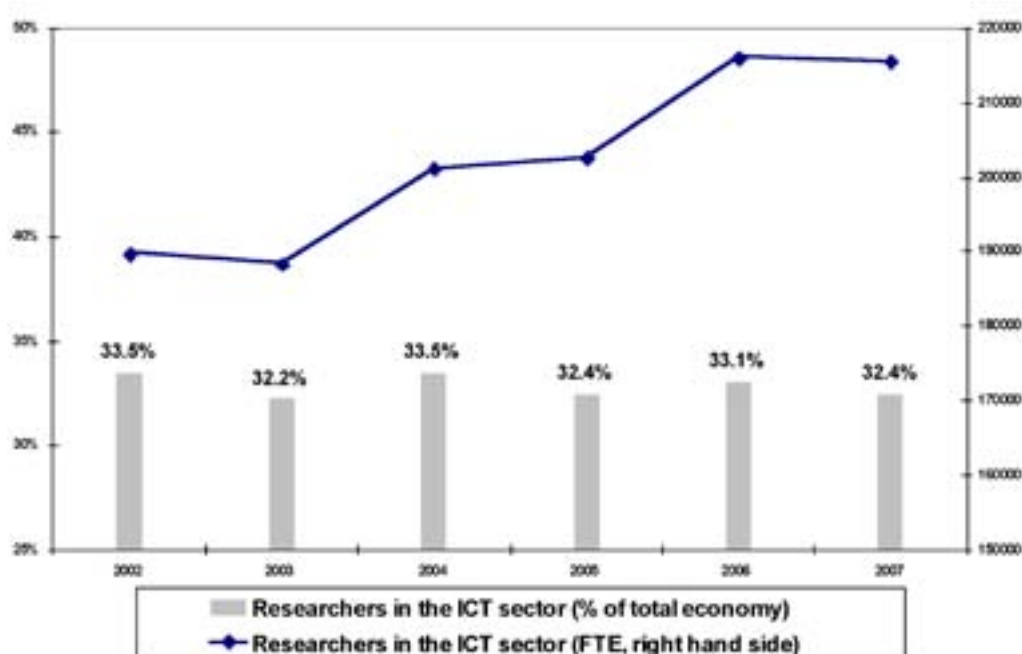
⁵⁷ R&D employment includes all personnel employed in R&D units; researchers are professionals engaged in the conception or creation of new knowledge, products processes, methods, and systems, and in the management of the projects concerned (OECD Frascati Manual (2002)). A precise definition and a concise description of the estimation methodology can be found in Annex 5.

also from the perspective of employment the knowledge intensity of this sector in relationship with the rest of the economy.

With respect to 2002, the number of researchers (FTE) in the ICT sector grew by almost 15%, at a rate similar to the rest of the economy. In 2007, for the rest of the economy, (except the ICT sector), there were 2.15 FTE researchers per 1,000 persons employed (down from 2.5 in 2002, due to a faster increase in total employment than in the number of researchers); the same ratio FTE researchers/employment stands at 34.2 for the ICT sector (up from 32.0 in 2002, due to a relative faster increase in the employment of researchers in this sector)

In other words, the intensity of R&D employment in the ICT sector was 15 times higher than the average for the rest of the economy, and the gap has been steadily increasing over the last years. A similar pattern can be observed with respect to ICT total R&D employment (including both researchers and support personnel). As

Figure 2-6: Researchers in the EU ICT sector: number (FTE) and % of total economy 2002-2007



Source: JRC-IPTS estimates based on Eurostat, OECD and national statistics.

pointed out above, these figures do not take into account ICT researchers employed outside the ICT sector.

2.5 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 17% of Gross Expenditure in R&D (GERD), 25% of overall Business Expenditure in R&D (BERD) and 32.4% 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 2007 from 2.2 to 3 million in Computer Services and Software and fell from 1.3 to 1.2 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 2002 and 2007, the number of researchers (FTE) in the ICT sector grew by about 15% to reach 216,000.

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

In the following sections, the report presents and analyses ICT GERD and its components for several countries, focusing on the EU and the US.

For the sake of clarity, the table below presents the most relevant figures used across these sections.

■ Table 3-1: GDP, GERD, and ICT GERD and its components (billion € PPP, EU and US, 2007)

2007 (Bill € PPP)	Gross Domestic Product	Total GERD	ICT GERD	ICT BERD	ICT GBAORD	ICT GOVERD
EU	12363.9	219.2	36.7	34.1	5.3	2.6
US	11703.8	310.2	87.8	83.8	10.4	4.0

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

Important note

Official statistical data is produced on an on-going basis by the relevant international organisations (Eurostat, OECD, US National Science Foundation (NSF)). It is normal to observe minor adjustments in the available data from one year to another. US R&D data has been nevertheless subject to a major revision by the NSF which was published by OECD in late 2009 (OECD 2009a). The revision follows the decision of the NSF to change its method for classifying industrial R&D, beginning with reference year 2004. The major impact of this revision is a 40% increase in the amount of R&D allocated to the manufacturing sector (i.e. in pharmaceuticals and ICT), mainly at the expense of the wholesale trade industries. Therefore R&D data for the US presented in this report is not directly comparable with the statistical data used in previous editions of the report. The current revision does not affect the overall trends observed before, or the relevance of our previous conclusions (see Annexes 3 and 6).

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)

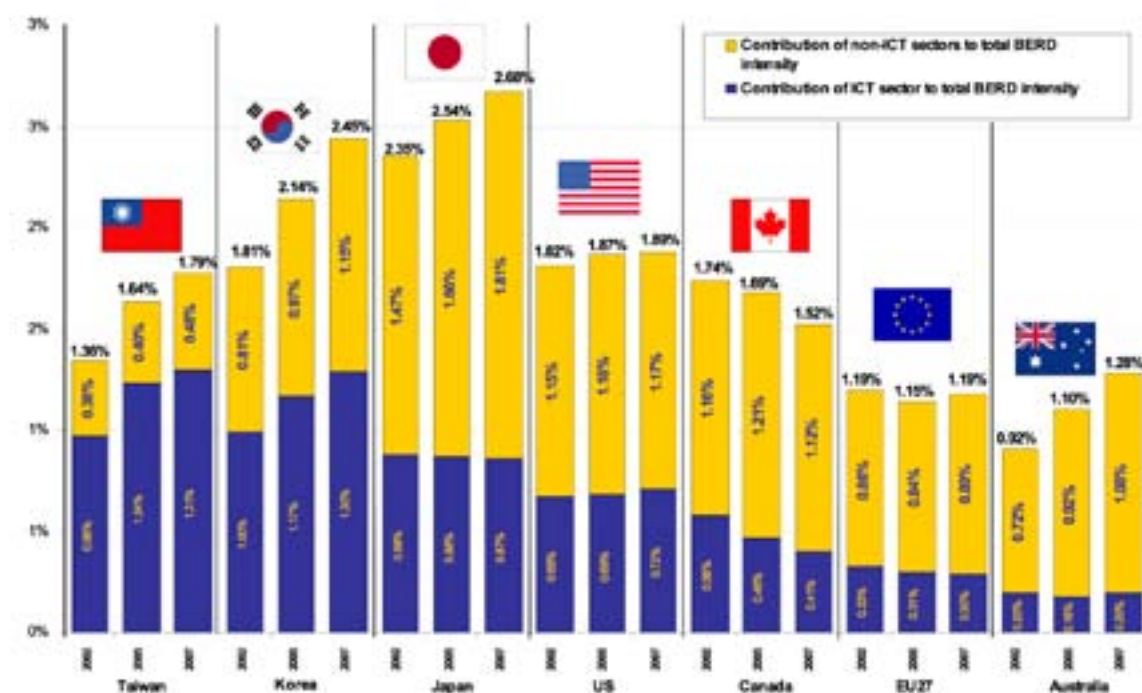
The ICT sector in the EU spent €36.6 billion on R&D in 2007 (BERD) - or €34.1 billion in PPP exchange rates.⁵⁸ This was far below the

US at €83.8 billion (in PPP exchange rates), but more than Japan (€31.1 billion), Korea (€13.8 billion), Taiwan (€7.6 billion), Canada (€3 billion) and Australia (€1.3 billion). The €36.6 billion spent in ICT research performed in the business sector amount to 0.30% of EU GDP (this is the *contribution of the ICT sector to total BERD intensity (BERD/GDP)* – see Figure 3-1), whilst the €83.8 billion PPP spent in the US correspond to 0.72% of the US GDP, a contribution more

58 PPP: Purchasing Power Parity or PPP 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. In this report, it allows adjustment

for differences in price levels, in order to compare various countries. The unit of account is an EU27 representative basket of goods and services expressed in euros.

Figure 3-1: Contribution of the ICT sector to total BERD intensity (BERD/GDP): 2002-2007



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

than 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 and Taiwan, where it is four times the EU level.

Notwithstanding the importance of the structural profile of each of these countries, which will be discussed later, it remains a reality that only Australia (of the countries compared above) has a lower level of ICT BERD intensity than the EU.

In 2007, total economy business spending on R&D in the EU amounted to 1.18% of GDP (total BERD intensity). Again, this is significantly less than the 1.89% of the US, and even further behind Taiwan, Japan and Korea. In fact, among the countries in this comparison, the EU ranks last in terms of total BERD as a share of GDP. Figure 3-1 ranks the EU and six comparison countries on the contribution of the ICT sector to total BERD intensity in 2007.

The ratio BERD/GDP saw very limited variation for the whole period 2002-2007, and so

did the ICT sector's respective ratios. If anything, a slight descending trend in the latter can be observed for the EU and a sustained increase for Korea and Taiwan. It is to be highlighted that the EU managed to maintain its level in ICT R&D investments despite two enlargements, when countries with low R&D intensities, especially in the business sector, joined the EU. Finally, it is worth mentioning that though investment in the ICT sector did not contract over the period (see comments on the ICT BERD growth in Section 4.2 and in particular the Figure 4-1), other areas of the economy grew.

One should also note that, in 2007, the ICT sector alone accounted for 60% of the total R&D intensity gap with the US, 38% of the gap with Japan, and a staggering 79% of the gap with Korea. Indeed, in Korea the ICT sector invests more in BERD relative to GDP (1.30% in 2007), than all sectors together in the EU (see Figure 3-1). When comparing the EU with Taiwan, the gap in ICT R&D actually surpasses 100% - Taiwan has a very strong specialisation in ICT with over 73% of

BERD performed in the ICT sectors (see more in next Section 3.1.2). Over the 2002-2007 period, the contribution of ICT to the total BERD gap between the EU and the main Asian competitors declined, mainly due to a faster increase in non-ICT sector BERD in these countries. When compared with the US instead, this contribution remains stable over the period.

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).⁵⁹ A relatively larger ICT sector is expected to 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 $\text{ICT BERD/GDP} = (\text{ICT VA/GDP}) * (\text{ICT BERD/ICT VA})$, gives the results shown in Table 3-2.

As the data in Table 3-2 indicates, part of the reason why the ICT sector contributes less to total economy BERD intensity in the EU than in competing countries 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 and Taiwan, where the ICT sector accounts for twice as much of the economy as it does in Europe. The difference with Japan and the US is sizeable, but much less significant. Australia's ICT sector is smaller than the EU's (relative to GDP).

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 US, 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 US 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 US firms in the different ICT sub-sectors.⁶⁰ Further analysis at ICT sub-sector and company levels can be found in Chapter 4 (Sections 4.4 and 4.5) and in Chapter 66 (Sections 6.3 and 6.4). The R&D intensity and the economic weight of the ICT sector in Japan, Korea and Taiwan are even bigger than they are in the US. Korea has the highest R&D intensity among the countries in our

Table 3-2: ICT BERD broken down into size and intensity factors, 2007

	ICT BERD in the economy (ICT BERD /GDP)	=	Size (ICT VA/GDP)	x	Intensity (ICT BERD/ICT VA)
Japan	0.87%		6.80%		12.8%
Taiwan	1.31%		10.61%		12.3%
US	0.72%		6.39%		11.2%
EU	0.30%		4.80%		6.2%
Australia	0.20%		3.60%		5.6%
Korea	1.30%		7.86%		16.5%

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

59 The different R&D intensity ratios used in the PREDICT report and their specific features are discussed in Annex 2.

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

sample, which is nearly three times as high as that of the EU. To a larger extent, the outstanding R&D intensity of the ICT sectors in the Asian countries is due to specialisation issues.

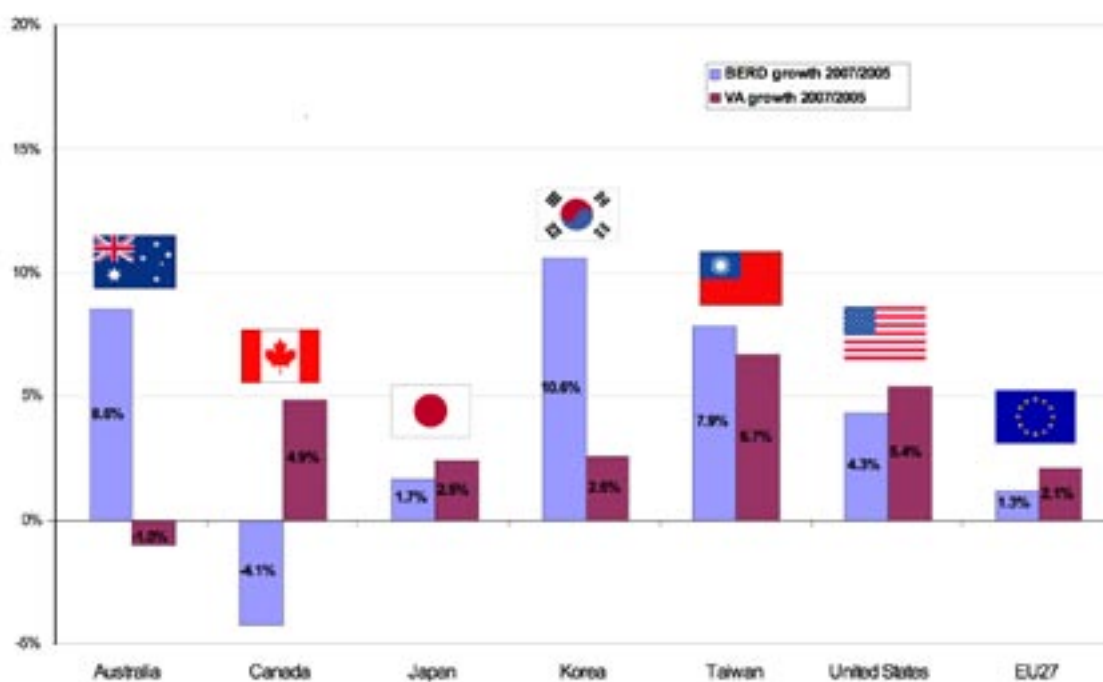
ICT manufacturing sectors, much more R&D intensive than services sectors, produce 3% of GDP in Japan, 5% in Korea and as much as 7% in Taiwan, as compared with only 1% in EU and 1.5% in US. Finally, the ICT sector's R&D intensity is lower in Australia than it is in the EU.

3.1.3 ICT BERD growth: international comparison

As was seen in Figure 3-1, the contribution of the ICT sector to total BERD intensity (ICT BERD/GDP) changed only a little during the period

2002-2007 in the Triad (the EU, the US and Japan) but kept driving general BERD growth in Korea and Taiwan. It is also interesting to consider how the dynamics of ICT expenditures relate to general inflation and to the development of the sector value added. For comparability reasons,⁶¹ Figure 3-2 shows average annual growth only for the period 2005-2007. The growth in the ICT BERD was, on average, above the growth of inflation for all the countries in the sample.⁶² For most of the countries, except Korea and Taiwan, 2003 was a year of negative real growth in ICT BERD, which started to pick-up in 2004. The highest growth rates were registered in 2006: almost 10% in the EU and Taiwan, 8% in the US and 15% in Korea. In 2007, growth rates for ICT BERD slowed substantially.

Figure 3-2: Average annual ICT BERD Growth, 2005-2007, percentage changes; data computed using GDP deflators



Source: JRC-IPTS estimates based on data from Eurostat, OECD and EU KLEMS.

⁶¹ Data for VA for Canada is not available before 2005; the year 2004 is an outlier for the US because of the revision of the BERD data.

⁶² Except Canada, for the 2002 – 2007 period.

R&D investments are generally procyclical, and their dynamics are related to the evolution of the ICT sector itself. After the dotcom crisis, value added rose above the inflation rate by 2004. The sector's highest growth over the entire 2002-2007 period was registered by Taiwan, with a staggering 7.5% average growth per year. Korea followed at a distance (3.8% p.a.), and Japan and the US at about 2.5% p.a. Europe had an average growth in ICT VA of only 1.2% p.a.⁶³ during that same period.

As shown in Figure 3-2, the differences between the growth of value added and the growth of ICT BERD over the last two years of the business cycle highlight a context in which the Triad countries (Japan, the US and the EU) slightly reduced the pace of their R&D investment. Other countries such as Taiwan, Korea, and Australia, were still making strong, sustained efforts to upgrade the knowledge intensity of their ICT production.

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

This section compares EU and US governments' total R&D financing and ICT R&D financing, respectively named total GBAORD⁶⁴ 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 sector⁶⁵ or industry⁶⁶ 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.

Nevertheless, ICT GBAORD data have 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 (NABS⁶⁷), does not allow direct calculation of the public funding of ICT R&D,⁶⁸ imposing the need to work with estimates. The underlying methodology is to estimate the share of ICT-related research in selected NABS categories. The result is an estimate of the total government funds for ICT R&D, irrespective of the industry in which this budget is spent.

The analysis of total GBAORD data (2007) shows that when expressed in comparable monetary terms (PPP), the US government spends annually €117.9 billion on R&D,⁶⁹ the EU spends €86.1 billion and Japan spends €24.3 billion.

In Europe, research financed from 'General University Funds' is in 2007 the main socio-economic objective at EU level (31.2% of the total), followed by 'Defence' (12.5%). Comparatively, funds from the 'Defence' budget cover only 4.5% of the total in Japan and almost 58% in the US. In Europe, 'Defence' represents major shares of total GBAORD in France (28.8%), the UK (23.4%), Sweden (16.4%) and Spain (13.1%).

63 To deflate the VA, we used the general GDP deflator, not sectoral prices, because the GDP deflator expresses better the purchasing power of the revenues of productive factors contributing to the creation of ICT goods and services.

64 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)

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

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

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

68 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 Annex 6.

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

As a share of total GBAORD, ICT GBAORD in the EU represents 6.1% of total government support to R&D activities, i.e. €5.3 billion of a total of €86.1 billion PPP, while the US government dedicates 8.8% of its total R&D spending to ICT, i.e. €10.4 billion PPP of a total of €117.9 billion PPP (Figure 3-3).⁷⁰

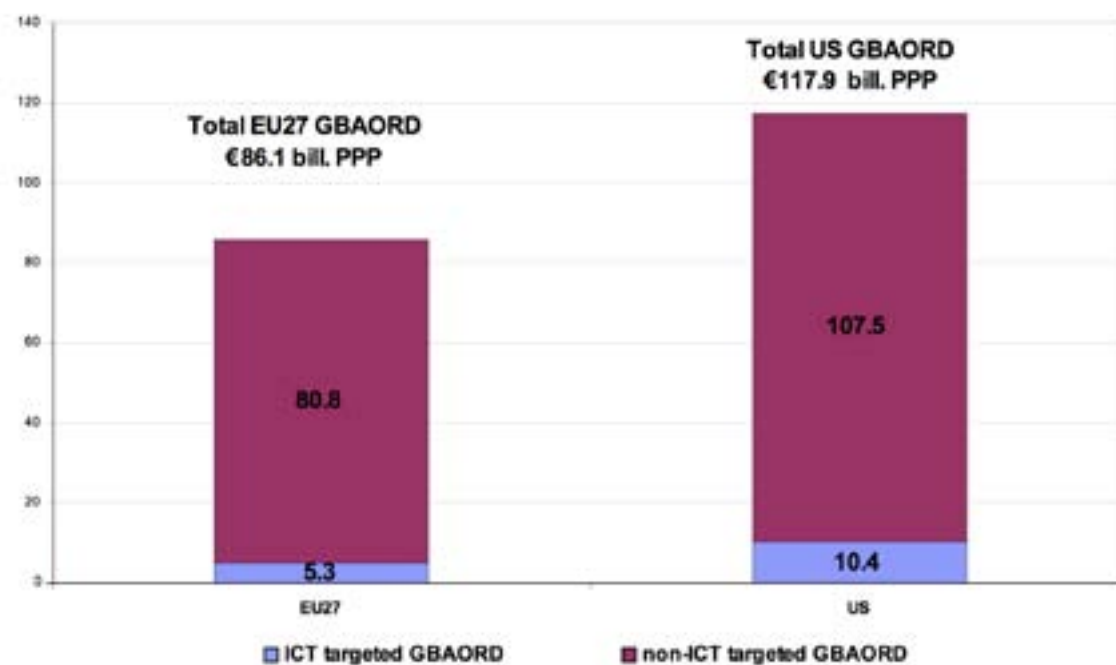
The following figures show GBAORD and ICT GBAORD, first in absolute value (PPP), and second, expressed as a percentage of GDP. This makes it possible to compare across countries while neutralising the effect of the size of the economies.

The EU figure of €86.1 billion of total GBAORD amounts to 0.71% of EU GDP, below the US GBAORD share of 1.01% of GDP, but slightly above Japan's share of 0.68% of GDP (not in the figure).

Finally, the €5.3 billion PPP spent by the EU governments on ICT research amount to 0.04% of EU GDP, whilst the €10.4 billion PPP spent by the US government correspond to 0.09% of US GDP.

To sum up, in 2007 public expenditures on R&D represented €117.9 billion (in PPP exchange rates) in the US against €86.1 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, the humanities. But EU public expenditures in R&D, for both the whole economy, and specifically for ICT R&D, lag behind US spending in absolute values and also as shares of GDP. The US invests more in R&D in proportion to its GDP and in real terms. The US also invests more in targeted ICT

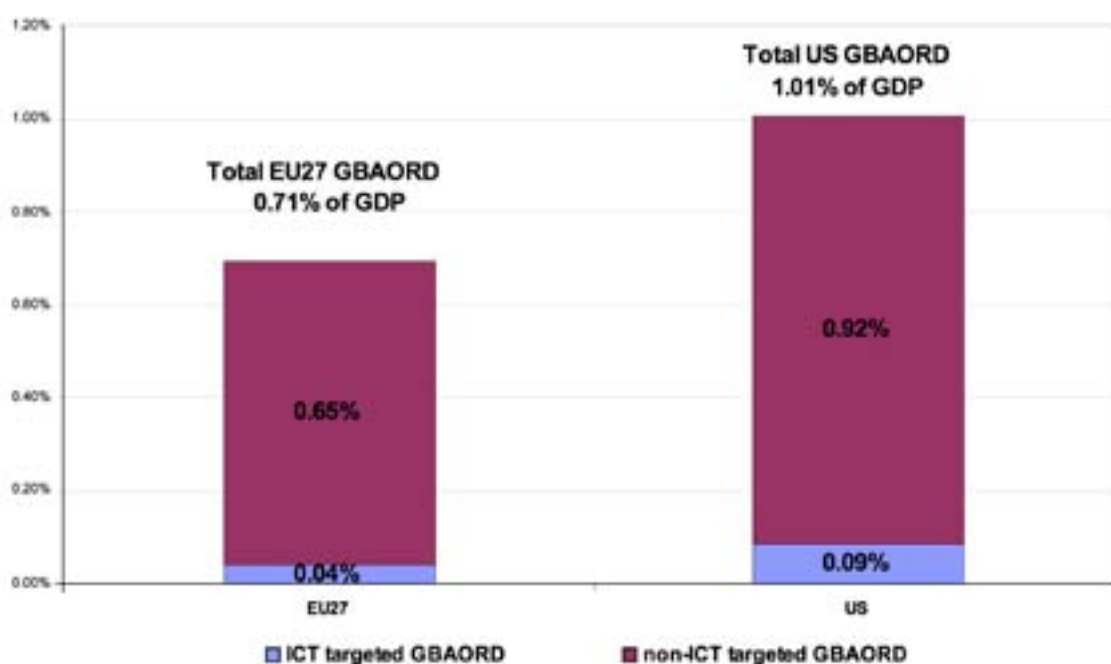
Figure 3-3: Public expenditures in R&D. EU and US (Billion Euros PPP), 2007



Source: Eurostat and JRC-IPTS calculations.

⁷⁰ All data and estimates will be available in the above mentioned forthcoming IPTS Technical Report on "Public Expenditures in ICT R&D".

Figure 3-4: Public expenditures in R&D as share of GDP. EU and US, 2007



Source: Eurostat and JRC-IPTS calculations.

R&D as a share of its overall public budget for R&D. In fact, in terms of shares of ICT GBAORD relative to GDP, the EU value is less than half that of the corresponding figure for the US (see Figure 3-4), while the total GBAORD as a share of GDP is only one third smaller. 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 or classified research in US defence expenditures for R&D⁷¹ 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 EU appears to be much larger than the one calculated strictly on the basis of available GBAORD data.

71 Unofficial sources in the US press, specialised in defence and homeland security, usually claim that such budgets to amount to billions of US\$, but quite evidently official sources are not available to confirm this, nor could they be expected to make such information available.

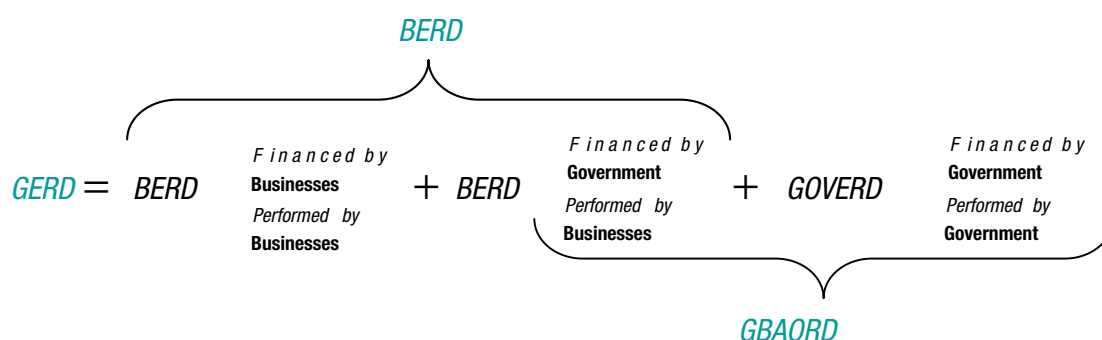
3.3 Contribution of the ICT sector R&D to the Barcelona target (ICT GERD)

The economic and social ambitions of the EU were set for the decade at the EU March 2000 Summit in Lisbon.⁷² 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 EU GDP, with business sector financing amounting to an average share of two thirds of this gross expenditure on R&D (GERD). The recently proposed EU2020 strategy maintains this objective high on the EU agenda.

GERD is defined as total expenditure on R&D performed within the EU territory during a given period. As shown in Figure 3-5, GERD can be

72 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".

■ Figure 3-5: Breakdown of GERD



broken down according to the sectors *financing* the R&D effort or to the sectors *performing* the R&D.⁷³ The main objective of this section is to estimate 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 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 sector⁷⁴ (GOVERD). Data for economy-wide GERD is available from dedicated surveys, but at industry level, estimations need to be made.

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

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.⁷⁵

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 US at sector level does not yet allow us to calculate directly, or in full detail, the ICT GERD data within a completely coherent methodological framework (see Annex 6). Nevertheless, the results presented here can shed some light on the total relative position of the EU vs. the US and provides interesting insights.

The EU spends €219.2 billion PPP on R&D (total GERD) while the US spends €310.2 billion (PPP). The results of our estimations show that out of this total R&D expenditure, the EU spends €36.7 billion on ICT GERD while the US spends €87.8 billion (PPP). Respectively, these ICT R&D figures correspond to 17% and 28% of total R&D expenditures in the EU and the US. These are important shares and underline the leading role of this domain in R&D, and even more so in the US.

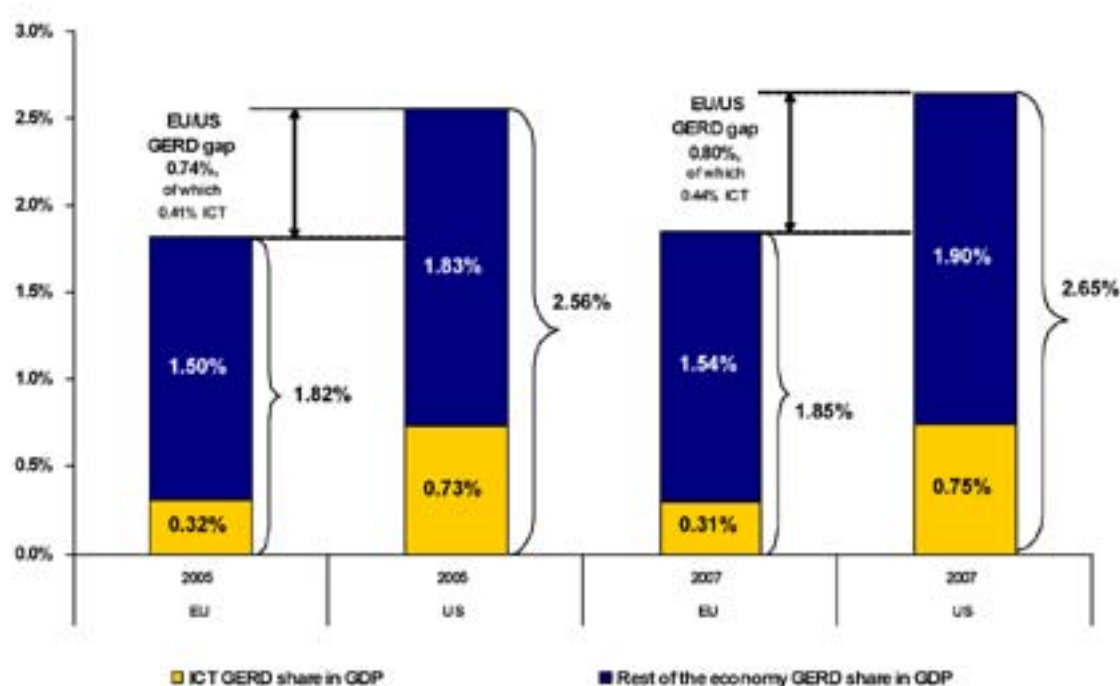
The gap between the EU and the US regarding total GERD amounts to €91 billion, while the ICT GERD gap amounts to some €50 billion. The ICT

⁷³ The economic sectors considered are: business enterprises, government, higher education, private non-profit and abroad.

⁷⁴ 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 origin. Research performed abroad is marginal and not taken into account in GERD. For further methodological details, see Annex 6.

⁷⁵ 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, EU and US, 2005 and 2007



Source: Eurostat and JRC-IPTS calculations.

sector is therefore responsible for more than half of the R&D gap between the US and the EU.

Indeed, throughout this report it is observed that figures on EU ICT R&D are consistently between 40% to 50% of the corresponding figures for US ICT R&D: this is true for ICT BERD, ICT GBAORD and, consequently ICT GERD. These ratios are also fairly constant over time.

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 US (in € billion PPP).

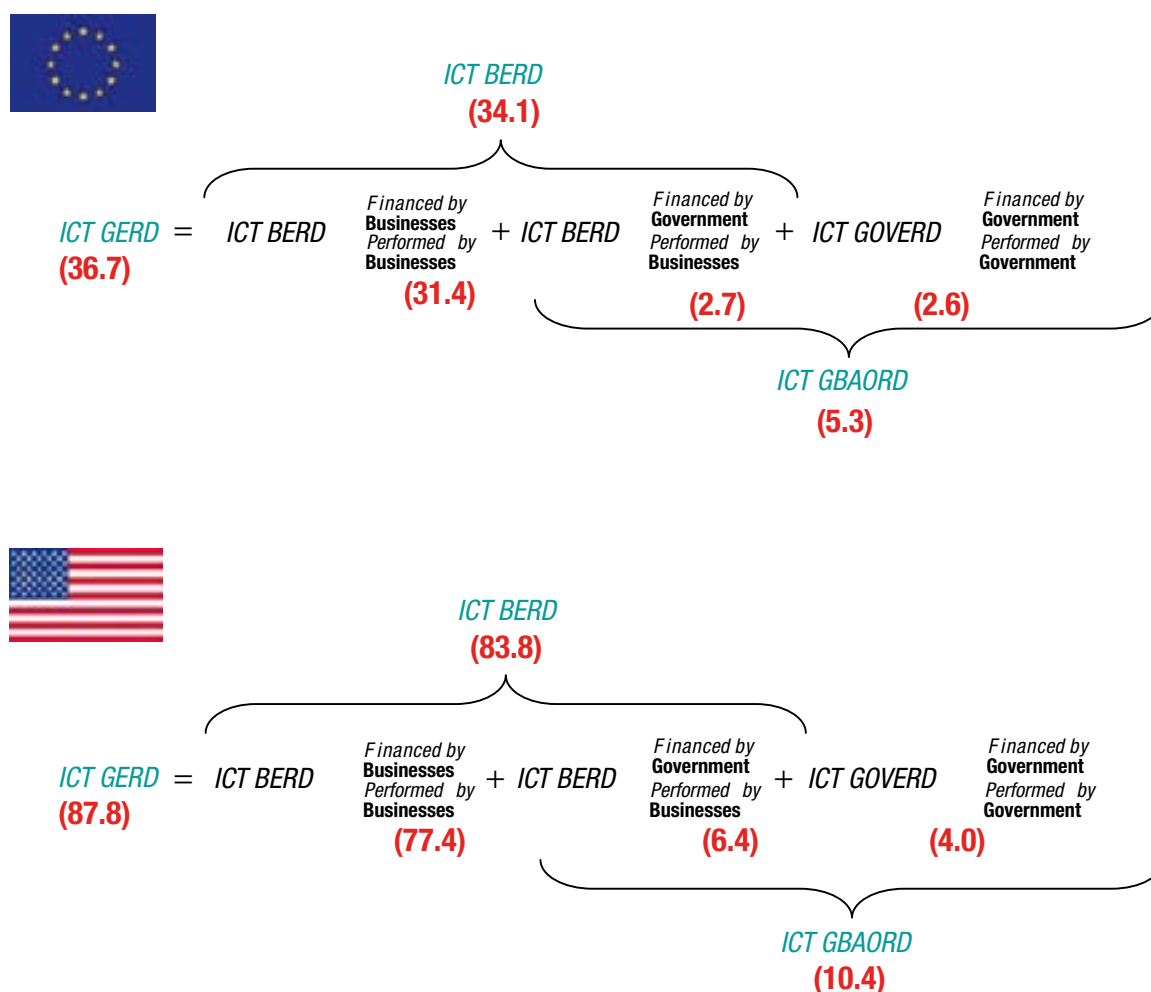
Several interesting observations can be made. In both the US and the EU, the *share of*

total ICT GERD performed by business sector (ICT BERD) is as high as 93% for EU and 95% for the US. This is different from the situation at the level of the total economy R&D, where the ratio BERD/GERD is 71% for the US and 64% for the EU.

On the financing side, structural similarities between the US and the EU also exist. In both cases, the *share of ICT BERD financed by the business sector* is over 85%, and significantly higher than the share of total R&D financed by the business sector and the private non-profit sectors at the level of the total economy (57% for the EU and 69% 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 to a larger extent 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.

Following the last statistical revision of US data, which increased ICT BERD by about 10%, the share of ICT BERD financed by the government

Figure 3-7: Breakdown of ICT GERD for EU and the US (Billion Euros PPP), 2007



became similar: 7.3% for both the EU and the US in 2007. It is interesting to observe that in contrast, at the level of the economy as a whole, the share of R&D financed by business in the US is over 10 percentage points higher than it is in the EU.

To sum up, achieving the EU Barcelona target of GERD at 3% of GDP is still rather a long way off, with the EU investing 1.85% of GDP (in 2005), and the US investing 2.65%. Here, the well known total R&D gap with the US amounts to a GERD/GDP difference of 0.80%. Figure 3-6 also shows the EU/US ICT GERD gap in relative terms: the US invests 0.75% of its GDP in the ICT sector R&D, while the EU invests only 0.31%. Hence, there is an ICT GERD intensity (ICT GERD/GDP) gap of 0.44%, or over half of the total gap of 0.80%.

The data analysed in this section on ICT GERD can be summarized as follows:

- The total US ICT GERD appears to be 2.5 times higher than the EU ICT GERD, measured either in absolute terms or relative to the size of the economy (GDP): the US invests €87.8 billion PPP or 0.75% of its GDP in ICT R&D, while the EU invests €36.7 billion PPP or 0.31% of its GDP.
- When compared with data published before, current results should not be interpreted as an increasing gap EU-US in terms of ICT GERD, as it is due to the revision of underlying data. It is very reasonable to assume nevertheless that current figures reflect better the size of the EU-US gap.

- The contribution of ICT sector to the total R&D intensity (GERD/GDP) gap between the US and the EU reads as follows: 0.44% out of the total R&D intensity gap (0.80%) between the US and the EU is due to the EU ICT (see Figure 3-6).

3.4 Conclusions

Regarding BERD, the EU ICT sector contributes a significant share of the gap in BERD intensity between the EU and its main global competitors. For example, in 2007 the ICT sector alone accounted for 60% of the total R&D intensity gap with the US, 38% of the gap with Japan, and a staggering 79% of the gap with Korea (see Figure 3-1). Indeed, in Korea the ICT sector invests more in BERD relative to GDP (1.30% in 2007) than all sectors together in the EU. 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.

Over the 2002-2007 period, in most of the countries except Canada, ICT BERD grew more than the economy-wide inflation. With the exception of Korea and Taiwan, for the rest of the countries, the years of the highest growth in ICT

BERD were 2005 and especially 2006. For all the countries in our sample, these rates slowed down significantly in 2007.

Total ICT GERD reflects the total R&D expenditures in the public and private ICT sector. It takes into account not only the ICT BERD, but also the R&D performed in the ICT public and higher-education sectors.

International comparison of ICT GERD highlights the role of ICT in explaining differences in national performance. Unfortunately, data shortages allow only tentative estimations of ICT GERD for the EU and the US only. The US ICT GERD is 2.5 times higher than the EU. The US invests 0.75% of its GDP as ICT GERD, while the EU invests only 0.31% of its GDP, hence over half the total R&D intensity gap between the US and the EU (0.80%) is due to the EU-US ICT R&D intensity gap (0.44%).

Further, the analysis of the ICT GERD and its decomposition may bring important insights to the debates over the role that the public financing of ICT R&D may have in complementing the efforts of the ICT business sector. So far, estimates of available data show that the structural behaviour of US and EU public sectors are not very different. However, further investigation is needed to assess the actual role and qualitative characteristics that the public investments in ICT R&D truly play in the EU as compared with the US.

■ 4 R&D in ICT by ICT sub-sector

4.1 Economic weight and BERD

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 64 and 72). As shown in Table 4-1, these are very different from each other in terms of relative size, BERD and competitive strength.

As can be seen from Table 4-1, 75% of value added is accounted for by the two service sectors (NACE 64, 72). These also have higher value added/turnover ratios, indicating a lesser dependence on intermediate inputs, especially in Computer Services and Software, which are most labour intensive (measured as the ratio number of employees/turnover).

Measurement Instruments also create a relatively high value added and are comparatively labour intensive, while the other two ICT manufacturing sub-sectors have comparatively lower value added/turnover ratios.

Not surprisingly, a large share of ICT BERD (almost 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.

■ Table 4-1: Turnover, employment, value added, BERD for the ICT sub-sectors, 2007⁷⁶

Sub-Sector (NACE)	Turnover		Employment		Value added		BERD	
	€ bn	(%)	thousands	(%)	€ bn	(%)	€ bn	(%)
30 IT Equipment	59.5	(4.3%)	159.9	(4.3 %)	13.8	(2.3%)	1.3	(3.6%)
32 IT Components, Telecom & Multimedia Equipment	225	(16.2%)	747.7	(16.2%)	52.5	(8.9%)	14.1	(38.5%)
33 Measurement Instruments	153	(11.1%)	1070	(11.1%)	64.3	(10.9%)	7.5	(20.8%)
64 Post and Telecom Services*	540	(38.9%)	3000	(38.9%)	245.5	(41.4%)	4.3	(11.7%)
72 Computer Services and Software	408	(29.5%)	3011.5	(29.5%)	216.6	(36.5%)	9.3	(25.4%)
Total ICT	1385.5	(100%)	7989.1	(100%)	592.7	(100%)	36.6	(100%)

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

Note: * Figure on BERD refer to the NACE class 642, Telecom Services only; all the rest of the figures on the row cover the whole NACE class 64, Post and Telecom Services

76 Table in nominal terms. The BERD total of €36.6 Billion (nominal) is equivalent to the €34.1 Billion (PPP) used in the earlier chapters for comparability reasons (see Section 3.1, footnote 58).

4.2 BERD growth: comparison by ICT sub-sector

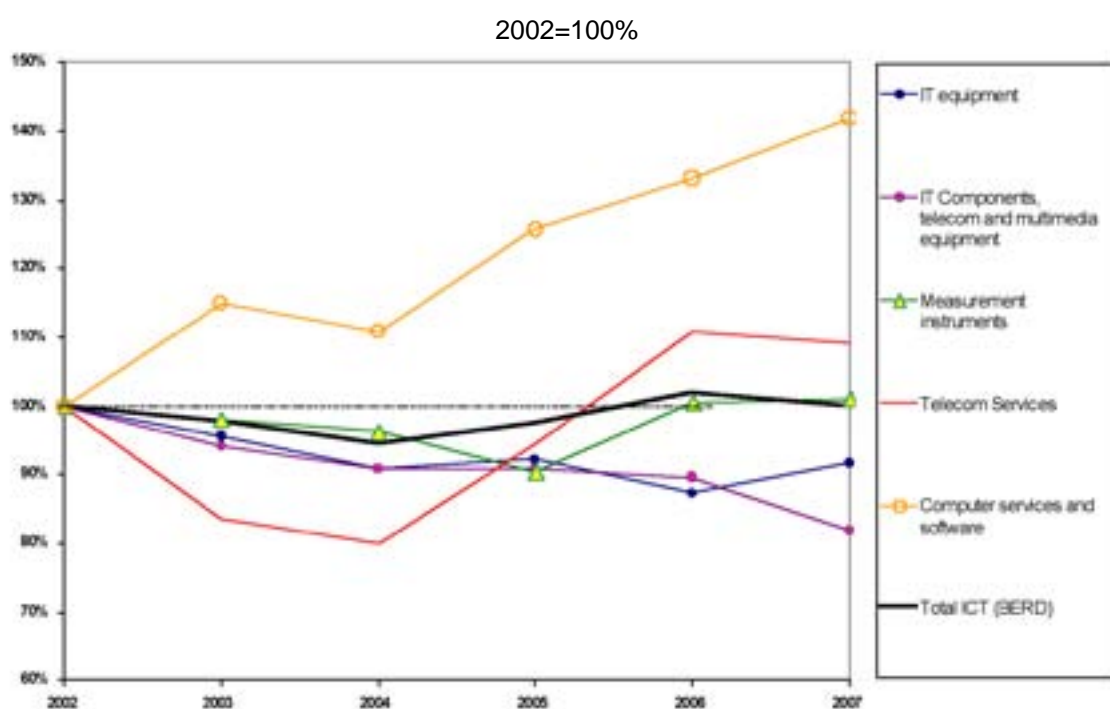
Analysing BERD growth by ICT sub-sector (see Figure 4-1) provides further evidence of the different trajectories of the different sub-sectors. However, what springs to mind first is that, although in real terms the total ICT BERD had very small fluctuations between 2002 and 2007 relative to general inflation, this is only the aggregated result of rather strong sectoral movements.

The only sector that saw sustained high rates of growth every year is the Computer Services and Software. As a result, it now has the second largest BERD in the ICT sector, as is shown in Table 4-1, but it is still far behind Components, Telecom and Multimedia Equipment, despite the pronounced decrease in the latter. In fact, Components, Telecom and Multimedia Equipment, is the subsector with the highest

share in the total BERD, and also the only sector for which a clear long-term trend towards decreasing BERD can be discerned. It is worth noticing that the R&D intensity of this sector declined over the 2002-2007 period, in parallel with an increase in the R&D intensity of the Telecom services. 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. However, the figures for BERD growth in Telecom Services should be treated with care, since the total is quite small and the number of players is very small. Hence adjustments, that may be part of normal business strategies at company level, may induce fluctuations in the total.

Finally, despite the slight growth in 2007, the IT Equipment sub-sector continues on a downward trend in R&D effort, from an already low base.

Figure 4-1: Real growth of ICT BERD in the EU, values deflated with the GDP deflator



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

4.3 ICT R&D employment by sub-sector

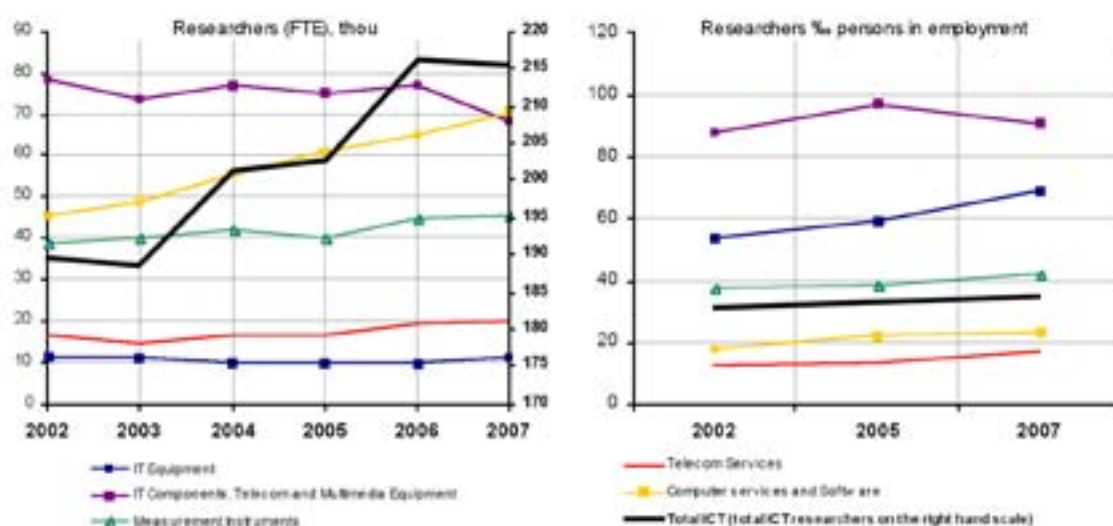
A similar picture of the ICT sub-sectors emerges when we look at numbers of researchers and researcher intensity⁷⁷ (Figure 4-2). In 2007, the 71,000 researchers in the Computer Services and Software sub-sector alone accounted for 33% of the 215,000 total ICT sector researchers. The Components, Telecom and Multimedia Equipment sub-sector is next, at almost 32% (68,000 researchers). 2007 is the first year when the number of researchers in the Computer Services and Software surpassed the number of researchers in the Components, Telecom and Multimedia Equipment sub-sector. In 2007, ICT manufacturing industries together employed 58% of the total number of ICT sector researchers, down from 62% in 2005.

From 2002 to 2005, the number of researchers fell by 14% in IT equipment with an even higher drop in the overall employment in this sub-sector. However, the number of

researcher began to grow again in 2006, and BERD expenditures in the sub-sector also increased. By 2007, there was basically the same number of researchers in the IT Equipment sector as in 2002 at a much lower total employment, but the growth of the BERD/researcher ratio was below the inflation rate. These developments in the IT sector were accompanied by an increase in the labour productivity, albeit concentrated in the 2002-2005 period. This suggests that the EU IT Equipment sector is currently increasing its innovation-based competitiveness after it went through an important restructuring phase following the dotcom crisis.

The research labour force expanded slightly faster than the rest of the ICT sector in Measurement Instruments and in Telecom Services, compensating for the important decline in 2007 in the Components, Telecom and Multimedia Equipment. Computer Services and Software were by far the most dynamic: the number of researchers grew by 25,000 FTE units which equals the aggregated growth for the whole ICT sector.

Figure 4-2: EU ICT sector researchers and R&D employment intensity by industry, 2002-2007



Source: JRC-IPTS estimates based on Eurostat, OECD and national statistics.

⁷⁷ Researcher intensity is defined as share of researchers' employment on total employment.

R&D employment research intensity,⁷⁸ is also very diverse among the ICT sub-sectors, ranging from over 90 (FTE) researchers per 1,000 employed in Telecom and Multimedia Equipment to about 18 per 1,000 in Telecom services. Services have, on average, much lower R&D employment intensity than manufacturing. From 2002 to 2007, this intensity grew in all ICT sub-sectors, by 3 to 7 percentage points according to the sector. The impressive 15 percentage points growth in IT Equipment is as explained above the result of different dynamics in the number of researchers vs the total employment.

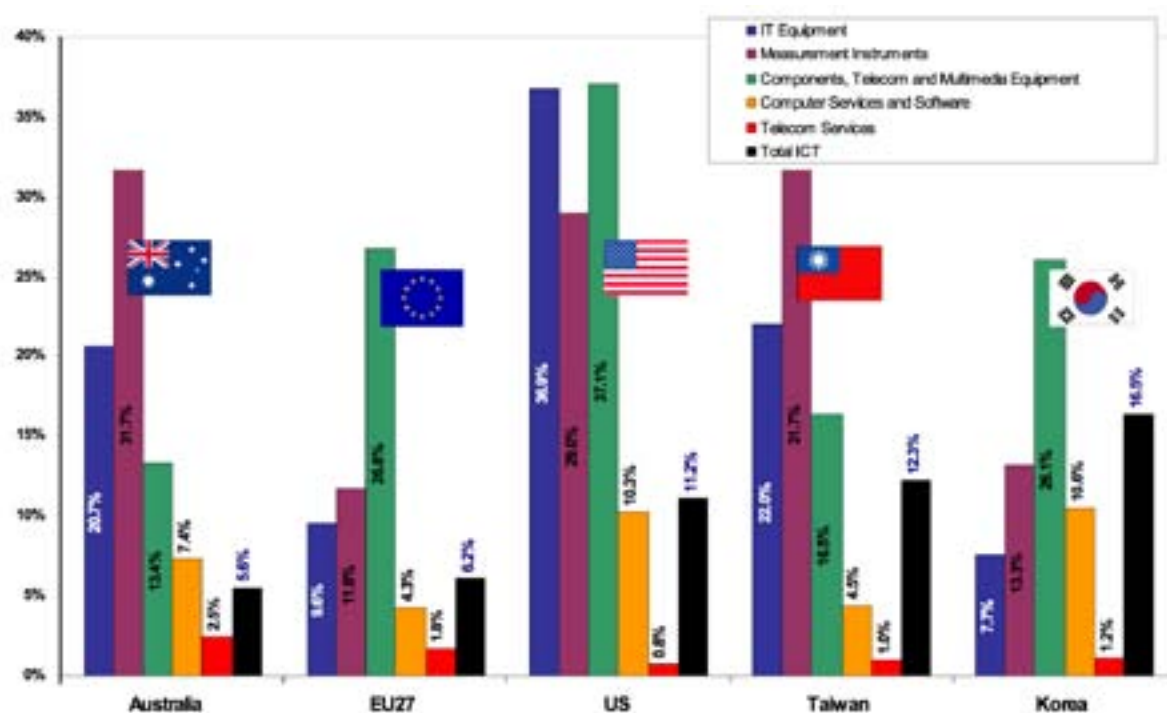
Finally, the share of researchers in total R&D personnel (both in FTE units), is overall about 10% higher in the ICT sector than the EU economy average. It has however been declining

since 2005. In 2007, this ratio was about 66% in Components, Telecom and Multimedia Equipment and in Telecom Services (declining by 4 percentage points since 2005), 64% in Measurement Instruments and in Computer Services and Software, and only 50% in IT Equipment. Intensity measured as total R&D personnel/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,⁷⁹ we will look first at the

Figure 4-3: ICT sub-sector R&D intensities (BERD/VA in 2007)



Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS.

⁷⁸ The different R&D intensity ratios used in this report and their specific features are discussed in Annex 2.

⁷⁹ The sectoral disaggregation presented in this chapter does not include data for Canada and Japan due to the unavailability of comparable data at this level of disaggregation.

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 US is reflected in all the sub-sectors, except the Telecom Services.

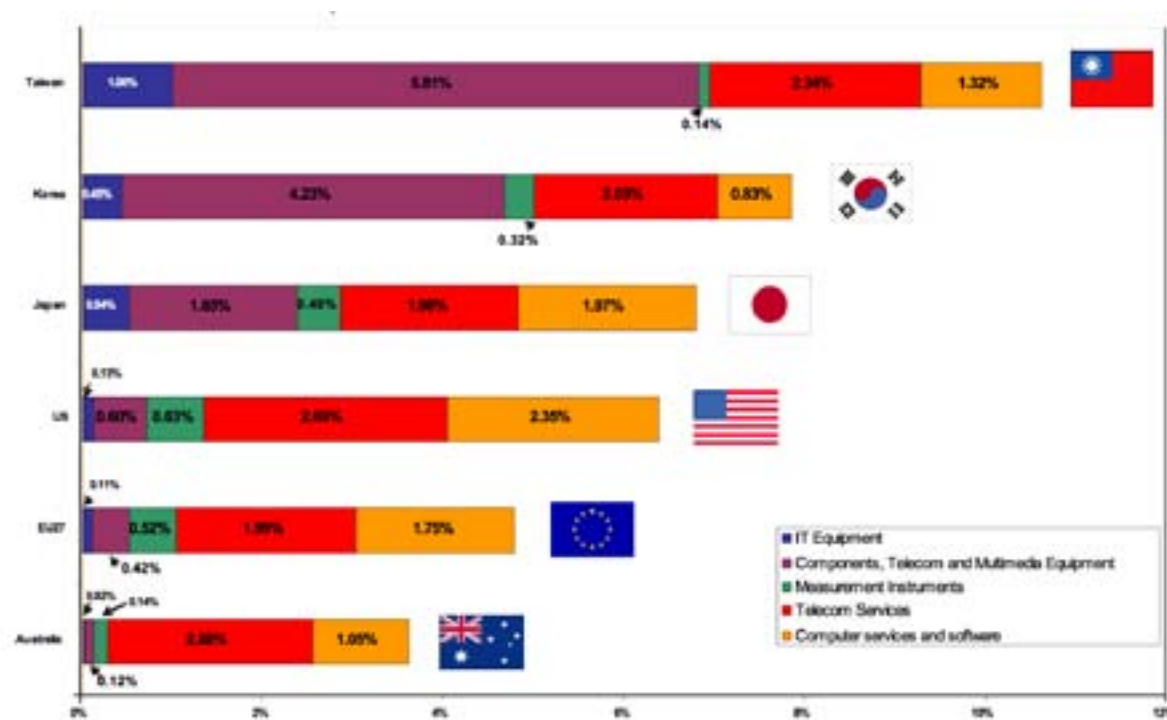
The comparative analysis of R&D intensities reveals different patterns of R&D specialisation. The EU's highest R&D intensity is in Components, Telecom and Multimedia Equipment, at the same value as Korea. The US ICT manufacturing sector seems the less specialised in terms of R&D investments/value added. From the countries in our sample, the fast growing Computer Services and Software sector is most R&D intensive in Korea and US.

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

As shown in Table 3-2, the relative economic weight of the ICT sector (ICT VA/GDP) is smaller

in the EU than in either Japan or the US. Taiwan and Korea have an even higher specialisation in ICT production. 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 US, but very different in Japan, Korea or Taiwan (see Figure 4-4). The Asian countries have a comparatively much bigger ICT manufacturing sector. Japan's IT Equipment sector relative to GDP is five times bigger than the EU's or the US's and has an R&D intensity almost double that of the US. It is three times bigger than the IT Equipment sector in the EU. An even clearer case of specialisation is Taiwan, which has the most R&D intensive ICT sector (in Components, Telecom and Media Equipment) with a share in GDP higher than the share of the entire ICT sector in EU. This preponderance of ICT manufacturing in the Asian countries explains to a large degree why their overall ICT R&D intensity is higher than that of the EU or the US as shown in the previous section (Figure 4-3), given the much higher R&D intensity of ICT manufacturing than of ICT services.

Figure 4-4: Economic weight of the ICT sub-sectors % of sub-sector's value added in GDP, 2007



Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS.

Contrary to the case of Japan, the higher R&D intensity of the ICT sector in the US 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 US than in the EU, but represents a fairly similar share of the overall ICT sector. The major role is played by the R&D intensities at sub-sectoral level.

The lower R&D intensity in the EU than in the US 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 6.3 and 6.4) but it will require further analysis.

4.6 Conclusions

In the ICT sector, services account for the lion's share of value added and employment. The majority of R&D spending takes place, however, in manufacturing, although most 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 than in the US in ICT and all its sub-sectors but the Measurement Instruments (where the R&D intensity of the corresponding EU sector is two thirds of the EU one) and Telecom Services, sector in which the EU shows an intensity double than the US. 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. Japan's higher overall ICT BERD intensity is due to its highly intensive ICT manufacturing sector, which in relative terms (as share in GDP), is twice as large as it is in the US and nearly three times the size of EU ICT manufacturing. As regards ICT services, however, the EU's BERD intensity is higher than Japan's in Computer Services and Software, but lower in Telecommunications.

Sustained growth in 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, in an international perspective it is worth noticing that even countries with a pronounced specialisation in Manufacturing as Taiwan and Korea have higher R&D intensity in the Computer and Services Sectors. To confirm the potential of EU in the Software area, further investigation is required, and needs to range from issues on industrial organisation in some of the non-EU countries to statistical procedures and coverage.

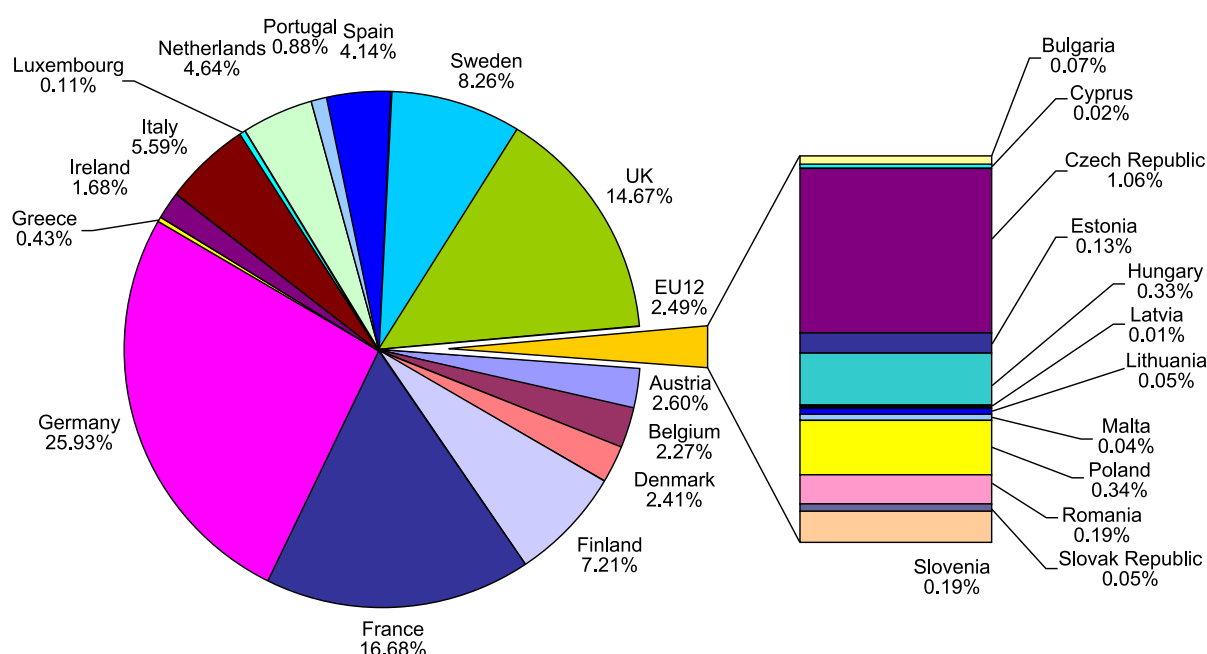
■ 5 R&D in the ICT sector by EU Member State (ICT BERD, ICT GBAORD)

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 (which together cover more than half of the total EU ICT BERD), followed by Sweden, Finland and Italy. When compared with the 2004-2005 period, the results for 2006-2007 show changes in national shares in ICT BERD than can be less attributed to price convergence than before. The shares in the EU of the three biggest investors taken together slightly increased between 2005 and 2007 (by 1%) but this is almost entirely due to a surge in R&D investment in the UK Telecom sector. In fact, both France and Germany decreased

in share, but this was due to faster growth in the rest of the EU, compared with their steady, but moderate, growth in the R&D of their ICT sectors. The significant increase of Spain's and Portugal's shares in total EU BERD is explained by the dynamics in specific sectors: the Computer Services and Software sub-sector in Spain (with a growth of over 50% in real terms in BERD), the Portuguese Telecom Services (almost 7-fold growth) and the Portuguese Computer Services sector (almost 4-fold growth). The decline in the share of Austrian ICT BERD in total is explained by a sudden drop of R&D investment in the Multimedia and Telecom Equipment sector. EU15 Member States⁸⁰ contributed 97.5% of the ICT business R&D expenditures and the new Member

■ Figure 5-1: Distribution of ICT BERD shares in EU countries % of total EU ICT BERD, 2007 (Total EU BERD = €34.1 Bill PPP)



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

⁸⁰ EU15 Member States refers to those countries that were already EU Member States before 1 May, 2004.

States (EU-12⁸¹) contributed only 2.49% (see Figure 5-1). With the exception of the Czech Republic, the bulk of increase of ICT sector R&D in the new Member States is also to be found in the services sectors, and particularly in Computer Services and Software. In fact, services sectors in the new Member States perform more than half of the total national ICT R&D, whereas in the EU15, the same share is below 40%. The smooth evolution of the EU as a whole hides quite interesting structural volatility which suggests relocation and specialisation and also catching up, especially in the services sectors.

As Figure 5-2 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 of the Member States. However, while Finland has an outstanding ICT BERD intensity, its non-ICT BERD intensity is close to the EU average. In 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. Country size also plays a role: smaller countries cannot broaden the range of their R&D investment very much as, quite often, their industries are also narrowly specialised.

Methodological note

This report uses purchasing-power parities (PPP) rather than current exchange rates, also for countries inside the Eurozone, in order to adjust for differences in price levels.⁸² 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, whilst Spain, Germany and the new Member States have higher shares.

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

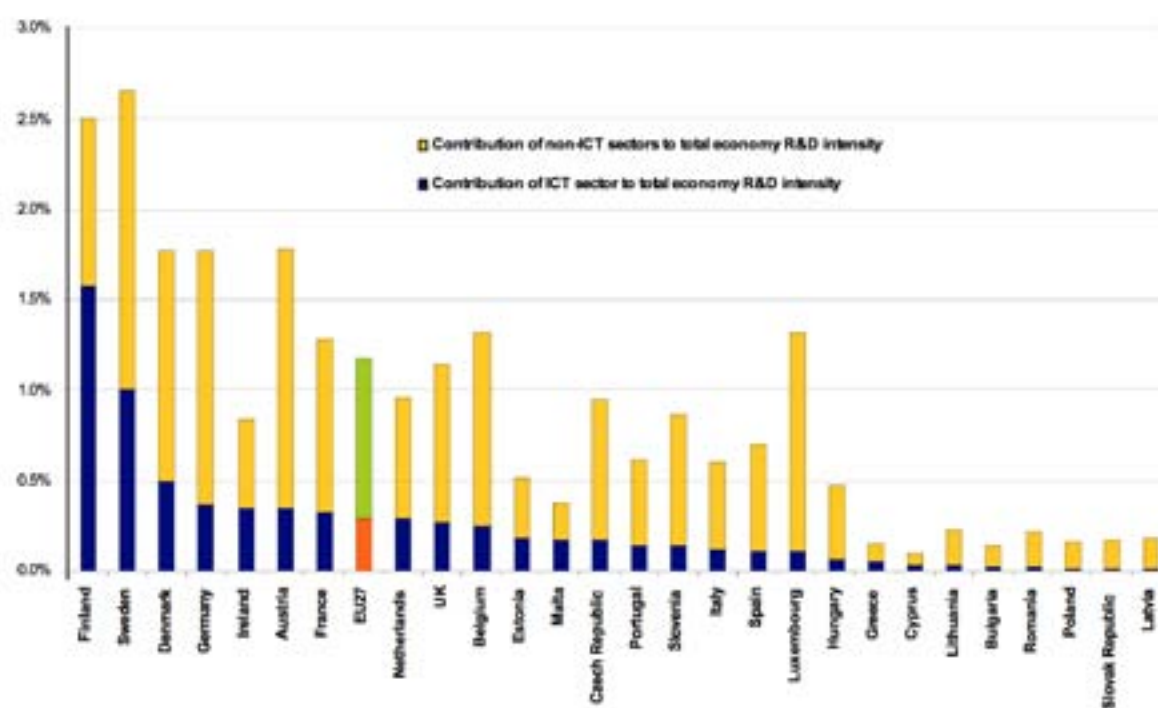
This section looks at the contribution of ICT BERD intensity (ICT BERD/GDP) to total economy BERD intensity (BERD/GDP), by EU Member States. The contribution of ICT BERD intensity (ICT BERD/GDP) to total BERD intensity (BERD/GDP) depends on the size of the ICT sector, which can be measured as ICT value 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.

The Nordic states are followed by most of North-western Europe. For these countries, 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 their economies. Most of the new Member States combine extremely low ICT BERD intensity with low BERD intensity for the rest of their economies. The overall picture is one of decreasing ICT BERD intensity contribution as one moves from North to South and from West to East. However, some of the recent EU Member States like Estonia, Malta, the Czech Republic and Slovenia are fast improving their performance. Compared with the situation in 2005, Romania also registered remarkable progress, due to an explosive increase in R&D investments of companies in the Computer Services and Software sector (almost 20-fold real growth between 2005 and 2007).

⁸¹ EU12 Member States refers to those countries that have become Member States of the EU since 1 May, 2004.

⁸² The JRC-IPTS 2008 Reference Report "Mapping R&D Investment 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.

Figure 5-2: Contribution of ICT sector to total BERD intensity (BERD/GDP) by Member State – EU, 2007



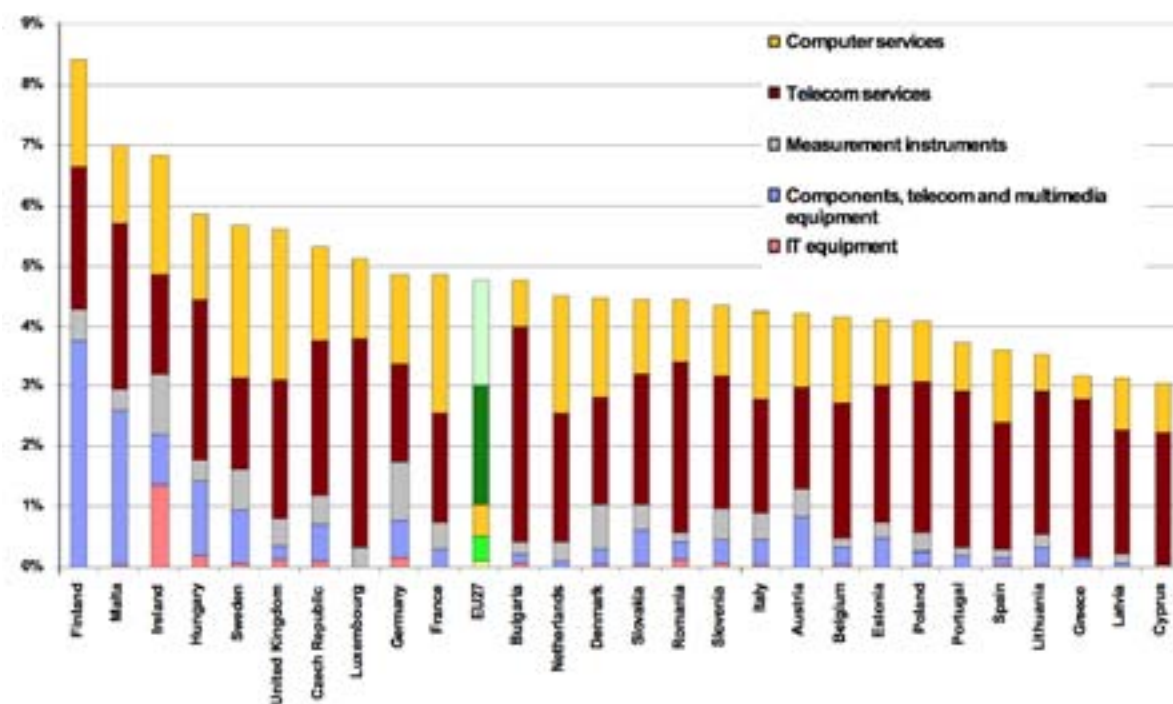
Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics.

5.3 The weight of the ICT sector in the economy by 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 5-3 shows that the ICT sector has the largest share of the economy in Finland and the lowest in Cyprus. Figure 5-3 also shows that the ICT sector in Finland is heavily 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. It also shows that Finland, Ireland and Malta are specialised in the production of ICT. On the other hand, in other small countries where the ICT sector makes a relatively higher contribution to the total BERD intensity as Estonia, Greece and Cyprus, this does not seem to be the case.

Specialisation does not necessarily mean high R&D intensity. 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. Austria reduced its R&D investment in Components, Telecom and Multimedia Equipment sector to half between 2005 and 2007 and consequently the contribution of its ICT sector to the total economy R&D intensity declined. Malta and Hungary do not show a strong ICT contribution to total BERD intensity, reflecting the orientation of their ICT sector towards assembly and manufacturing, rather than innovation.

Figure 5-3: Weight of the ICT sector in the economy of EU countries ICT VA / GDP, 2007



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

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

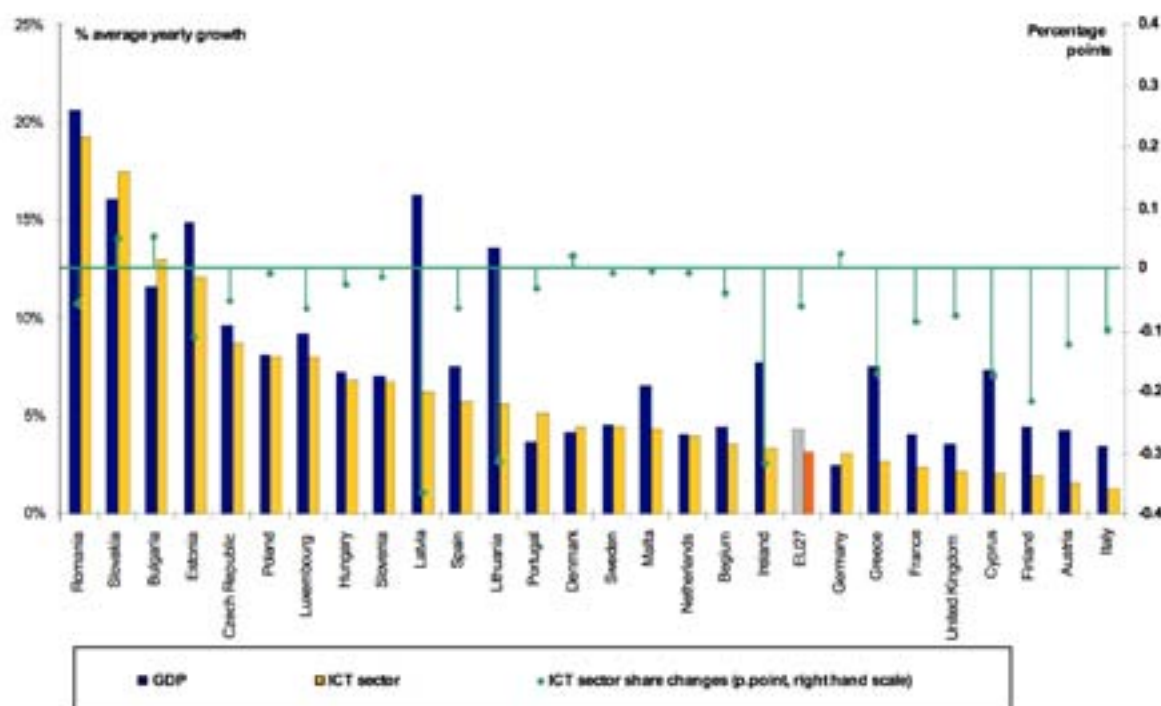
A discussion on changes in the weight of the ICT sector in national economies must obviously take into account the changes that occurred in the sizes of the national economies themselves. Figure 5-4 indicates that national trends regarding the dynamics of the ICT sector (also taking into account national economic performance dynamics) are very different in the 27 Member States.

From 2002 to 2007, two of the three countries most heavily specialised in ICT, Finland and Ireland (as seen in Figure 5-3), saw significant decreases in the shares of the ICT sector in their economies (as measured by ICT value added/GDP, in percentage points).⁸³

In Finland, Ireland, and also Lithuania, Latvia, Greece, Cyprus, Austria and Italy, this decrease stemmed from a faster growth in the rest of the economy. Most importantly, this remains true for the EU as a whole. In fact, very few Member States saw increases in ICT value added that were more rapid than in total GDP, with Germany and Denmark as the only important exceptions. Of the New Member States, only Slovakia and Bulgaria saw the growth of their ICT sectors outpace the growth of GDP. It is difficult to assess the true significance of this observation. It is reasonable to expect that the EU entered a phase of technology diffusion, when the rest of the sectors enjoy ICT-enabled growth. It might also be the case that the evolution of the EU is a part of wider international specialisation. The share of value added produced by the ICT sectors continues to grow in the US and remains rather stable in

⁸³ Finland resumed strong growth in 2006 and 2007 in Components, Multimedia and Telecom Equipment and owes the reversal of the trend observed in the previous report to Nokia's performance

Figure 5-4: Average yearly change in GDP, in the value added of the ICT sector and in the weight of the ICT sector in the economy of EU countries, 2007-2002



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

Note: data for Malta covers the period 2004-2007.

other technologically advanced countries such as Japan, Korea or Taiwan.⁸⁴

5.5 The BERD intensity of the ICT sector by Member State

Looking at the BERD intensity⁸⁵ of the ICT sector (ICT BERD/ICT value added) by Member State (Figure 5-5) provides a very similar picture (in terms of Member State ranking) as that of the contribution of ICT BERD intensity to total BERD intensity (shown in Figure 5-2). 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.

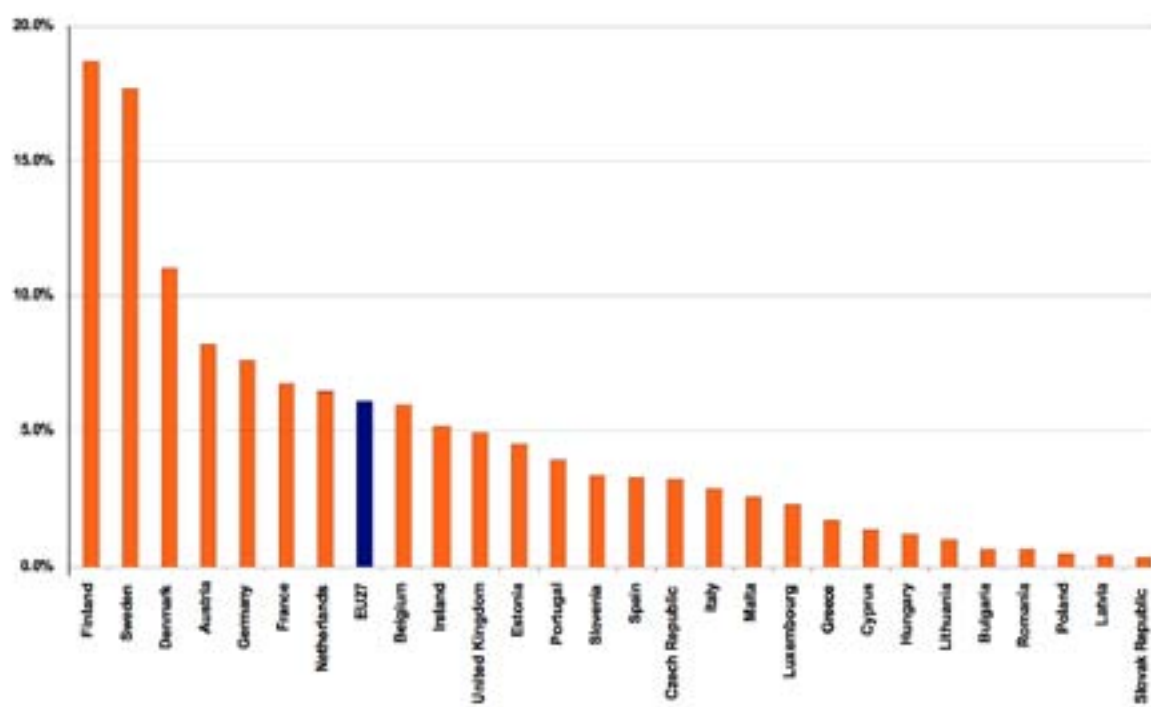
5.6 Change in the BERD intensity of the ICT sector by Member State

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? We will approach some of these issues further on.

⁸⁴ Additionally, the growth rates given in these paragraphs are computed in nominal prices to avoid problems induced by the choice of price indices for the ICT sector. The figures should not be used to benchmark countries unless they have a similar inflation level. Alternatively, relative prices would need to be used to assess the growth rates in order to draw further conclusions.

⁸⁵ The different R&D intensity ratios used in the PREDICT report and their specific features are discussed in Annex 2.

Figure 5-5: ICT BERD Intensities in EU countries, 2007 ICT BERD/ICT value added



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

From 2002 to 2007 for the EU as a whole, there is a slight decrease (yearly average of 0.08 percentage points) in ICT BERD intensity (ICT BERD as a share of ICT value added), as shown in graph A of Figure 5-6.

The majority of the new Member States concentrate their R&D efforts on the ICT sectors. They have very high rates of growth in BERD and specifically in ICT BERD, but because they started from extremely low levels (see Graph A), these rates reflect the catching-up phase, as well as their choice for specialisation in ICT. In most cases, the rise in the ICT BERD is accompanied by a rise in the R&D intensity.

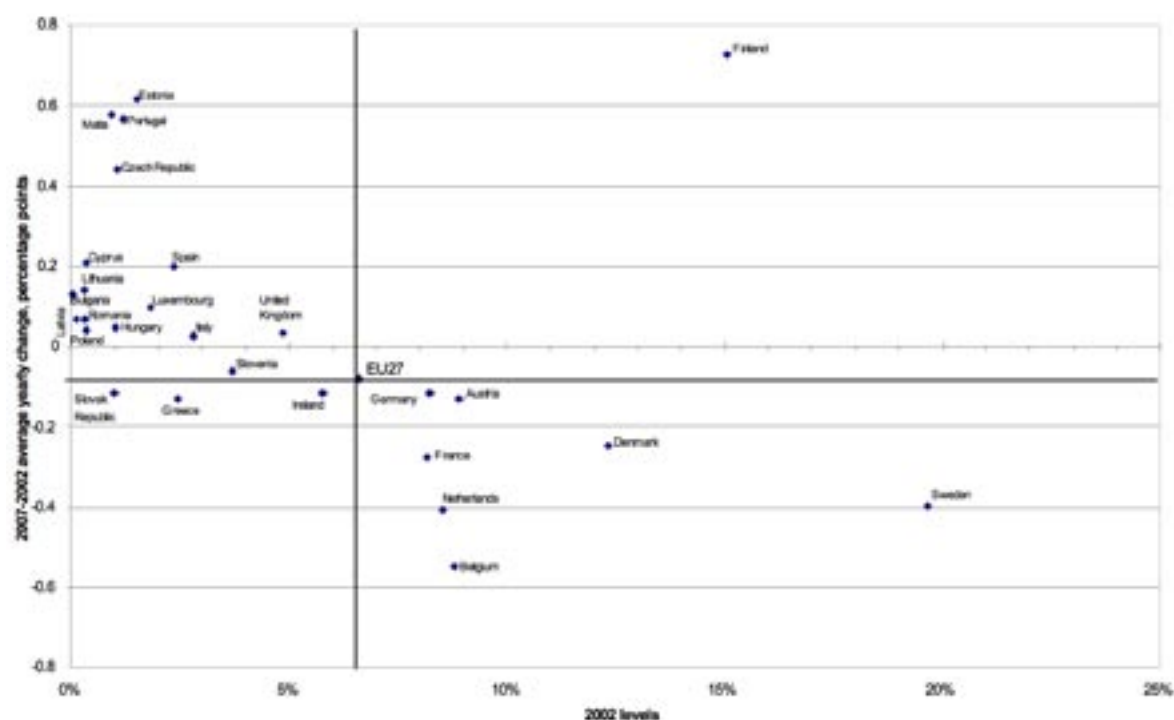
The dynamics of ICT R&D intensity for the two EU leaders, Finland and Sweden,

are extremely different, with an average yearly increase of ICT BERD intensity of 0.7 percentage points in Finland, and a decrease in Sweden of a yearly average of 0.4 percentage points. Nevertheless, they both have increasing shares of the ICT sector in total BERD, hence the best prospects for keeping the specialisation and EU leadership in ICT. In the case of Sweden, ICT BERD *intensity* dropped (see Graph A of Figure 5-6) in spite of an increase in BERD (Graph B), because of the important growth of the ICT sector (increased value added) outlined in Section 5.5. Similar dynamics happened in Germany.

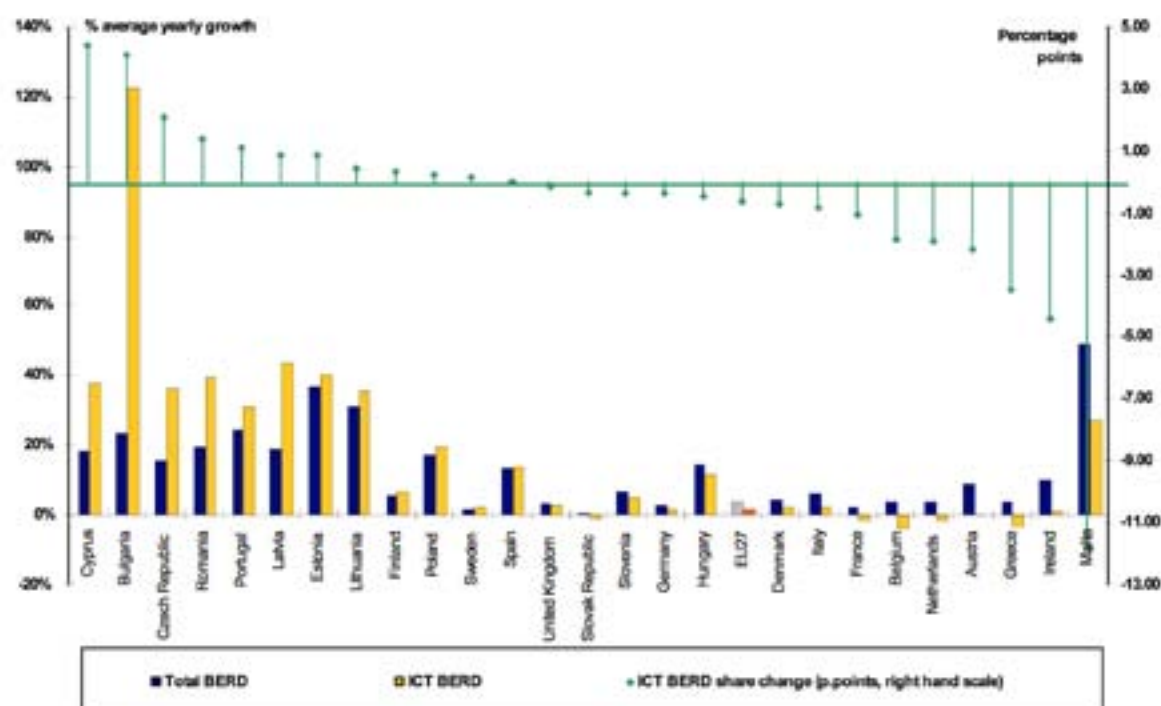
Many of the New Member States saw an increase in ICT BERD intensity (Graph A) with a rise in both ICT BERD and value added (Graph B).

Figure 5-6: The dynamics ICT BERD intensities in the EU:

A) ICT BERD as a % of ICT value added in 2002 and yearly average change 2007-2002, in percentage points



B) BERD percentage changes (total and ICT sector, left scale), and changes in the share of ICT sectors in total BERD (percentage points – right scale), 2007-2002



Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics. Percentage changes are computed from nominal values in Euros.

5.7 Government financing of ICT R&D by Member State

5.7.1 National shares in ICT GBAORD

ICT GBAORD measures government support to ICT-related R&D activities.⁸⁶ This section presents EU Member States data on ICT GBAORD or *government ICT R&D financing*: Government Budget Appropriations and Outlays in Research and Development related to ICT.

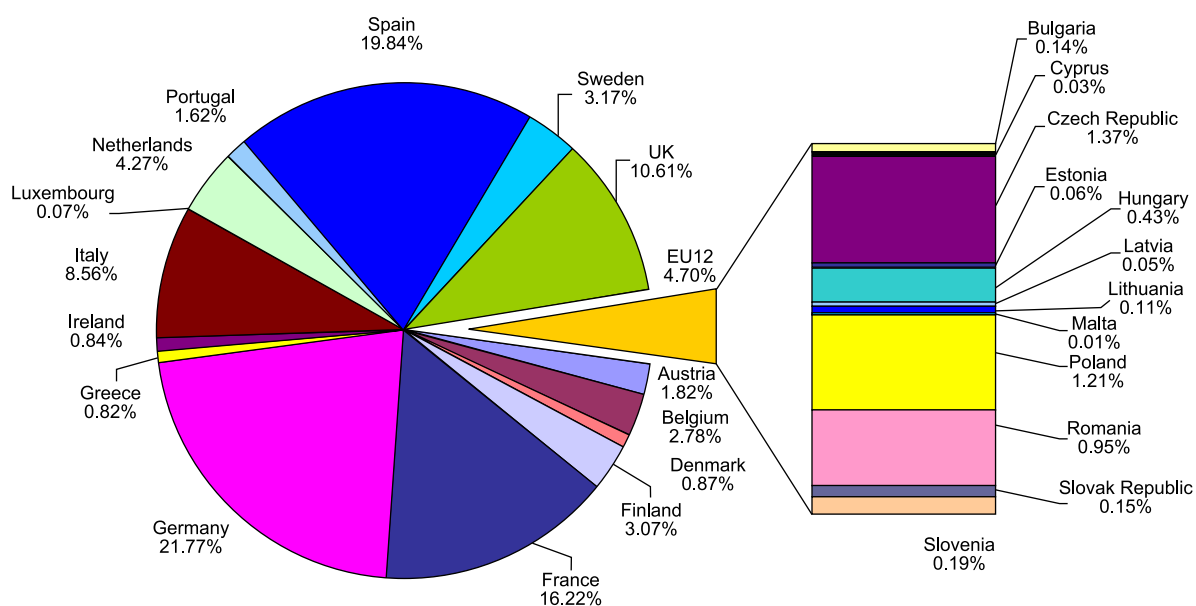
As observed in Section 5.1 with ICT BERD, ICT GBAORD in the EU is dominated by the largest economies (see Figure 5-7). Germany (21.8% of the total EU ICT GBAORD), Spain (19.8%) France

(15.2%), the UK (10.6%), and Italy (8.5%) represent together 76% of EU ICT GBAORD. As expected, governments invest in proportion to their financial capacities. The new Member States contribute only 4.7% of the total EU ICT GBAORD, which is a share far below their economic weight (almost 12% of the total EU GDP).

5.7.2 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 5-7: Distribution of ICT GBAORD in EU countries % of total EU ICT GBAORD, calculated on PPP values, 2007



Source: Eurostat and JRC-IPTS calculations.

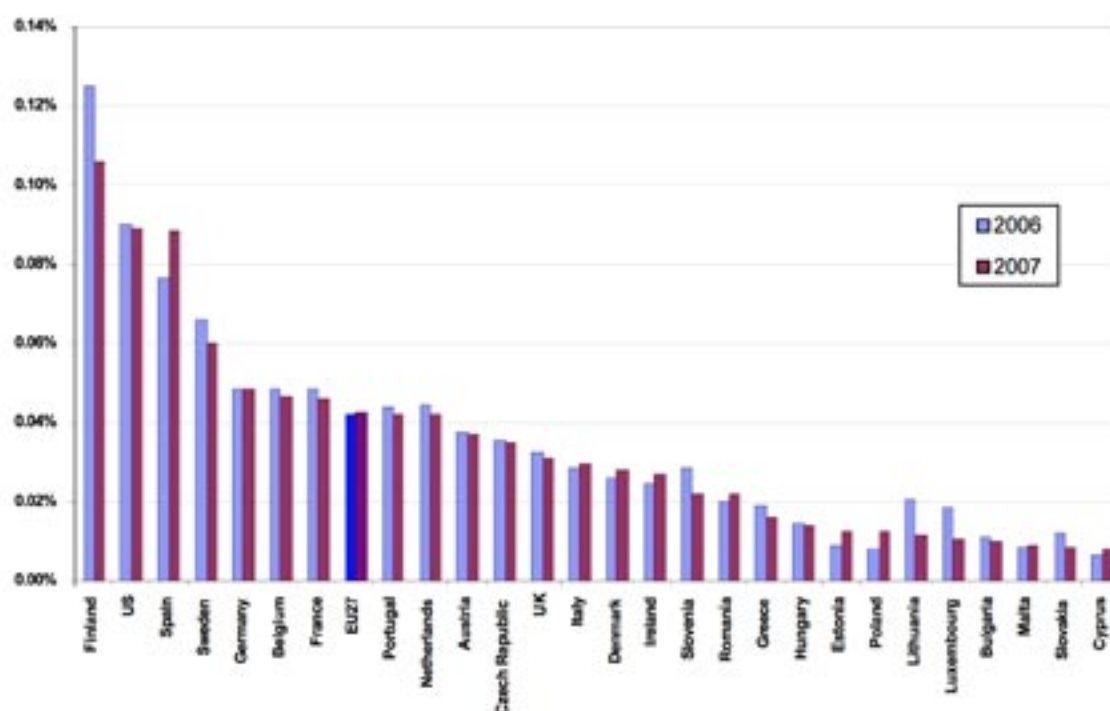
Notes: ICT GBAORD data at Member State level have to be taken with even more caution than those presented at EU level in Section 3.2, because ICT GBAORD is obtained by applying estimated national shares in selected categories of the NABS⁸⁷ classification.⁸⁸ It is also important to note that GBAORD figures 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.

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

88 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".

86 For more information about GBAORD definition and methodologies, see Annex 6.

Figure 5-8: Share of ICT GBAORD in GDP – EU Member States and the US, 2006 and 2007



Source: Eurostat and JRC-IPTS calculations.

Figure 5-8 shows data for 2006 and 2007. Please note that the data for 2005, 2006 and 2007 is not directly comparable due to changes in classifications and methodology at Eurostat and refinements of our estimation methodology as explained in the methodological annexes. The position of Spain, which surpassed Sweden and is close to being on a par with the US, is mainly due to a substantial increase in its total GBAORD expenditures from €8.4 billion (PPP) in 2005 to €12.7 billion (PPP) in 2007. For ICT, this result might appear surprising, especially when compared with the country's much more modest position in ICT BERD. This is a consequence of Spain's distribution of ICT funding and performance: the country holds some of the highest and increasing share of public support in Industrial and productive systems R&D and in defence R&D (including R&D of ICT related nature), but this research is most likely to be performed by various manufacturing sectors rather than by the ICT sector itself. The data shows that Finland remains nevertheless a clear

leader, with a share of publicly-financed ICT research in GDP well above other Member States and even above the US. Sweden comes third among the EU countries. This Nordic 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 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, Belgium and Portugal are worth highlighting. Though they are not among the high performers in terms of ICT BERD intensity, both their ICT GBAORD shares indicate public policies to support ICT R&D.

5.8 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 EU ICT BERD. Sweden, Finland and Italy add another 20%. 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 Value Added) 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 seven 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 2007 was very different within the groups of countries. For example, Finland's already high BERD intensity further increased whereas Sweden's decreased. 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, and in the last years of the interval, Romania and Bulgaria), others have experienced drops (Slovenia, Slovakia).

ICT GBAORD is distributed around Europe very similarly—but not exactly- to ICT BERD, with Italy, Spain and the New Member States as a whole showing higher shares of ICT GBAORD than ICT BERD, and Sweden, Finland and UK showing much lower shares in ICT GBAORD than in ICT BERD. The five largest EU economies represent 76% of EU ICT GBAORD, with Germany, France and the Spain contributing 57% of ICT GBAORD and UK and Italy adding another almost 20%. The Netherlands, Finland, Sweden, and Belgium add another 13%.

Finland, Spain and Sweden lead in ICT GBAORD intensity (ICT GBAORD/GDP). These three countries come first in a group of six Member States that are above the EU average. Finland is above the US in ICT GBAORD intensity, and in share of ICT GBAORD in total national GBAORD (at a level that is more than 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, ICT sector importance had the strongest decrease in the more specialised countries, including Finland, and Ireland. This indicates a possible reduction in structural disparities.

■ 6 ICT sector company R&D

The analysis in this chapter is based on company data from the *2008 EU industrial R&D Scoreboard*⁸⁹ (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 in 2007. According to JRC-IPTS estimates, the *Scoreboard* covers about 80% of all company R&D investments worldwide. From the *Scoreboard*, we have extracted the subset of ICT sector companies, which we refer to in this chapter as *ICT Scoreboard*.

This chapter is an update and extension of a similar chapter in the 2009 report on R&D in ICT in the EU (Turlea et al., 2009). It is mainly based on data from 2007, instead of 2006 as was the case in the 2009 report. In addition to the section analysing Computer Services and Software in the previous report, two further sections have been added, on IT Components and on Telecom Equipment. Company demographics (i.e., age of companies) of almost one hundred major R&D investing companies have also been researched and analysed.

The data presented in this chapter is not directly compatible with the data used in the previous chapters. The *Scoreboard* attributes each company's total R&D investment to the country in which the company has its registered headquarters and to one single sub-sector (ICB⁹⁰ and NACE class), regardless of whether some of the performed R&D concerns products or services related to sectors other than the one the company is attributed to. 'R&D investment' in the *Scoreboard* is the investment funded by the companies themselves, and is subject to

R&D accounting definitions. It excludes R&D carried out under contract for customers such as governments or other companies. Thus, *Scoreboard* R&D investment data is different from BERD data, which includes all expenditures related to R&D performed in the business sector in a given country, regardless of the source of funds or the location of registered headquarters. BERD data also typically allocates the BERD sectorally, either by 'principal activity' (the sector corresponding to the main activity of the company) or by 'product field' (the sector for which the R&D has been conducted).⁹¹

The analysis in this chapter covers R&D investments for the aggregate ICT sector and for its sub-sectors, over time (2004-2007), for the EU and three benchmark countries/regions (the US, Japan and the Rest of the World [RoW]). In some cases, the EU and RoW have been divided into their constituent countries.

In the *Scoreboard*, the EU and non-EU groups include companies with different volumes of R&D investment. In 2007, the R&D investment threshold for the EU group (of 1,000 companies) was about €4.3 million and that for the non-EU group (also of 1,000 companies) about €24 million. In order to compare EU and non-EU companies on a similar basis, it is preferable to use the same R&D investment threshold for both groups, and therefore to consider only EU companies with R&D investments above the non-EU threshold of €24 million. This comprises a group of 402 EU companies, representing approximately 95% of total R&D investment by

⁸⁹ European Commission (2008d).

⁹⁰ The Industry Classification Benchmark - see <http://www.icbenchmark.com/>

⁹¹ For a fuller methodological description, including a discussion of the differences between *Scoreboard* data and BERD data, see Annex 7. For a discussion on the issue of BERD versus company R&D data, see e.g. Azagra Caro & Grablovitz (2008), European Commission (2007) or Lindmark et al. (2008) and Annex 7.

the EU 1,000 group. Hence, there are 1,402 (ICT and non ICT) companies in total in the group of *Scoreboard* companies analysed in this chapter.

Finally, in order to create a comparable dataset of ICT top R&D investing companies (henceforth *ICT Scoreboard*) from the *Scoreboard*, only the companies belonging to the following NACE classes have been extracted: 30 (IT Equipment), 32.1 (IT Components), 32.2 (Telecom Equipment), 32.3 (Multimedia Equipment), 64.2 (Telecom Services) and 72 (Computer Services and Software). Extracting the relevant ICT companies generated a sub-set of 453 ICT companies out of the 1,402 companies mentioned above.

The population of these 453 *ICT Scoreboard* companies is distributed as indicated in Table 6-1. It can be seen that more than half (51%) the companies have headquarters in the US, while less than 18% are from the EU. It can also be noted that more than two thirds of the companies

are in the IT Components (42%) and Computer Services and Software sub-sectors (27%).

6.1 ICT sector company R&D investments in a global perspective

The ICT sector is clearly one of the key R&D investing sectors in the world economy. In 2007, to put the ICT figures in perspective, the 1,402 top global R&D investing companies spent €373 billion on R&D, of which €129 billion (or 35%) were invested by ICT sector companies.

6.1.1 Comparing company R&D investments of ICT and non-ICT sectors across world regions

Figure 6-1 compares the R&D investments of ICT and non-ICT sector companies for 2007, showing the size of those investments by EU, Japan, RoW (e.g., Korea, Taiwan, Australia and Canada) and US companies.

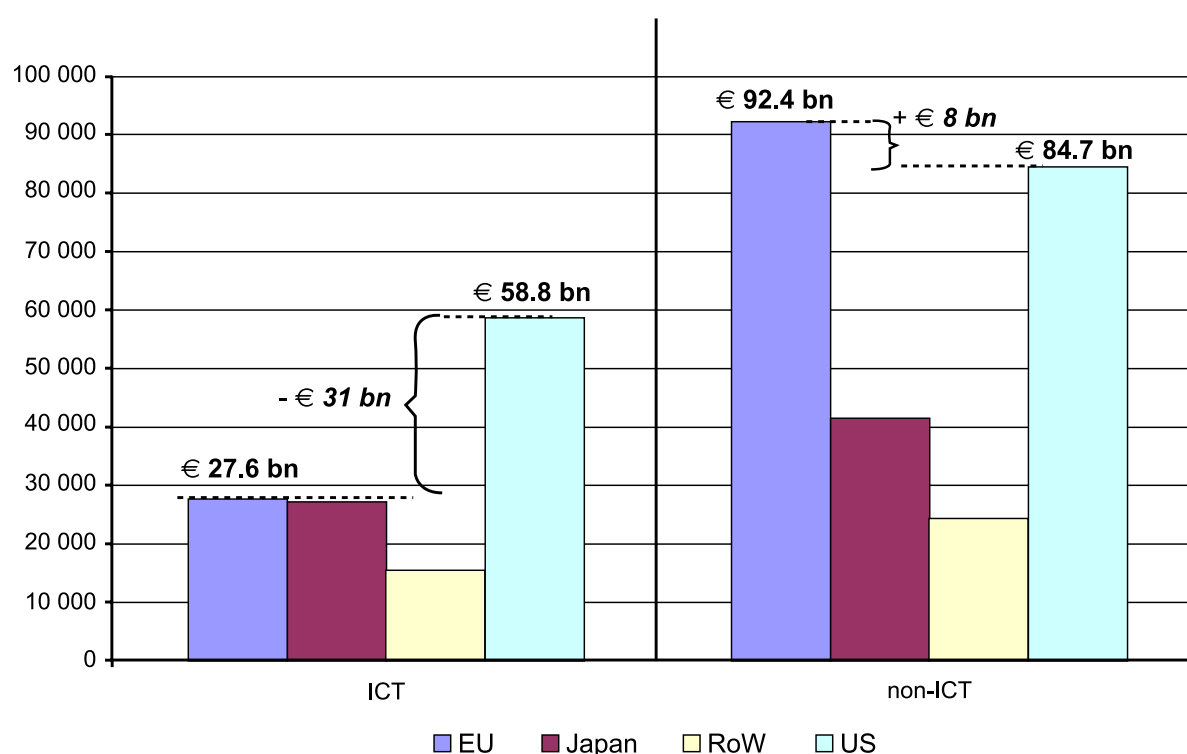
Table 6-1: Distribution of ICT Scoreboard companies by sectors and regions of registered headquarters (2007)

	NACE class	EU	Japan	RoW	US	Total
30	IT equipment	4	9	13	32	58
32.1	IT components	23	33	36	97	189
32.2	Telecom equipment	10	1	13	28	52
32.3	Multimedia equipment	3	5	3	1	12
33.2-33.3	Electronic measurement instruments	-	-	-	-	-
64.2	Telecom services	10	2	7	2	21
72	Computer services and software	31	2	17	71	121
Total ICT sector		81	52	89	231	453

Note: In the Scoreboard there are no companies classified in NACE 33.2-33.3 (Electronic Measurement Instruments – EMI). This is mainly due to the classification method of the Scoreboard. The Scoreboard assigns companies to primarily ICB-sectors, and only as a second step, it uses correspondence tables, to assign the companies also to NACE-sectors. Note also that EMI is a fragmented sector with many SMEs (Lindmark et al. 2009). Companies which the Scoreboard classified in other sectors appear to conduct a large share of the R&D investment in EMI. This poses an analytical problem in comparing with BERD data, which includes this sector. Even though EMI is clearly an important part of ICT-sector (as recognised in other parts of this report), it should also be noted that EMI will not be part of the new OECD definition of the ICT-sector (ISIC Rev.4).⁹²

92 This change resulted from a redefinition of the guiding principle of what is an ICT good, because it was increasingly difficult to justify the inclusion of this industry while excluding others that also use electronic processing to perform some detection, recording or control process. See further: <http://www.oecd.org/dataoecd/49/17/38217340.pdf>

Figure 6-1: R&D investments in the ICT sector and non-ICT sectors by EU, US, Japanese and RoW 'top R&D investing' companies, in millions of € (2007)



Note: Nominal terms, not adjusted for inflation.

As shown in Figure 6-1, the total R&D investments of EU ICT Scoreboard companies amounted to €27.6 billion in 2007, as compared to €92.4 billion for non-ICT Scoreboard companies. Comparatively, US ICT companies invested €58.8 billion, while their non-ICT counterparts invested €84.7 billion that same year. EU ICT firms, as a whole, invest far less in R&D than their US counterparts while EU non-ICT firms, as a whole, invest more than their US counterparts. In 2007, there was an ICT R&D differential with the US of €31 billion.⁹³ However, the figure also shows that EU non-ICT company investments are higher than in any other world region, including the US. In fact, EU non-ICT companies invested €8 billion more than their US counterparts in 2007.

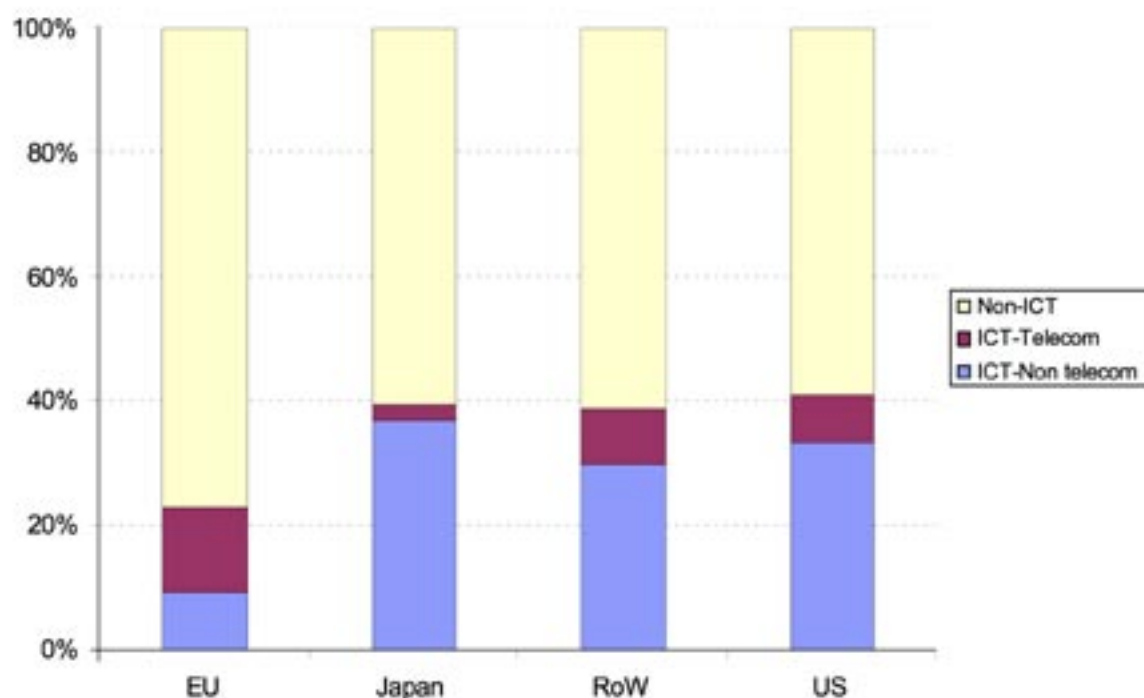
Figure 6-2 compares the shares of ICT and non-ICT R&D investments by the *Scoreboard* companies, in different world regions: the EU, Japan, the RoW (e.g. Korea, Taiwan, Australia and Canada) and the US, for 2007. It also distinguishes between Telecom⁹⁴ and non-Telecom R&D investment shares.

Figure 6-2 shows that, the ICT sector's R&D investment share (as a percentage of total R&D investment) is different when looking at EU companies and non-EU companies. ICT sector non-EU companies R&D investments account for about 40% of the total R&D investments. This share is only 23% for EU companies.

⁹³ Note that there are also non-ICT sectors where the EU is lagging behind the US, notably Pharmaceuticals and Biotechnology, where the company R&D differential was about € 15 billion in 2007. For more details, see the 2008 *Scoreboard* report (European Commission 2008d).

⁹⁴ Telecom Equipment and Telecom Services.

Figure 6-2: ICT-sector and non-ICT sector 'top R&D investing' company R&D Investment as a percentage of total R&D investment, per world region, in % (2007)



Note: ICT-Telecom includes Telecom Equipment and Telecom Services.

Comparatively also, ICT R&D investments by EU companies seem very concentrated in the telecom-related sub-sectors, i.e. in Telecom Equipment and Telecom Services taken together, and especially in Telecom Equipment. Almost 60% of total EU ICT companies R&D investments, that is €16.5 billion out of €27.6 billion, are invested by telecom companies. The corresponding rates in other regions are much lower. Hence, not only is the proportion of ICT R&D as part of total R&D lower for EU companies than for rest of the world, but the non-telecom part within the ICT investment is even lower.

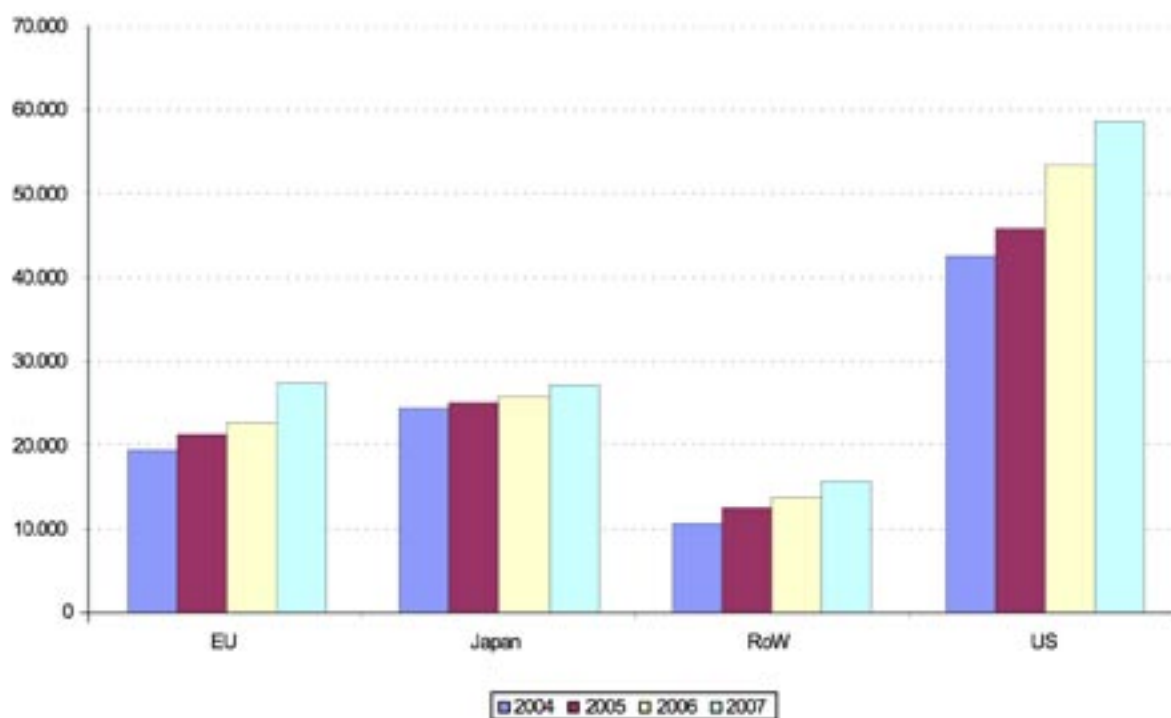
6.1.2 Trends in R&D investments of the overall ICT sector across world regions

Figure 6-3 shows the evolution of ICT sector R&D investments, in nominal terms, for ICT Scoreboard companies with headquarters in the above mentioned geographical regions between 2004 and 2007.⁹⁵

It can be seen that EU ICT firms' R&D investments increased year by year (Compound Annual Growth Rate from 2004 to 2007 – CAGR 12.2%) and that this growth accelerated in 2007, when it reached about a 20% growth rate. Companies from the other regions also

⁹⁵ 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 of a given year, e.g. 2007. Therefore, the set of top investors varies from one year to the next and those that invested most, say in 2007, are not necessarily the ones that invested most in 2005.

Figure 6-3: R&D investments in the ICT-sector by EU, Japanese, RoW and US ICT Scoreboard companies, in millions of € (2004-2007)



Note: Figures are nominal, i.e. not adjusted for inflation.

consistently increased ICT R&D investments during the same time period. While R&D growth in Japan appeared to be relatively modest (CAGR 3.7%), the RoW increased R&D investments relatively rapidly (CAGR 13.1%). The increases shown by US companies were very high (€16 billion in only three years, more than the other regions taken together), also with a high relative growth rate (11.3%).

In other words, the data suggest that the already dominant US companies further increased their R&D investment lead, although EU firms show a very positive trend, with seemingly higher relative growth rates (see further below).

6.2 Country-level perspective

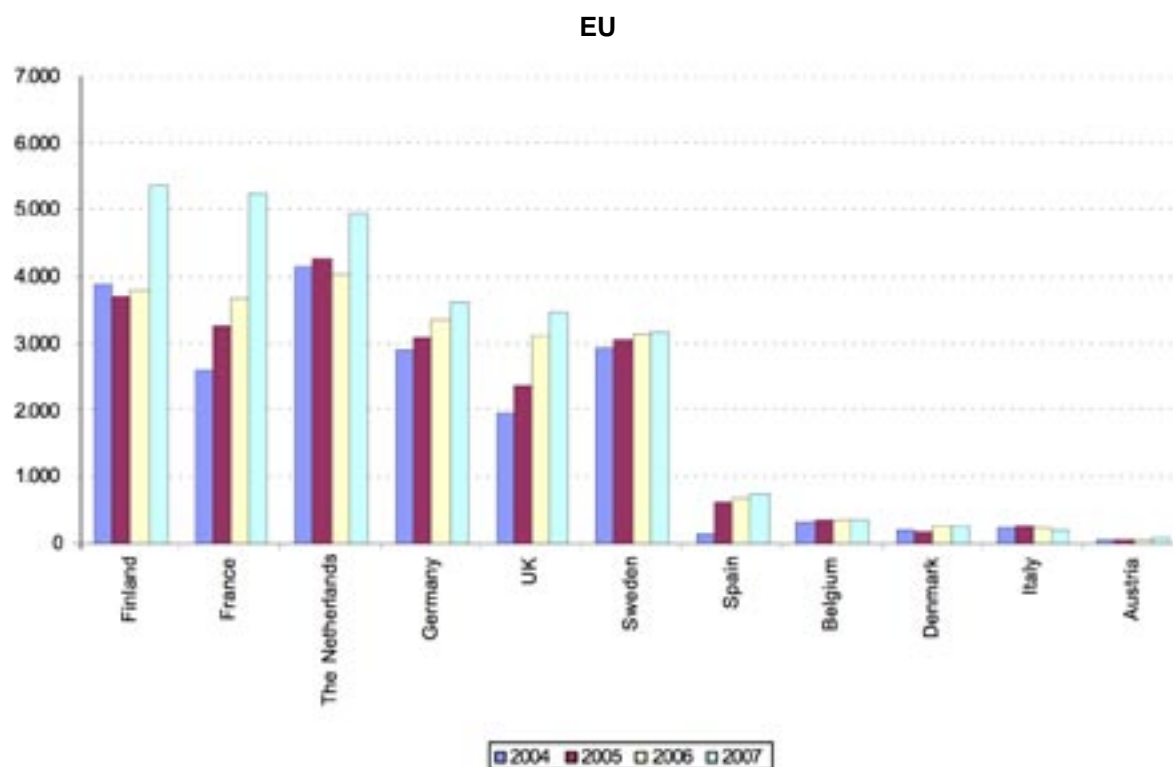
Figure 6-4 offers a breakdown of *ICT Scoreboard* companies R&D investment per country of registered headquarters in the EU and the RoW

(excluding the US and Japan) for the period 2004-2007. It shows an interesting indirect geographical mapping of the major ICT companies.

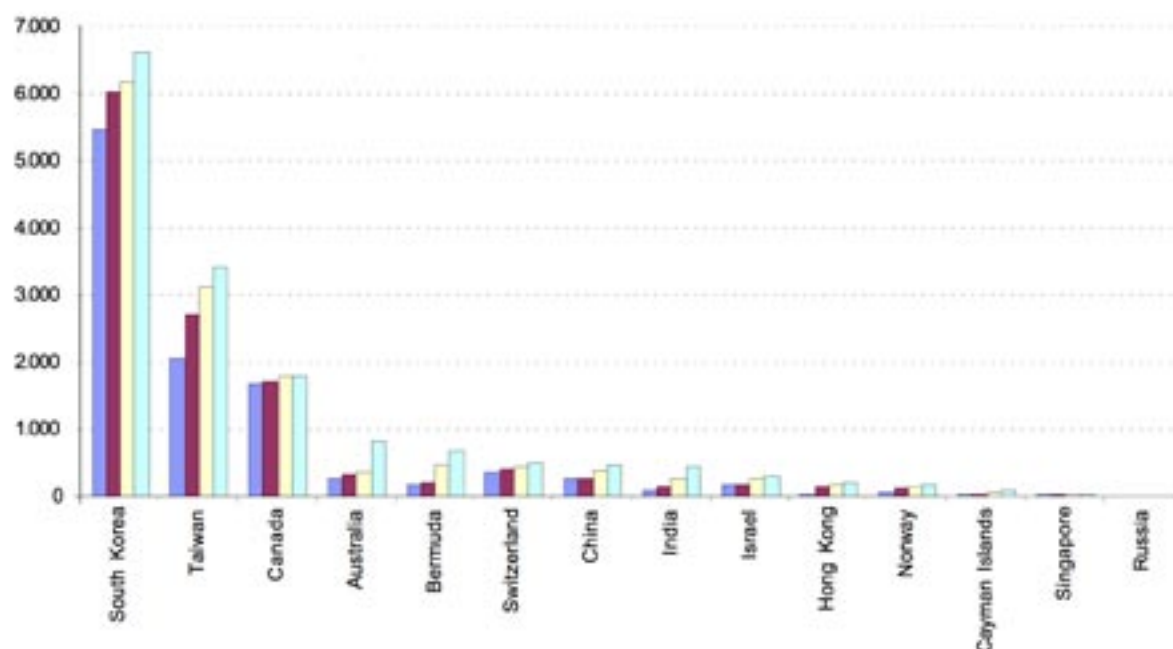
Breaking down R&D figures for the EU and the RoW to country level, we find that the major R&D investments (in the ICT sector) outside the US and Japan are made by companies registered in Finland, France, the Netherlands, Germany, the UK and Sweden within the EU, and in South Korea, Taiwan and Canada outside the EU. In terms of absolute growth between 2004 and 2007, French companies stand out with an increase of R&D investment of €2.6 billion, followed by UK, Finnish, Taiwanese and Korean companies (€1.1-1.5 billion). In relative terms, Indian companies also increased their R&D investments rapidly, but starting from low levels.⁹⁶

⁹⁶ As did Australia, due to a jump in Telstra's (telecom services) reported R&D investments.

Figure 6-4: R&D investments by ICT Scoreboard firms per country of registered headquarters in the EU and the RoW (excluding the US and Japan) in millions of €, 2004-2007



RoW



Note: Nominal terms, not adjusted for inflation.

Within the EU, the ICT sector top R&D investment growth must be further interpreted. Year-on-year variation in R&D investments might also signal organisational adaptations, reflecting growth strategies of large multinational companies. Further analysis indicates the rapid growth in France is largely due to France Telecom (2004-2006) and to the Alcatel merger with Lucent (2007), which resulted in ICT R&D being attributed, in the *Scoreboard*, to France instead of the US. The R&D growth in the UK is largely, but not fully, attributable to that of BT. Finland's R&D growth in 2007 is a result of the creation of Nokia-Siemens, which meant that Siemens Telecom Equipment R&D was attributed in the *Scoreboard* to Finland and to the Telecom Equipment sub-sector, instead of being distributed to Electrical

Components & Equipment and to Germany. In the Netherlands, NXP started reporting R&D in 2007, which led to a jump in R&D figures. Hence, although recent ICT R&D growth in EU companies is quite substantial, much of it can be explained either by mergers and acquisitions (not corresponding therefore to overall growth of R&D investment), or by increasing reported R&D in telecom services companies' (e.g. FT, BT) annual accounts.⁹⁷

The 20 major R&D investing ICT companies of the 2007 *ICT Scoreboard* are listed in Table 6-2. Of these, five are EU-based (shown in red) while the others have their headquarters in either the US (7), Japan (7) or Korea (1). Of the five EU firms, three are in the Telecom Equipment sub-sector.

Table 6-2: Top 20 R&D investing ICT sector companies in 2007

Rank 2007	Rank 2006	Company	NACE subsector	4 digit ICB subsector	Country	R&D (€ mill.)	Sales (€ mill.)	R&D/Sales (%)
1	1	Microsoft	CSS*	Software	US	5584	41325	13.5
2	5	Nokia	Telecom equip.	Telecom equip.	Finland	5281	51058	10.3
3	2	Samsung	IT components	Electronic equip.	Korea	4438	71979	6.2
4	3	Intel	IT components	Semiconductors	US	3936	26219	15
5	4	IBM	CSS	Computer services	US	3931	67566	5.8
6	6	Matsushita	Multimedia equip.	Leisure goods	Japan	3539	55764	6.3
7	15	Alcatel-Lucent	Telecom equip.	Telecom equip.	France	3368	18005	18.7
8	7	Sony	Multimedia equip.	Leisure goods	Japan	3330	47483	7
9	9	Cisco Systems	Telecom equip.	Telecom equip.	US	3077	23885	12.9
10	8	Motorola	Telecom equip.	Telecom equip.	US	3029	25048	12.1
11	10	Ericsson	Telecom equip.	Telecom equip.	Sweden	2911	19872	14.6
12	12	Hitachi	IT equip.	Computer hardware	Japan	2526	62742	4
13	11	HP	IT equip.	Computer hardware	US	2470	71130	3.5
14	13	Toshiba	IT equip.	Computer hardware	Japan	2412	43569	5.5
15	18	Canon	IT components	Electronic equip.	Japan	2255	27437	8.2
16	14	NEC	IT equip.	Computer hardware	Japan	2049	28485	7.2
17	20	Oracle	CSS	Software	US	1875	15341	12.2
18	22	BT	Telecom services	Fixed line telecom	UK	1705	28188	6
19	17	NTT	Telecom services	Fixed line telecom	Japan	1666	65880	2.5
20	19	Philips	Multimedia equip.	Leisure goods	Netherlands	1604	27037	5.9

* Note: CSS = Computer Services and Software. Red: EU headquartered companies.

⁹⁷ For the US, Japan and the RoW, there are no similar observed trend-breaks of sudden jumps in R&D investments and therefore we have not carried out the corresponding investigations.

Looking now at R&D investments increases for the time period 2004-2007 (see Table 6-3), a quite different set of companies emerges. The majority of these companies are based in the US, including Internet-related firms such as Google and Yahoo!. Four EU companies appear however among the top six positions, namely Alcatel-Lucent, Nokia, NXP and BT.

This good performance calls for some comments. Three of these companies are placed there in part as result of mergers, acquisitions or spin-offs. As mentioned above (in this section), the Alcatel merger with Lucent (2007) and the creation of Nokia-Siemens, have led to a mathematical jump in the R&D investment increases of these companies. In the Netherlands,

NXP started reporting R&D in 2007, which led to a jump in *Scoreboard* R&D figures. Hence, the R&D increases of the three top EU ICT R&D growth companies are likely to only partially reflect real R&D growth. Finally, Telefónica's R&D increase is partly explained by the fact the Spanish telecom operator reported very low R&D expenses for 2004 only (as compared to 2003 for instance). The dip in 2004 figures leads to a mathematical increase in R&D investment for the time periods 2004-2007.

A final note concerns the possibility that there may be companies not included in the *Scoreboard*, such as Huawei, the large and fast growing Chinese telecom equipment company, which would probably have made it onto the list,

Table 6-3: Top 20 R&D investing ICT sector companies per absolute growth in nominal terms (2004-2007)

Rank	Company	NACE subsector	4 digit ICB subsector	Country	R&D Growth (04-07) € million	CAGR (04-07)
1	Alcatel-Lucent	Telecom equip.	Telecom equip.	France	2032	36.1%
2	Nokia	Telecom equip.	Telecom equip.	Finland	1447	11.3%
3	Microsoft	CSS	Software	US	1354	9.7%
4	Google	CSS	Internet	US	1180	75.1%
5	NXP	IT components	Semiconductors	Netherlands	1058	-
6	BT	Telecom services	Fixed line telecom	UK	994	33.9%
7	Motorola	Telecom equip.	Telecom equip.	US	936	13.1%
8	Cisco	Telecom equip.	Telecom equip.	US	894	12.1%
9	Samsung	IT components	Electronic equip.	South Korea	856	7.4%
10	Oracle	CSS	Software	US	855	22.5%
11	Qualcomm	Telecom equip.	Telecom equip.	US	759	36.4%
12	Intel	IT components	Semiconductors	US	668	6.4%
13	AMD	IT components	Semiconductors	US	624	25.5%
14	AT&T	Telecom services	Fixed line telecom	US	615	125%
15	Canon	IT components	Electronic equip.	Japan	569	10.2%
16	Telstra	Telecom services	Fixed line telecom	Australia	565	44.9%
17	Yahoo!	CSS	Internet	US	552	45.5%
18	Broadcom	IT components	Semiconductors	US	544	34.5%
19	EMC	IT equip.	Computer hardware	US	515	20.3%
20	Telefonica	Telecom services	Fixed line telecom	Spain	507	89.8%

Notes: CSS= Computer Services & Software, nominal terms, not adjusted for inflation. Red: EU headquartered companies.

As discussed in the text, the increases of Alcatel-Lucent, Nokia, NXP and Telefónica are unlikely to reflect a real strong increase of R&D investment in these companies during the period.

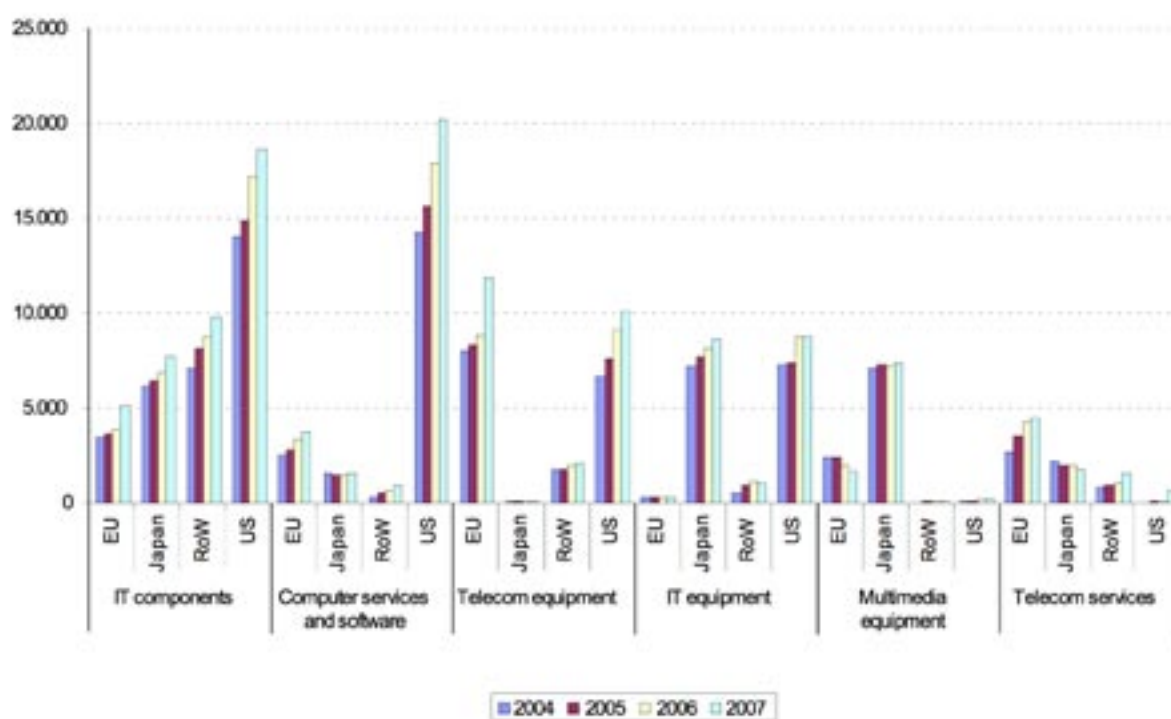
had they reported R&D spending. Huawei claims to invest at least 10% of its revenues in R&D⁹⁸ and as it increased its revenues from USD 3,827 million in 2004 to USD 12,840 in 2007,⁹⁹ it follows that it had a substantial rise in R&D investment.

6.3 ICT sub-sector analysis

Figure 6-5 shows the size and evolution of R&D investments in the ICT sub-sectors by EU, Japanese, RoW and US *ICT Scoreboard* companies for the period 2004-2007. Table 6-4 shows global *ICT Scoreboard* investment and R&D investment growth.

Clearly, the most important sub-sector in terms of R&D investment is **IT Components**. It accounts for about one third of the global R&D investments and R&D growth in the ICT sector. It is also the only sub-sector, where companies from all four regions display sizable R&D investments. R&D investments in IT Components are however increasing more rapidly and at higher levels by firms from outside the EU than by EU firms, especially by those from the US, but also those from the RoW. There was a sharp increase in R&D investments by EU firms in 2007 (mainly due to NXP, as mentioned in the previous section) but EU companies R&D investment in this sector is still the lowest in comparison to the other regions. This sub-sector is further analyzed in Section 6.4.

Figure 6-5: R&D investments in the ICT sub-sectors by EU, Japanese, RoW and US *ICT Scoreboard* companies, 2004-2007, € million



Note: Nominal terms, not adjusted for inflation.

98 See http://www.huawei.com/corporate_information/research_development.do

99 See http://www.huawei.com/corporate_information/annual_report/annual_report_2008/five_year_summary.do

Table 6-4: Global ICT Scoreboard R&D investment per ICT sub-sector and absolute growth in nominal terms, (2004-2007)

Sub-sector	R&D 2007 (€ billion)	R&D growth 04-07 (nominal, € billion)
IT components	41.4	10.6
Computer services and software	26.6	7.8
Telecom equipment	24.3	7.6
IT equipment	18.9	3.5
Multimedia equipment	9.6	-0.2
Telecom services	8.6	2.6
Grand Total	129.5	32.0

Second in size and growth come the R&D investments in **Computer Services and Software**. Most of the changes in this sector are happening in its Software and Internet segments. In this sector, US firms dominate, with EU firms in second place, but far behind. This sub-sector is further analyzed in Section 6.5.

The third largest R&D investing sub-sector, just slightly below Computer Services and Software, is **Telecom Equipment**. Here, EU companies dominate R&D investment, and their nearest challengers are US companies. In this sub-sector, too, US companies increased their R&D investments more rapidly than EU companies up to 2006. In 2007, however, there was a big increase in the EU R&D investment, which largely reflected mergers and acquisitions (see Section 6.2). This sub-sector is further analyzed in Section 6.6.

IT Equipment occupies a middle position, displaying relatively high total R&D investment with moderate growth. In this sector, it is Japanese rather than EU companies that are challenging the US for the global R&D investment leadership position.

The only sub-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 total R&D investment. R&D in **Multimedia Equipment** is largely conducted by Japanese companies and it does not seem to be growing at all. EU companies' R&D shows a clear negative trend, even though their R&D

investments in this sub-sector are overstated by *Scoreboard* data. This is 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 these segments may, in turn, be considered as ICT R&D).¹⁰⁰

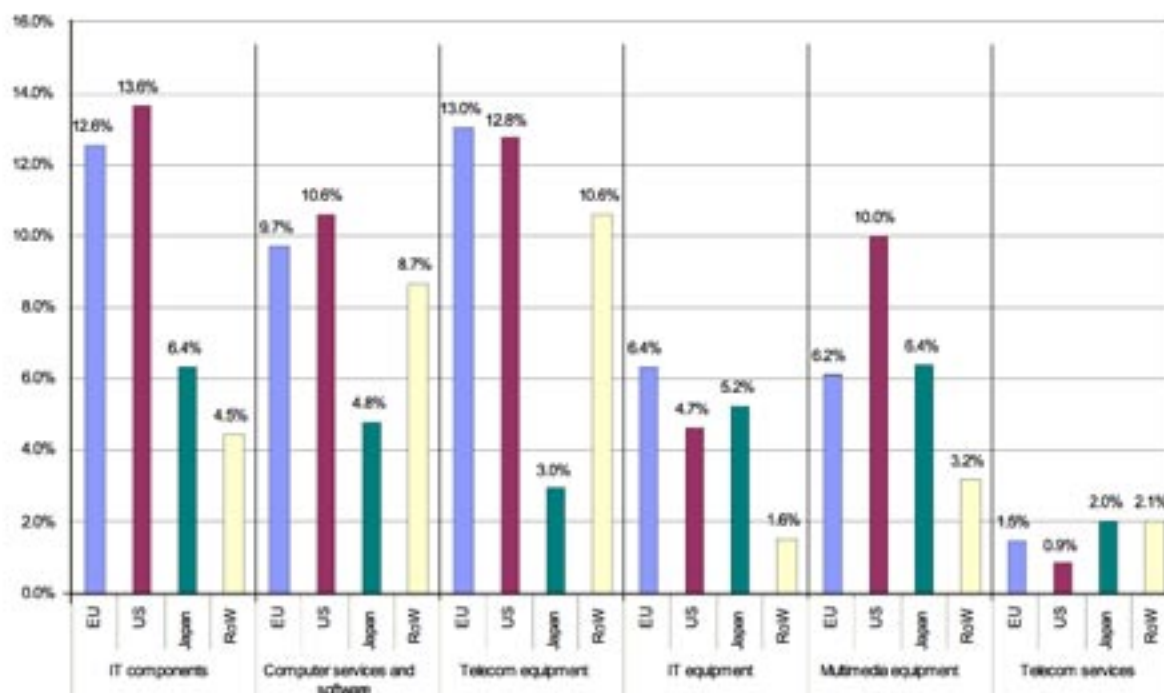
R&D in **Telecom Services** is growing relatively fast (with the exception of Japan). Telecom Services is, with Telecom Equipment, the second sector where both EU R&D investment levels and trends are more positive than for the other regions.¹⁰¹ EU telecom services companies have consistently increased their R&D spending in the last couple of years, although the increase appears to have slowed down in 2007.

Figure 6-6 shows R&D intensities (R&D investment/net sales) per ICT sub-sector in the EU, US, Japanese, and RoW regions as determined by the *ICT Scoreboard* companies for 2007. Relating R&D

¹⁰⁰ See Philips Annual Report (2007) available online at <http://www.philips.com/about/investor/financialresults/annualreports/index.page>

¹⁰¹ We may also note that the EU ICT R&D system is very concentrated in the telecom-related sub-sectors, especially Telecom Equipment. €16.5 billion out of €27.6, or almost 60%, billion are invested by telecom companies. The corresponding rates in other regions are between 9 and 23%. Hence, not only is the proportion of ICT R&D as part of total R&D lower for EU companies than for rest of the world, the IT (non-telecom) part is even lower.

Figure 6-6: R&D intensities (R&D investment / net sales) in EU, US, Japanese, and RoW ICT Scoreboard companies, 2007 (%)



investments to net sales (R&D intensity) for companies in different regions shows divergent patterns across the sub-sectors and across the regions.

A first observation is that, with the exception of Multimedia Equipment, in most sub-sectors, EU and US companies show very similar R&D intensity levels.¹⁰² As discussed in e.g., Lindmark et al. (2008), this means the *ICT Scoreboard* R&D gap between the US and the EU is not necessarily due to the lower R&D intensities (i.e., R&D to sales ratio) of the EU companies operating in same sectors, but may instead be due to the differing size and composition of the ICT industries in the two regions.

The other regions differ quite a lot from this EU/US pattern. In IT Components, Computer Services and Software, and Telecom Equipment,

EU and US R&D intensities are well above those of Japanese companies. On the other hand, Japanese companies show close or higher R&D intensities in IT Equipment, Multimedia Equipment and Telecom Services. These results must be interpreted with caution at this point. The relatively low R&D intensities of Japanese companies in some sectors may be due to differing R&D accounting practices. Also the Japanese figures appear to vary less across the sub-sectors. This may be due their relatively high level of diversification across the ICT subsectors, which would tend to make their R&D intensities converge across sub-sectors.

IT Components, IT Equipment and Multimedia Equipment companies from the RoW generally show lower R&D intensities than their counterparts in the EU and the US. In Computer Services and Software, and in Telecom Equipment these intensities are lower but much closer to those of the EU or the US. In Telecom Services, they shift above the EU and US figures. Observations

¹⁰² The exception that appears in Multimedia Equipment is due to the fact that the US figure results from one unique observation - that of the US company, Harman.

such as those related to Telecom Equipment are largely explained by the R&D investments of Canadian Nortel and for those related to Telecom Services by Australian Telstra's relatively high R&D investment which increase the average of the RoW group. On average however, it appears that EU and US ICT firms are ahead of the RoW and Japan in terms of R&D intensity.

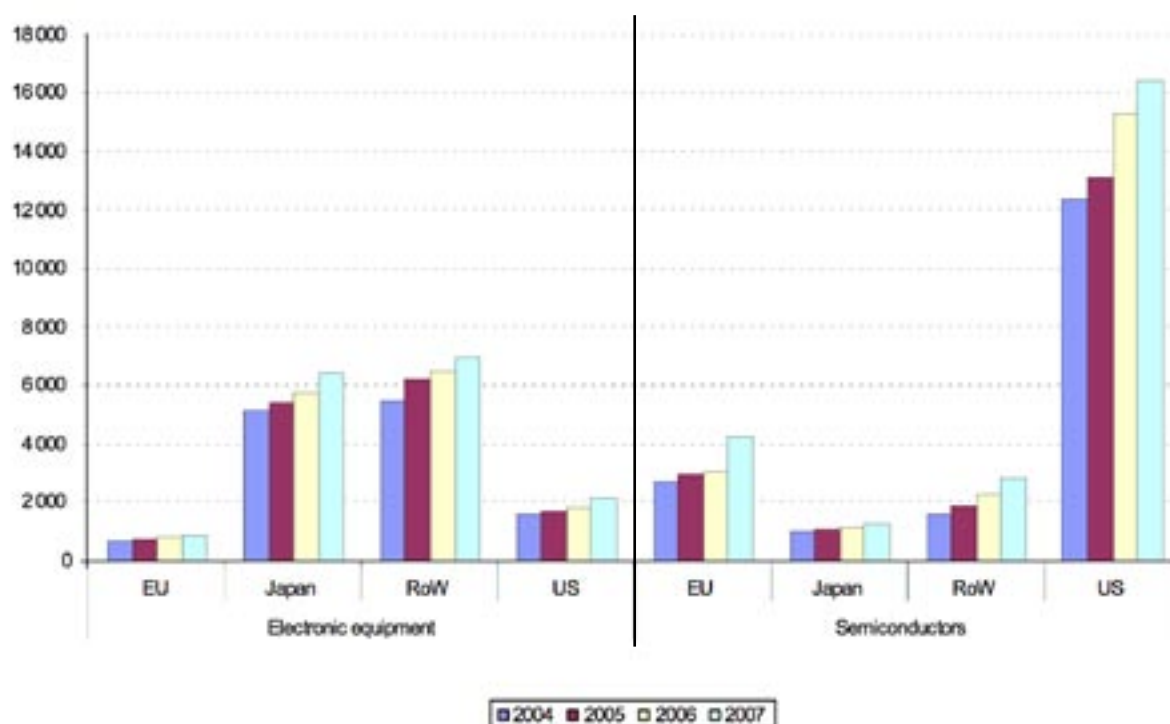
6.4 R&D in the IT Components sub-sector

As mentioned above, IT Components is the most important ICT sub-sector in terms of R&D investment. This sub-sector can be subdivided into the 'ICB-subsectors' of (1) Electronic

Equipment which includes diversified (primarily Asian) electronics firms such as Samsung, Canon and Sharp¹⁰³ and (2) Semiconductors, which includes a number of specialized semiconductor companies such as Intel. Figure 6-7 clearly illustrates the differentiated R&D investment profile of EU and US companies versus Japanese and RoW companies in these segments.

Table 6-5 illustrates sub-sectoral compositions, demographics and dynamics of the Top 10 R&D investors for IT Components in the four regions. It can be noted that there is a bigger presence of EU firms (e.g. STM, Infineon and NXP) and US firms (e.g., Intel, TI, AMD) in Semiconductors than in Electronic Equipment.

Figure 6-7: R&D investments in the IT Components sub-sector as divided into Electronic Equipment and Semiconductors, by EU, Japanese, RoW and US ICT Scoreboard companies, 2004-2007, € million



¹⁰³ Hence, 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.

Table 6-5: Top 10 US, EU, Japanese and RoW R&D investing companies in IT Components (2007)

Company	ICB subsector	State / Country	R&D 07 (€ mn)	€ R&D 04-07 (€ mn)	RDI 2007	R&D CAGR	Age
US			11 096	2 447	17.0%	8.7%	45.4
Intel	Semicond.	California	3 936	668	15.0%	6.4%	42
TI	Semicond.	Texas	1 474	121	15.6%	2.9%	80
AMD	Semicond.	California	1 263	624	30.7%	25.5%	41
Broadcom	Semicond.	California	922	544	35.7%	34.5%	19
Appl. Mtrls.	Semicond.	California	781	103	11.7%	4.8%	43
Freescale	Semicond.	Texas	779	119	19.9%	5.7%	80
Micron	Semicond.	Idaho	551	34	14.2%	2.2%	32
Nvidia	Semicond.	California	473	244	16.9%	27.3%	17
Agilent	El. equipment	California	469	-170	12.6%	-9.8%	71
LSI	Semicond.	California	448	160	25.2%	15.8%	29
EU			4 604	1 555	13.9%	14.7%	63.3
Infineon	Semicond.	Germany	1 169	24	15.2%	0.7%	58
STMicro.	Semicond.	Netherlands	1 166	176	17.1%	5.6%	53
NXP	Semicond.	Netherlands	1 058	1 058	22.9%	-	57
ASML	Semicond.	Netherlands	489	155	12.8%	13.6%	26
Agfa-Gevaert	El. equipment	Belgium	200	9	6.1%	1.5%	143
Invensys	El. equipment	UK	136	-33	4.0%	-6.9%	191
Gemalto	El. equipment	Netherlands	106	61	6.5%	33.2%	31
ARM	Semicond.	UK	100	29	28.5%	12.0%	20
CSR	Semicond.	UK	96	78	16.6%	72.2%	12
ASM Intl.	Semicond.	Netherlands	83	-2	8.6%	-0.9%	42
Japan			6 199	1 249	7.0%	7.8%	71.5
Canon	El. equipment		2 255	569	8.2%	10.2%	73
Sharp	El. equipment		1 162	313	6.1%	11.0%	98
Sanyo	El. equipment		779	13	5.7%	0.5%	60
Pioneer	El. equipment		363	47	7.3%	4.8%	72
Tokyo Electr.	Semicond.		349	78	6.7%	8.9%	47
Omron	El. equipment		319	34	7.1%	3.8%	77
TDK	El. equipment		306	95	5.8%	13.2%	75
Murata	Semicond.		237	28	6.8%	4.2%	66
Yokogawa El.	El. equipment		222	57	8.4%	10.3%	95
Rohm	Semicond.		207	15	8.6%	2.6%	52
RoW			8 131	2 144	4.8%	10.7%	29.1
Samsung	El. equipment	Korea	4 438	856	6.2%	7.4%	41
LG Electr.	El. equipment	Korea	1 233	105	3.2%	3.0%	52
Marvell Tech.	Semicond.	Bermuda	664	482	33.5%	54.0%	15
Hynix	Semicond.	Korea	431	139	6.8%	13.8%	27
TSMC	Semicond.	Taiwan	378	115	5.6%	12.8%	23
Hon Hai	El. equipment	Taiwan	324	174	0.9%	29.5%	36
U:d Microel	Semicond.	Taiwan	203	48	8.5%	9.4%	30
MediaTek	Semicond.	Taiwan	193	116	11.3%	35.9%	13
Nanya	Semicond.	Taiwan	137	46	11.9%	14.6%	15
Chunghwa	El. equipment	Taiwan	131	64	3.9%	24.9%	39

Notes: Annual reports, company information and Wikipedia have been used for determining the age of the companies. Age is 2010 minus the birth year. The resulting average age has been calculated per region. Note also that the company Maxwell Technology has its headquarters in California (US), but is registered in Bermuda. STM is essentially a Franco-Italian company, although registered in the Netherlands (and with headquarters in Switzerland). Colours: Blue: Companies older than 50 years. Black: Companies between 30 and 50 years old. Red: Companies younger than 30 years, and older than 15 years. Green: Companies 15 years or younger.

The large US R&D investors are mainly semiconductor companies. These are relatively young companies from Silicon Valley (California) and, to some extent, Texas. Several of them were started by key people who had worked at Fairchild Semiconductors (also in Silicon Valley).

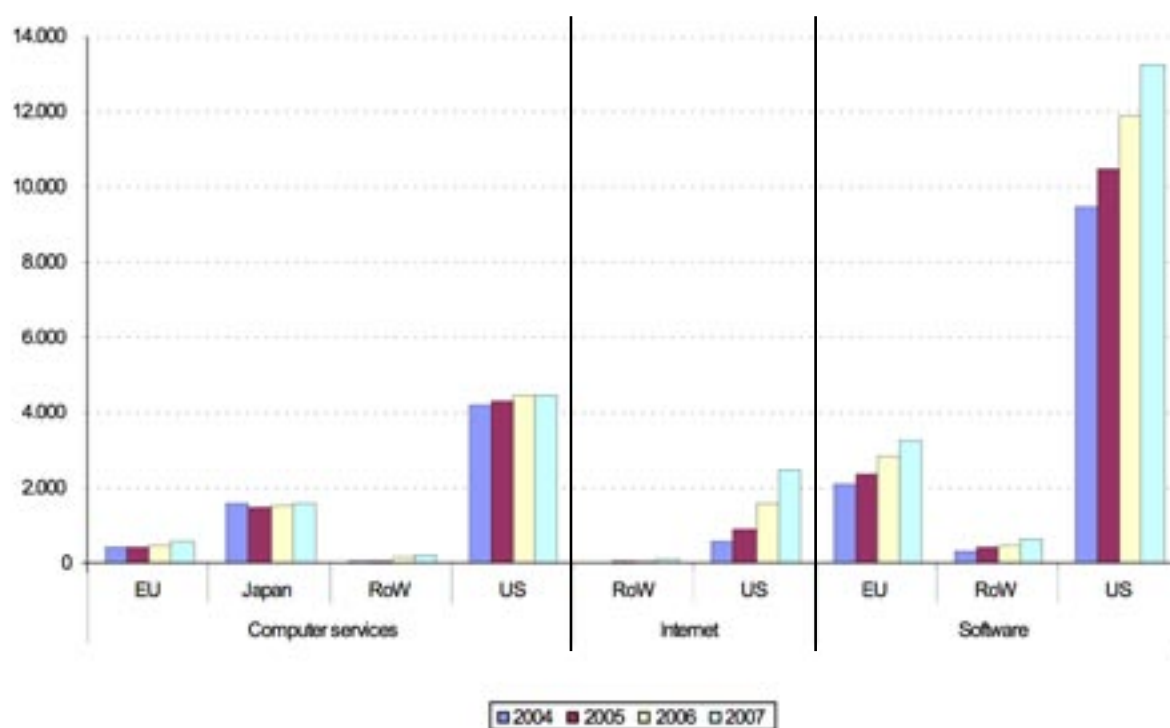
The EU IT Components sector is largely dominated by three semiconductor companies (Infineon, STM and NXP). Two of these, NXP and Infineon, are spin offs from Philips and Siemens respectively, while the third– STM - is the result of a merger between French and Italian chipmakers. Down the list, there are examples of younger, often fab-less semiconductor firms, such as ARM and CSR.¹⁰⁴

Japanese firms are typically older and more diversified. They span several consumer electronic product areas, and sometimes semiconductor activities as well. The major R&D investors in the RoW are exclusively from Korea and Taiwan¹⁰⁵ and are younger than the companies from the other regions (especially the ones from Taiwan, whose economy developed relatively later).

6.5 R&D in the Computer Services and Software sub-sector

This section briefly focuses on the Computer Services and Software sub-sector, as it is the most dynamic sub-sector in R&D in the EU and even

Figure 6-8: R&D investments in the Computer Services, Internet and Software ICB subsectors by EU, Japanese, RoW and US ICT Scoreboard companies, 2004-2007, € million



Note: Nominal terms, not adjusted for inflation.

¹⁰⁴ See Tuomi (2009) for a recent overview of the current state and potential future developments in semiconductor IP firms

¹⁰⁵ For more details about the Taiwanese ICT industry and its R&D, see Liu, et al. (2010).

more so in the US. We do so by looking at the R&D dynamics in its constituent ICB subsectors and for the ten top R&D investors in the EU and the US.

Figure 6-8 shows differences in R&D investment dynamics between the three ICB subsectors. First, among the 1,402 top R&D investors of the 2007 *Scoreboard*, there are no EU or Japanese companies in the Internet ICB subsector and no Japanese ones in the Software ICB-subsector.

Computer Services is clearly the least dynamic segment in terms of R&D growth. It is also, by nature, less R&D intensive (at about 5% on sales). However, there may be more R&D conducted in the sector than the figures suggest, since the companies in the sector are likely to be involved in development projects financed by their customers. These R&D efforts would be accounted for in the R&D efforts of the customer firms. On the other hand, the R&D efforts in the sector are, to a very large extent (79%) made by IBM (US) and Fujitsu (Japan), that are not pure Computer Services companies, and invest a lot in R&D on IT hardware and software.

The dynamics of Software and Internet ICB subsectors are very different from Computer Services. Both Software and Internet display R&D growth rates, both in absolute and relative terms and very high R&D intensity (14.7% for Software and 13.8% for Internet). Software R&D has been persistently and rapidly growing for many years, and Internet R&D has grown, mainly through Google and Yahoo!, from almost nothing in the early 2000s to some €2.5 billion in 2007. One may also notice that these sub-sectors consist mainly of US companies, although the EU has a significant R&D presence in Software, (largely through SAP, which conducted almost 40% of the EU *ICT Scoreboard* company R&D in this ICB subsector).

The following Table 6-6 illustrates sub-sectoral compositions, demographics and dynamics of the Top 10 R&D investors for Computer Services and Software in the four regions.

Looking at the major R&D investors of the Computer Services and Software sub-sector in the EU and the US, it is clear (from Table 6-6) that the US companies, as an aggregate, outperform the EU ones in almost every respect. In 2007, R&D investments were almost €16 billion compared to less than €3 billion in the EU. From 2004 to 2007, US firms increased R&D investment by more than €5 billion, which is also more than five times the increase by EU firms. However, in terms of relative growth, EU companies have grown their R&D at about the same rate as their US counterparts (13.8% on an average yearly basis as compared to 13.6% for the US firms). This observation contrasts with the one made in the earlier PREDICT report (Turlea *et al.*, 2009) which noted a much higher relative R&D growth among US firms. The rise in R&D CAGR by EU companies is partly due to the rising R&D investment of SAP, and also partly due to the exclusion of Telent from the *Scoreboard*.¹⁰⁶

There are no large R&D investors in the *Scoreboard* from outside the EU and the US except for Fujitsu, which is why only five companies are shown in the table for Japan and the RoW. There are a few quite new and highly R&D intensive companies from India in the *Scoreboard*, and at lower levels (not shown here) from Israel, indicating some dynamism in these two countries. An interesting question for further research would be to investigate the likelihood of these firms becoming major R&D investors, and the median time they would take to do so, based on historical patterns in other countries.

106 Telent, previously listed in the *Scoreboard* as an EU company, was formed in 2006 from the UK and German services businesses of Marconi Corporation (formerly General Electric Company) which had not been acquired by Ericsson. It is no longer a listed company and therefore is no longer included in the *Scoreboard*. Telent showed declining R&D figures in the previous (2007) *Scoreboard*, and these affected the overall growth negatively.

Table 6-6: Top 10 EU and US R&D investing companies in the Computer Services and Software sub-sector, plus 5 Japanese and RoW companies (2007)

Company	ICB subsector	Country	R&D 07 (€ mn)	Δ04-07 (€ mn)	CAGR	RDI	Age
EU			2931	943	13.8%	11.0%	34.2
SAP	Software	Germany	1458	438	12.6%	14.2%	38
Dassault Syst.	Software	France	292	57	7.5%	23.2%	29
UBIsoft	Software	France	226	146	41.2%	33.2%	24
Amdocs ^{d.)}	Software	UK	158	71	22.2%	8.1%	28
Sage	Software	UK	152	50	14.4%	9.6%	29
Fujitsu Siem. ^{a.)}	C. services	Netherlands	145	3	0.6%	2.1%	25
Indra ^{b.)}	C. services	Spain	141	64	22.4%	6.5%	89
Business Obj.	Software	France	133	68	26.9%	15.5%	20
Symbian ^{c.)}	Software	UK	128	66	27.3%	48.5%	29
Misys	Software	UK	98	-20	-6.0%	13.8%	31
US		(State)	15829	5045	13.6%	10.4%	35.4
Microsoft	Software	Washington	5584	1354	9.7%	13.5%	35
IBM ^{e.)}	C. services	New York	3931	397	3.6%	5.8%	114
Oracle	Software	California	1875	855	22.5%	12.2%	33
Google	Internet	California	1450	1180	75.1%	12.8%	12
Yahoo!	Internet	California	818	552	45.5%	17.1%	15
Symantec	Software	California	612	384	38.9%	15.2%	28
CA	Software	New York	430	-90	-6.2%	14.7%	34
Adobe	Software	California	419	207	25.4%	19.4%	28
Intuit	Software	California	356	119	14.5%	19.1%	27
Cadence Systems	Software	California	354	88	10.0%	32.1%	28
Japan & RoW		Country	1 913	214	4.0%	5.9%	32.8
Fujitsu	C. services	Japan	1 556	20	0.4%	5.0%	75
Polaris	Software	India	114	43	17.2%	63.8%	17
Prithvi	C. services	India	95	95		70.9%	12
Cognos	Software	Canada	94	32	14.7%	13.8%	41
Open Text	Software	Canada	54	24	21.9%	13.3%	19

Notes: CAGR = Compound Annual Growth Rate (in nominal terms, not adjusted for inflation. Annual reports, company information and Wikipedia have been used for determining the age of the companies. Age is 2010 minus the birth year. Resulting average age has been calculated per region. Colours: *Blue: Companies older than 50 years. Black: Companies between 30 and 50 years old. Red: Companies younger than 30 years, and older than 15 years. Green: Companies 15 years or younger.*¹⁰⁷

107 The age of companies is calculated from the start of the main activity of the company, rather than its incorporation (if different). In the case of mergers, the age of the main or oldest ancestor is given.

- a.) The age of Fujitsu Siemens (now a subsidiary of Fujitsu) has been estimated. The company has a long history of mergers and acquisitions involving the computer activities of Ericsson, Nokia, ICL, Siemens and Nixdorf, although it was incorporated in 1999.
- b.) Indra also has a long history which can be traced back to 1921. It was incorporated in its current form in 1993.
- c.) Symbian (now fully owned by Nokia) began around 1981 as EPOC, an operating system for PSION's handheld devices. It was later spun-out and incorporated as Symbian in 1998.
- d.) Amdocs is listed in the Scoreboard as a UK company, but appears, from most other sources, to be essentially US.
- e.) In the previous report (Turlea et al. 2009), IBM's age was stated as a bit lower. CTR, later to become IBM, was formed in 1911, but CTR was in turn a merger of 4 companies, of which the one most often called the forerunner of IBM was formed in 1896. This is the date of birth used here. It should also be noted that Cognos is a subsidiary of IBM.

It can also be seen that, in general, most firms are relatively young, i.e. around 30 years old. Several of these have taken advantage of the opportunities presented by the growth of the 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 10 list – Yahoo! and Google. Clearly, the US seems until now to be more capable of growing companies in the new emerging software and services parts of the ICT sector than other regions of the world.

6.6 R&D in the Telecom Equipment sub-sector

As mentioned above, the third largest R&D investing sub-sector is Telecom Equipment, where most R&D is invested by EU and North American companies (much of the RoW R&D investments were made by the Canadian company Nortel,

which in 2009 was acquired partly by Ericsson and partly by US Avaya). US companies increased their R&D investments more rapidly than EU ones up until 2006. In 2007, however, there was a big increase in the EU's R&D investments, which can largely be attributed to mergers and acquisitions (see Section 6.2).

It can also be noted that in the EU, €11.6 billion (out of €11.9 billion) were invested by just three firms (Nokia, Ericsson and Alcatel-Lucent). This can be contrasted with the US, where much of the R&D and R&D growth is attributable to a large number of rapidly growing 'medium-sized' companies (e.g. Juniper), although there are big companies in the US as well (Motorola and Cisco). The prevalence of relatively young companies in California, with large rapidly growing R&D investments, is also striking. These indications challenge the usually-accepted strength and dynamism of the EU Telecom Equipment sector.

Figure 6-9: R&D investments in the Telecom Equipment sub-sector by EU, Japanese, RoW and US ICT Scoreboard companies, 2004-2007, € million

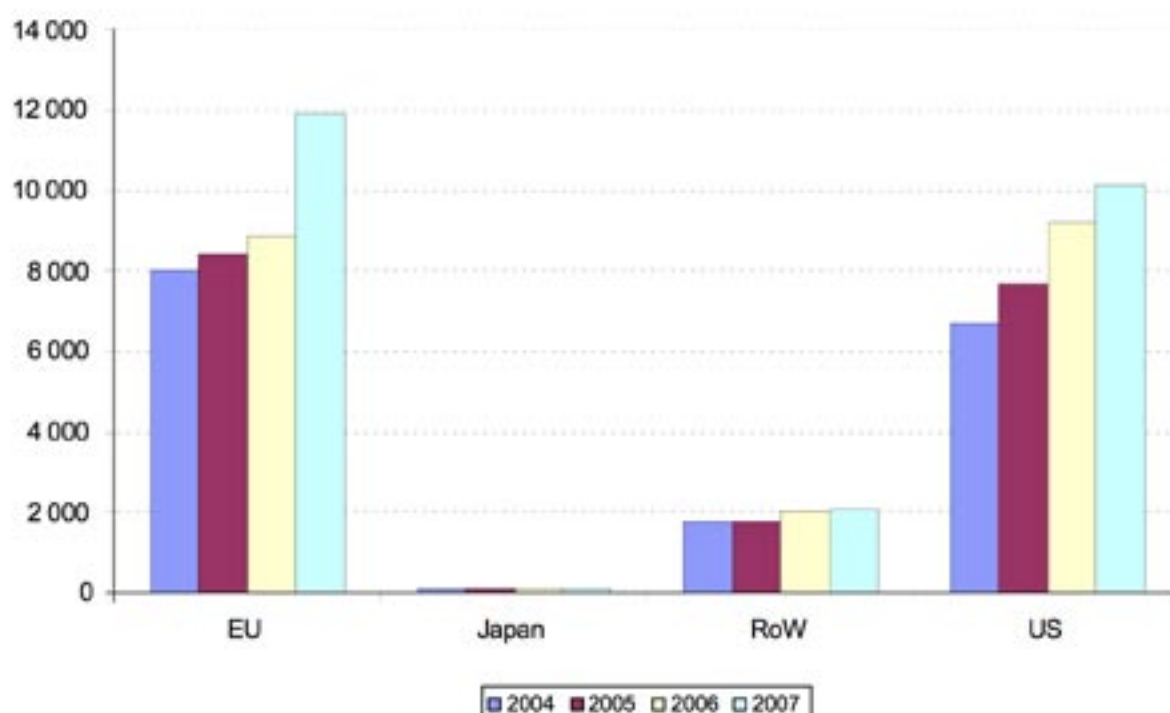


Table 6-7: Top 10 R&D-investing companies in the Telecom Equipment sub-sector in the US, the EU, and in Japan and the RoW combined (2007)

Company	State/Country	R&D 07 (€ mn)	Δ R&D 04-07 (€ mn)	RDI 2007	R&D CAGR	Age
US		9 163	3 275	12.9%	15.9%	64.4
Cisco	California	3 077	894	12.9%	12.1%	26
Motorola	Illinois	3 029	936	12.1%	13.1%	82
Qualcomm	California	1 251	759	20.6%	36.4%	25
Juniper Networks	California	426	263	22.0%	37.7%	14
Corning	New York	386	144	9.6%	16.8%	159
Avaya	New Jersey	341	93	9.7%	11.2%	138
Tellabs	Illinois	235	63	17.9%	11.1%	35
Harris	Florida	160	84	5.5%	28.2%	115
3Com	Massachusetts	141	77	16.0%	29.8%	31
UTStarcom	California	115	-38	6.8%	-9.1%	19
EU		11 934	3 871	13.0%	14.0%	85.5
Nokia	Finland	5 281	1 447	10.3%	11.3%	145
Alcatel-Lucent	France	3 368	2 032	18.7%	36.1%	138
Ericsson	Sweden	2 911	311	14.6%	3.8%	134
Italtel	Italy	103	41	19.0%	18.2%	89
GN Store Nord	Denmark	72	26	9.0%	16.2%	189
Spirent Comm.	UK	63	-29	19.2%	-11.7%	74
ADVA	Germany	42	30	16.9%	50.6%	16
Wavecom	France	34	-14	16.6%	-10.7%	17
Option	Belgium	31	16	10.1%	28.8%	24
Thrane & Thrane	Denmark	29	10	17.2%	14.4%	29
Japan and RoW		2 110	247	9.4%	4.2%	54.1
Nortel Networks	Canada	1 178	-161	15.7%	-4.2%	115
ZTE	China	301	89	9.2%	12.3%	25
RIM	Canada	246	177	6.0%	52.6%	26
OKI Electric	Japan	130	32	3.0%	9.7%	129
ECI Telecom	Israel	75	17	16.6%	9.3%	49
Aastra	Canada	38	22	9.0%	32.3%	15
Eltek	Norway	37	26	6.0%	51.4%	40
Alvarion	Israel	35	16	21.7%	22.7%	18
Vtech	Hong Kong	35	9	3.3%	10.0%	34
Tandberg	Norway	35	21	8.0%	38.1%	77

Notes: CAGR = Compound Annual Growth Rate (in nominal terms, not adjusted for inflation). Annual reports, company information and Wikipedia have been use for determining the age of the companies. Age is 2010 minus the birth year. Resulting average age has been calculated per region. Colours: Blue: Companies older than 50 years. Black: Companies between 30 and 50 years old. Red: Companies younger than 30 years, and older than 15 years. Green: Companies 15 years or younger.

Japan and the RoW are listed together in Table 6-7, because of the relatively limited number of major R&D investors from these regions. It should be noted, however, that several major Asian electronics firms, such as NEC and Samsung, also have strong presences in Telecoms.

6.7 Summary and conclusions

The findings in this chapter essentially corroborate those reported in the 2009 report (Turlea et al., 2009), with some minor differences and additions. EU ICT sector companies make very substantial R&D investments, and show

similar R&D intensities to those of their US competitors. At an aggregate level, however, they invest less in R&D than companies from the US, and they represent a smaller share of total R&D in the EU than ICT R&D represents elsewhere.

In comparison with the US, there is a gap in ICT sector R&D (for the analyzed sample of companies). However, as shown in Figure 6-6 and by other JRC-IPTS research,¹⁰⁸ this is not necessarily because individual US companies are more R&D intensive than EU ones. R&D intensity (i.e., R&D investment to sales ratio) is instead more likely to be sector-specific than region-specific. In other words it is an industrial and market characteristic, rather than a national one (at least in the comparison between the US and Europe). This suggests that this company-level ICT R&D gap is, in fact, mostly due to the presence of a large number of top R&D investing US ICT sector companies. This is perhaps the most striking and important observation from the *ICT Scoreboard* – that more than half the top global R&D investing ICT companies are from the US.

Our analysis suggests that, in absolute terms, the already dominant US companies further increased their R&D investment lead (in volume), although EU companies show a very positive trend with seemingly higher recent relative growth rates. Much of this growth, at least in 2007, is however a result of mergers, acquisitions and spin-offs, and the resulting re-classification of R&D investment, rather than real increases. It can also be noted that the major R&D investing companies in the EU are registered in Finland (mainly Nokia), France (Alcatel-Lucent and FT), the Netherlands (Philips, NXP and STM), Germany (SAP, Infineon and Deutsche Telekom), the UK (BT) and Sweden (Ericsson).

Worldwide, the most important sub-sector in terms of R&D investment 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. In terms of size and

R&D dynamics, it is followed by Computer Services and Software and by Telecom Equipment. These three sectors show a strong presence of US firms with high R&D investments and growth. The top EU R&D spending companies are pre-dominantly in Telecom Equipment, but also in IT Components and Telecom Services. Asian companies, on the other hand, hold very strong R&D positions in IT and Multimedia Equipment and also in IT Components.

This chapter also provided separate analyses on the three largest R&D investing sub-sectors, IT Components, Telecom Equipment and Computer Services and Software. For IT Components, it was found that the Electronic Equipment segment largely includes diversified (primarily Asian) electronics firms such as Samsung, Canon and Sharp while the Semiconductors segment includes a number of specialized semi-conductor companies such as Intel. There is also a sizable presence of EU firms (e.g. STM, Infineon and NXP) as well as some younger firms, such as ARM and CSR. Young semiconductor firms with rapidly increasing in R&D investment are even more present in California and Taiwan

The Software and Internet segments of Computer Services and Software were the most dynamic ones in terms of R&D investment, displaying high R&D intensities as well as high growth rates. On the positive side, this report shows that a significant number of EU Computer Services and Software companies increased their R&D investments relatively faster than their US counterparts. This is an improvement on the situation described in the 2009 report. On the other hand, the absolute R&D investments and investment growth figures of EU companies remain very much lower than those of US companies. The US Internet industry also hosts some young companies with high and rapidly growing R&D investments, which are not present in the EU. There are indications that rapidly growing companies like these are also present in India.

108 Lindmark et al. (2008), European Commission (2008d) and European Commission (2009 forthcoming)

Telecom Equipment has long been regarded as a stronghold of the EU ICT industry, including world leaders such as Nokia, Ericsson and Alcatel-Lucent. However, with the exception of these three giants, there is very low R&D investment and growth by EU companies. In contrast, the US has many companies, often from a data communication and Internet background, of varying sizes, which are raising their R&D investment at rapid rates. Patterns from Japan and the RoW are mixed, although there is clearly a rapidly growing and very

competitive Telecom Equipment sector in China (although some companies, notably Huawei, cannot be analysed using *Scoreboard* data).

Finally, in the three ICT sub-sectors investigated, it must be noted that the number of relatively young, large and rapidly growing R&D investing companies in California is strikingly high. In fact, their R&D levels are higher than those of all EU companies taken together. Most of these companies are clustered in the San Francisco Bay area (Silicon Valley).

■ 7 ICT patents in the European Union

7.1 Introduction

This chapter provides an analysis of ICT inventive activity in the EU by taking into account patent applications data as a proxy of the inventive activity itself.¹⁰⁹

7.1.1 Methodology update¹¹⁰

The analysis is based on data from the PATSTAT database, which is developed and updated by the European Patent Office (EPO) and provides worldwide coverage of patent applications submitted to around 90 Patent Offices in the world.¹¹¹ The present analysis takes into account data from the April 2009 release of the PATSTAT database, and considers

priority patent applications submitted to the 27 EU Member States Patent Offices, the European Patent Office and the United States Patent and Trademark Office (USPTO), from 1990 to 2006. Patents are attributed to countries using either the ‘inventor criterion’ or the ‘applicant criterion’, by exploiting the fact that patent data provide separate information on the country of residence of the inventors and on the applicants who have legal title to the patent.¹¹²

Compared to the patent analysis presented in the 2009 version of this annual report (Turlea et al., 2009), the present analysis encompasses several methodological improvements which are presented in the following Box).

109 Being aware of the limitations pointed out by the literature with regard to such an exercise.

110 See also the patent data methodological information in Annex 8.

111 PATSTAT is the name under which the EPO Worldwide Patent Statistical Database is known. It contains worldwide coverage of information on patent applications. The database is designed and maintained by the EPO (<http://www.epo.org>), as member of the Patent Statistics Task Force led by the Organisation for Economic Co-operation and Development (OECD). Other members of the Patent Statistics Task Force are the World Intellectual Property Organisation (WIPO), the Japanese Patent Office (JPO), the US Patent and Trademark Office (USPTO), the US National Science Foundation (NSF) and the European Commission (EC), which is represented by Eurostat and by DG Research. Data are mainly extracted from the EPO’s master bibliographic database DocDB and cover nearly 90 national Patent Offices, the World Intellectual Property Organisation (WIPO) and, of course, the EPO. The database provides a ‘snapshot’ of data available in the sources database at a specific point in time, and is updated twice per year. Detailed information on PATSTAT is available online at the EPO website: <http://www.epo.org/patents/patent-information/raw-data/test/product-14-24.html> (last accessed: 10 December 2009).

112 Please refer to Annex 8 for more detailed information about priority applications and about the ‘inventor criterion’ and ‘applicant criterion’.

Methodological improvements compared to the analysis in the 2009 PREDICT Report (Turlea et al., 2009)

A major improvement is the enlarged coverage achieved by including the United States Patent and Trademark Office (USPTO) among the patent offices considered. This inclusion is justified by two main reasons. First, USPTO applications include a high number of applications submitted by EU inventors. At times, EU applicants file an invention first with the USPTO, and then often use the priority rights¹¹³ to protect their invention in other markets. Also, EU inventors may be involved in priority applications that are filed by non-EU applicants in the US. Given the importance of the USPTO, this inclusion allows us to draw a more complete picture of inventive activity of the EU and its Member States. Secondly, the inclusion of the USPTO allows us to make more valid comparisons when using patent applications as a proxy for the inventive prowess of the EU and the United States, that otherwise would be affected by a serious 'home country bias'.¹¹⁴

In the future, it is envisaged that coverage of the analysis will be further enlarged by including other Patent Offices, for example the Japan Patent Office (JPO). The Patent Offices of China, India and Brazil could also be taken into account.

Another improvement concerns the application of more sophisticated solutions to some problems of missing information in the PATSTAT database, such as country of residence of inventors or applicants. The methodology is fully documented in Picci (2009) and in de Rassenfosse et al. (2009).

Last but not least, using the April 2009 release of the PATSTAT database not only allowed us to take into account more recent data (year 2006), but also provided updated data for previous years.

As a result of these improvements, the present analysis takes into account a number of EU applications which is, on average, about 50% higher than in the 2009 report.¹¹⁵

The reader should note that, due to the above mentioned improvements, data presented in the present report are not fully comparable with those published in the 2009 report.

7.1.2 Main observations

Main observations based on the data presented and analysed in this chapter are:

- When priority applications for all technologies are taken into account (i.e., not only ICT), the analysis shows that EU-based inventors file more priority applications than US-based inventors. The dynamics across time are slightly different: the total number of priority applications by EU inventors slowly but steadily increases from 1990 to 2000, then decreases to recover and stabilise from 2003. The pattern of priority applications with US inventors follows a smoother path over time. When taking into consideration the respective size of the two regions, the ratio of the total number of priority applications per million inhabitants is, however, higher for applications by US inventors than for applications by EU inventors.
- When considering only ICT priority applications, US inventors consistently filed more priority applications than EU inventors

113 The Paris Convention for the Protection of Industrial Property in 1883 established the system of "priority rights": applicants are allowed, within 12 months from first filing of their patent application at the Patent Office of a country – referred to as the priority country – to submit subsequent applications in other signatory countries, claiming the priority date of the first application. The first filing usually takes place in the applicant's own country. This approach represented a radical change, as earlier foreign applications used to be refused because the invention was no longer novel, having being disclosed in an earlier (priority) application. For further reference on priority rights and on the patenting procedure, see OECD (2009d).

114 The propensity of applicants to first submit applications to the patent office in their home country (or, in the case of a European Country, to the EPO) is at the root of what is referred to in the literature as "home country bias". See Picci (2009).

115 These figures refer to the inventor criterion, but the improvement is similar when the applicant criterion is considered (see Annex 8 for more details).

over the period 1990 to 2006. Since 1994, the ratio of ICT applications by US inventors over the total number of applications has always been above 20% (and close to 50% in 2006), while it has not exceeded 20% for ICT applications by EU inventors.

- At EU Member State level, several countries file many more patent applications than others: mainly Germany, the United Kingdom and France. Also when considering only ICT applications, these three countries taken together cover 75% of EU ICT applications. When taking into account country population or GDP, the Netherlands, Finland, Sweden and Italy also compete with the three largest EU countries. Finland ranked first in 2006, both in terms of ICT applications per million inhabitants and of ICT applications per GDP.

These observations are developed in the following two sections, the first mainly compares the EU (as a whole) with the US, and the second compares the inventive prowess of the different EU Member States.

7.2 ICT patenting activity by EU and US inventors

This section provides a comparative view of the innovative prowess of the EU as a whole, compared to the US.

7.2.1 ICT and total patenting activity: EU and US inventors

Figure 7-1 presents the total number of priority applications¹¹⁶ filed by EU-based and

US-based inventors between 1990 and 2006,¹¹⁷ both in all technology classes and specifically in the ICT classes (left hand scale). Shares of ICT applications in total applications are also presented (right hand scale).¹¹⁸

The figure shows that, during the whole period:

- when considering all technology classes together, more applications have been filed every year by EU inventors (dotted blue line) than by US inventors (dotted red line);
- when considering only ICT technology classes however, fewer ICT applications have been filed every year by EU inventors (solid blue line) than by US inventors (solid red line);
- consequently, in terms of *share of ICT applications* over the total, the US shares largely exceeds the EU ones.

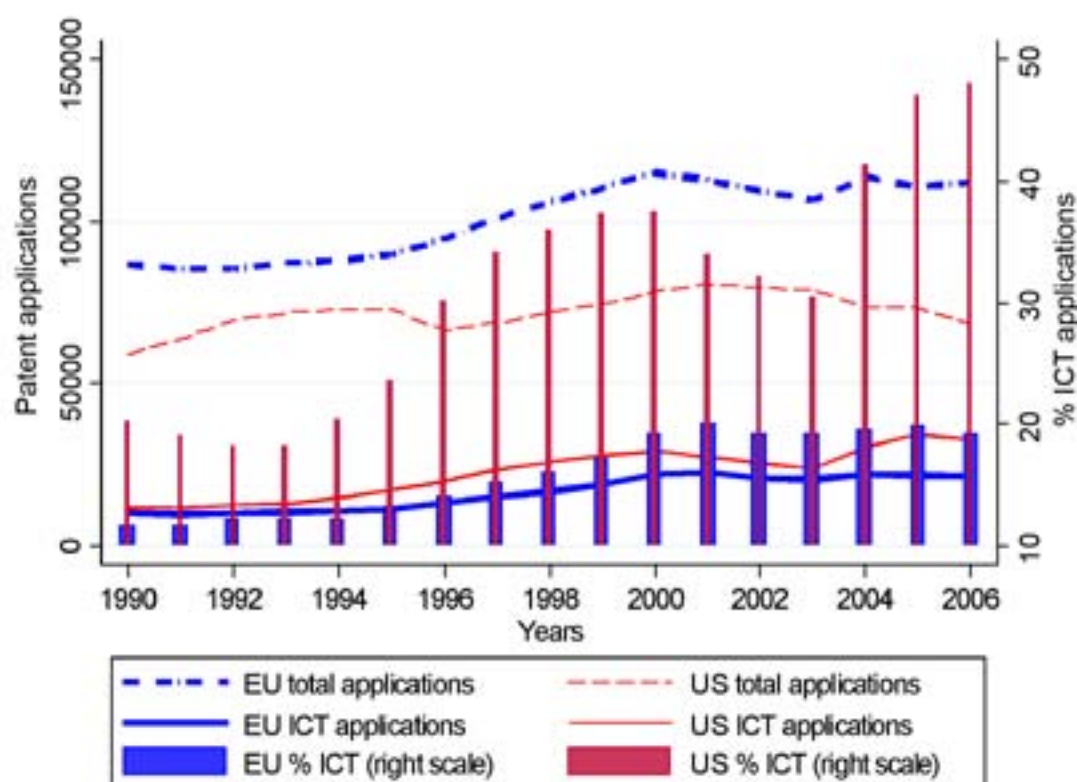
The total number of patents applications which involved at least one EU inventor (dotted blue line) increased from 86,500 in 1990 to 112,000 in 2006, still below its peak value of 115,000 in 2000. Similarly, the number of patent applications with at least one US inventor (dashed red line) increased from 59,400 in 1990 to 68,400 in 2006, below its peak value of 80,800 in 2001. When taking into account only applications in the ICT technological class, EU applications (solid blue line) follow a similar trend as the US ones (solid red line), but always with lower values. From 1990 to 2006, the number EU ICT applications increased from 10,000 to 21,500, while the number of US ICT applications increased from 12,000 to 33,000. In 2006, the number of EU ICT applications were therefore only about 2/3 the number of US ICT applications. As a

116 Please note that priority patent applications are assigned to countries by applying a fractional count when applications include inventors from different countries; this results in numbers of applications expressed with decimal figures. Please refer to Annex 8 for a more detailed description of the fractional count method. This remark is valid for the whole analysis.

117 Please note that in the most recent years (2005, 2006) data could be affected by delays in the PATSTAT updating procedure. This remark is valid for the whole analysis.

118 All applications have been calculated using the inventor criterion. Using the applicant criteria leads to identical results.

Figure 7-1: ICT and total priority patent applications by EU and US inventors



Source: JRC-IPTS calculations based on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices and the USPTO. Inventor criterion.

result, the share of US ICT applications on the total amount of US applications (solid vertical thin red bar) is consistently significantly higher than the share of EU ICT applications on the total amount of EU applications (solid vertical thick blue bar): close to 50% for US applications in 2006 versus close to 20% for EU applications.

Data presented in Figure 7-1 would seem to indicate that US inventors concentrate their patenting efforts more on ICT inventions than EU inventors do. However, many factors could influence the propensity to patent in ICT, for example the differences in patent regulation, and further investigation is necessary before drawing more conclusions from the above observations.

7.2.2 ICT patenting activity by technological classes: EU and US inventors

Figure 7-2 provides an insight into the subdivision of ICT technologies over time, in the

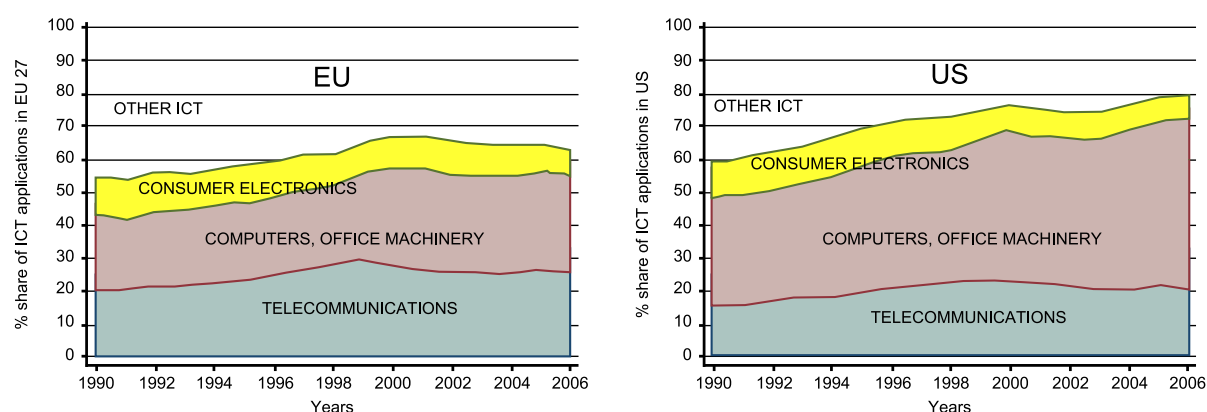
applications filed by EU and US inventors. All ICT applications are classified into the following four classes: Telecommunications, Consumers Electronics, Computers and Office Machinery, and a residual class named 'Other ICT'.¹¹⁹

The left-hand panel of Figure 7-2 presents the evolution of the shares of the technological subdivisions of ICT applications by EU inventors. The right-hand panel shows the same information for US inventors.

During the 1990s, the relative importance of Telecommunications and especially of Computers and Office Machinery applications increased, for both EU and US applications. The figure shows a stronger EU than US

¹¹⁹ Such subdivision is based upon the OECD ICT classes (OECD, 2008a) and the results thereof need to be taken with some methodological caution as they do not correspond to ISIC or NACE categories. See Annex 8 for more details.

Figure 7-2: Share of ICT priority patent applications, by ICT class, EU and US inventors



Source: JRC-IPTS calculations based on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States National Patent Offices and the USPTO. Inventor criterion.

Telecommunications share and a stronger US than EU Computers and Office Machinery share, reflecting regional industrial strengths.

From 1990 to 2006, the EU share of Telecommunications applications rose from 20% to about 25% with a peak close to 30% in 1999, while the US share rose from 15% to about 20% with a peak close to 25% in 1999.

During this period, the EU share of Computers and Office Machinery applications rose from 22% in 1990 to around 30% in 2000 and then stabilised, while the US share rose from 33% in 1990 to above 50% in 2006.

In both regions, the share of applications in Consumer Electronics slowly but continuously decreased during the period with shares in 2006 below 10%.

The residual 'Other ICT' share also decreased during the period in both the EU and in the US.

A comparison with the data presented in the 2009 Report,¹²⁰ where only applications submitted

to EPO and the 27 EU Patent Offices were taken into account, shows a different distribution in ICT technologies classes. Comparing Figure 7-2 above, with Figure 8-2 of the 2009 Report, we observe that the EU Telecommunications share decreased from about 30% to 25% (in 2004) while its Computers and Office Machinery share increased from 25% to 30%.

Since the data presented in this year's report also includes ICT applications to the USPTO, specificities of US software R&D capabilities and the different legal frameworks for software patenting may provide some explanations for this different distribution. Under the US legal framework, the patentability of a computer-implemented invention is allowed, while the European Patent Convention (EPC)¹²¹ expressly excludes computer programmes per se from patentable subject matters. The inclusion of patents filed to the USPTO by EU inventors could have increased the share of applications in the Computers and Office Machinery classes. However, further evidence and analysis are necessary to confirm such explanation.

120 Refer to pg. 73 in the JRC Report "The 2009 Report on R&D in ICT in the European Union" published in 2009, which is available at: <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2259> (Turlea et al., 2009).

121 Refer to the EPC, art.52, excluding "schemes, rules and methods for performing mental acts, playing games or doing business, and programs for computers"; available online at: <http://www.epo.org/patents/law/legal-texts/html/epc/1973/e/ar52.html> (last accessed: 22 January, 2010).

7.2.3 ICT and total patenting activity per capita: EU and US inventors

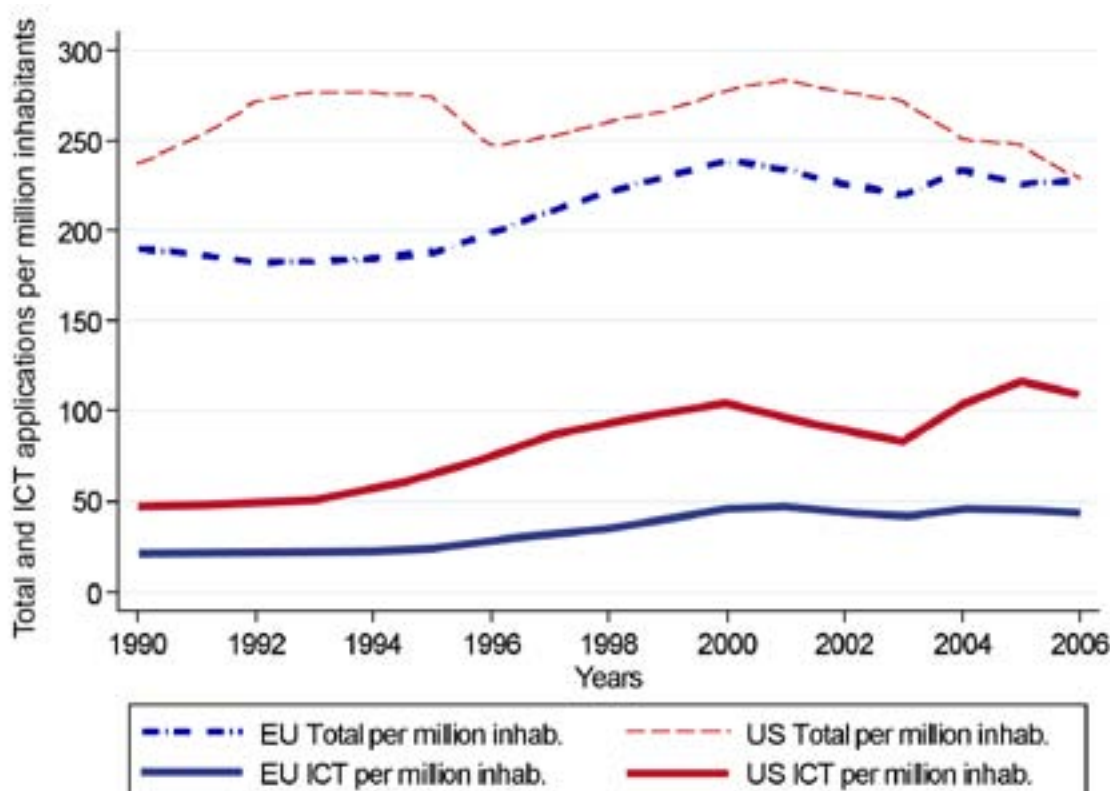
Figure 7-3 allows comparison between the US and the EU by taking into account both the total number of applications and the total number of ICT applications per million inhabitants. The share of ICT applications per million inhabitants is significantly higher in the US than in the EU, and about twice as large.

The total of EU inventors' patent applications per million inhabitants (dotted blue line) increased from 1990 to 2006 while US inventors' applications per million inhabitants (dashed red line) decreased during the same period. Although in 1990 the number of US applications was above the EU number (230 per million inhabitants vs. 190), in 2006 they were at 230 per million inhabitants for both regions.

When only ICT-related technologies are taken into account, the number of EU applications per million inhabitants ICT applications (continuous blue line) more than doubled (from 22 to 46) between 1990 and 2000, and stabilised afterwards (44 in 2006). The trend followed by US ICT applications per million inhabitants (continuous red line) is similar but with stronger variations: from 48 in 1990 to 104 in 2000, followed by a contraction between 2000 and 2003, finally reaching 110 applications per million inhabitants in 2006, more than twice the EU figure.

Therefore, in terms of both total applications and ICT applications per million inhabitants, the US has always had higher figures than the EU.

Figure 7-3: Total and ICT applications per million inhabitants, by EU and by US inventors



Source: JRC-IPTS calculations based on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States National Patent Offices and the USPTO. Inventor criterion.

7.3 ICT patenting activity by EU Member State inventors

This section provides a comparative view of the innovative prowess of the different EU Member States.

7.3.1 Member States ICT patenting activity – absolute terms

The following Table 7-1 presents three rankings of EU Member States. Countries are ranked according to the values reported in each column, which are respectively:

- (i) in Column I, the number of ICT priority patent applications in year 2006, according to the inventor criterion;
- (ii) in Columns II, the number of ICT priority patent applications in 2006, divided by the population, according to the inventor criterion;
- (iii) in Column III, the number of ICT priority patent application in 2006, divided by gross domestic product (GDP), according to the inventor criterion.

Table 7-1: ICT priority patent applications by EU Member State, 2006

I		II		III	
ICT Patent Applications		ICT Patent Applications/million inhab.		ICT Patent Applications/GDP (billion euro)	
DE	9290	FI	148	FI	4.66
FR	3467	DE	113	DE	4.00
UK	3084	NL	79	NL	2.43
NL	1296	SE	75	AT	2.39
FI	779	AT	75	SE	2.17
IT	748	FR	56	FR	1.92
SE	681	UK	51	UK	1.61
AT	616	DK	50	BG	1.55
BE	316	LU	43	DK	1.24
ES	274	IE	42	SI	1.22
DK	274	BE	30	EE	1.11
IE	177	SI	19	IE	1.01
CZ	93	IT	13	BE	1.00
GR	80	EE	11	HU	0.82
HU	74	CZ	9	CZ	0.82
PL	44	HU	7	LT	0.72
BG	40	GR	7	SK	0.62
PT	38	ES	6	LU	0.60
SI	37	SK	5	IT	0.51
SK	28	BG	5	GR	0.37
LU	20	PT	4	ES	0.28
RO	20	MT	3	MT	0.27
EE	15	LT	3	PT	0.25
LT	12	CY	3	RO	0.20
CY	2	PL	1	PL	0.16
LV	2	RO	1	CY	0.14
MT	1	LV	1	LV	0.07
EU	21,506	EU	44	EU	1.85
US	32,796	US	110	US	3.12

Source: JRC-IPTS calculations based on data from Eurostat, OECD, EU KLEMS and national statistics (million euro), on IMF data on population, and on the PATSTAT database (April 2009 release). Inventor criterion.

The reader should note that the use of fractional counting of patent applications (i.e., assigning ‘fractions’ of a patent application to different countries when it includes inventors residing in several countries¹²²) produces, as a consequence, decimal figures in the number of patent applications per country. These are, however, not shown in Column I of the table.

The first column of Table 7.1 shows that in 2006, Germany led in terms of number of ICT patent applications, with over 9,290 applications, a number 2.6 times higher than that of France in second position with 3,466 applications. UK comes third with 3,084 applications, followed by the Netherlands with 1,296 applications. All the other countries have less than 1,000 applications. 95% of all European ICT patent applications are filed by inventors based in the ten best performing countries: Germany, France, the UK, the Netherlands, Finland, Italy, Sweden, Austria, Belgium and Spain.

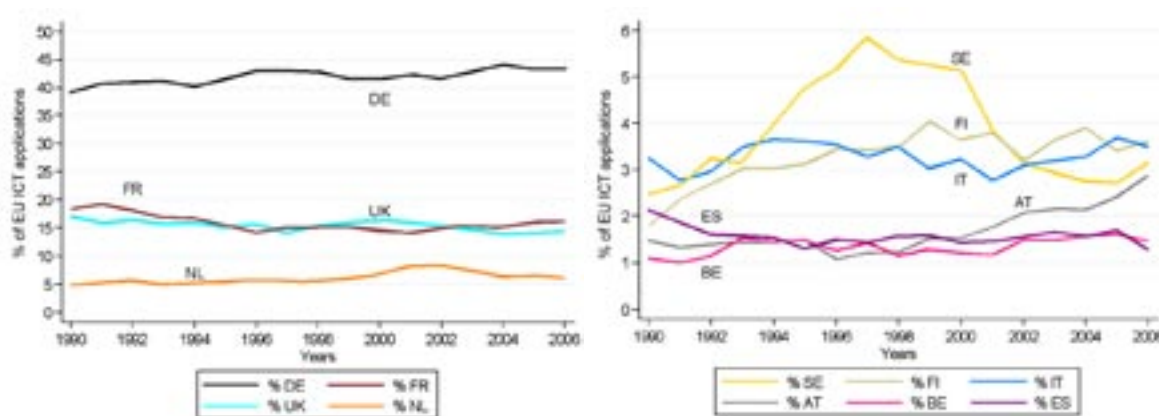
When considering the number of ICT applications per million inhabitants (Column II), and the number of ICT applications on GDP (Column III), in both cases the same countries are in the top positions: Finland, Germany and the Netherlands, followed by Sweden, Austria, France, the UK and Denmark.

7.3.2 Member States ICT patenting activity – EU shares

The next sections concentrate on the group of ten countries that filed the highest number of ICT priority patent applications, as seen above.

Figure 7-4 shows the evolution over time (1990 – 2006) of the contribution to total EU ICT applications of the ten ‘most ICT patenting’ EU countries. The left-hand panel presents the contribution (%) to the total number of EU ICT patent applications from the four EU countries with the highest number of ICT-related applications: Germany, France, the UK and the Netherlands. The right-hand panel covers the other six countries (the reader should note the difference in the vertical scales).¹²³

Figure 7-4: Contribution (%) to total ICT EU priority patent applications – inventor criterion



Source: JRC-IPTS calculations based on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices and the USPTO. Inventor criterion.

122 See Annex 8.

123 The applications are attributed per country, following the inventor criteria. Using the applicant criteria leads to identical results.

The left-hand panel of Figure 7-4 shows that Germany¹²⁴ is steadily leading with more than 40% of total EU applications since the early nineties; France and the UK follow and also maintain a relatively stable and high share of about 15%.¹²⁵ Inventors from Germany, France and the UK together consistently produce about 75% of all EU ICT patent applications. Of course, these results are affected by country size, but they seem to be consistent with expenditure data as described in earlier pages of this report. The Netherlands is the next best performer, with a share between 6 and 8% in recent years. Sweden, Finland, Italy and Austria come next, followed by Spain, and Belgium (see right-hand panel of the figure).

7.3.3 Share of ICT in total patenting activity by EU Member States, EU and US inventors

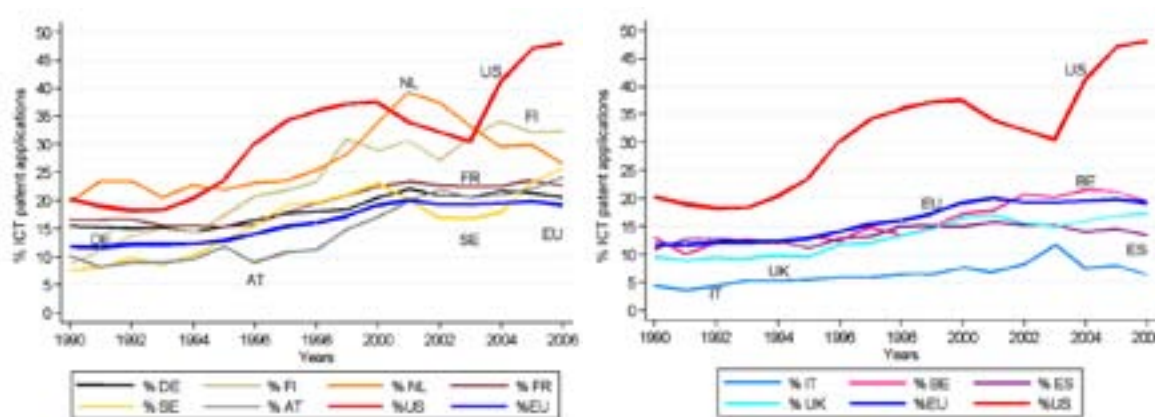
Figure 7-5 shows the evolution over time (1990 – 2006) of the share (%) of ICT applications

in the total number of patent applications at country level for the same group of ten EU countries with the highest number of ICT-related applications in 2006. The share of ICT applications in the total number of patent applications is also shown for the US, and for the EU as an aggregate, to allow comparisons.¹²⁶

The left-hand panel shows data for the six countries which are generally above the EU level in terms of the share of ICT-related applications on total patent applications. The right-hand panel covers the remaining four countries which perform, on average, below or in line with the EU level.

Germany, France and Belgium closely followed the EU trend that reached around 20% in the early 2000 and then stabilised. Sweden increased fast to similar levels, declined after 2000, then recovered. In 2006 Sweden was, together with Finland, Austria, and the US among

Figure 7-5: Share of ICT applications in total applications – inventor criterion



Source: JRC-IPTS calculations based on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States National Patent Offices and the USPTO. Inventor criterion.

124 As explained in the text, the applications are attributed per country, following the inventor criteria. From now on, for readability reasons, the text will refer to 'countries' (such as 'Germany') rather than to 'national ICT applications' (such as 'German ICT applications'). The reader should note that the data refers to the inventor criterion, as repeatedly stated in each graph, each country being in fact represented by the sum of the patent applications filed by inventors resident in that country.

125 Reduction in shares in most recent years could be related to late reporting of data from the other National Patent Offices to EPO or delayed updating of PATSTAT (see Picci, 2009).

126 The applications are attributed per country, following the inventor criteria. Using the applicant criteria leads to identical results.

the few countries that showed figures higher than in 2001. The Netherlands and Finland have the share of ICT applications closest to the US levels, although their share stagnated (Finland) or decreased (the Netherlands) after 2003 while the US share significantly increased.

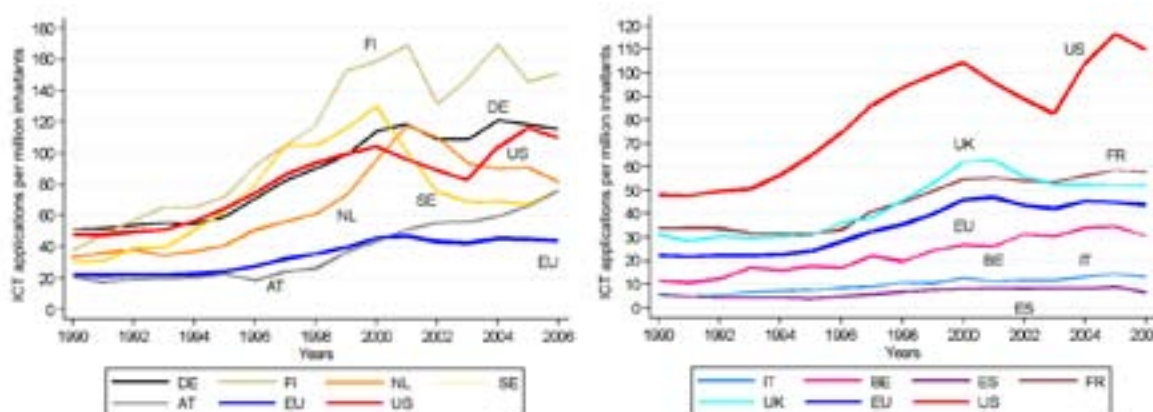
7.3.4 ICT and total patenting activity per inhabitant: EU Member States, EU and US inventors

Figure 7-6 shows the evolution over time (1990 – 2006) of the ratio of ICT applications per million inhabitants¹²⁷ for the ten best performing EU countries in terms of ICT priority patent applications in 2006.¹²⁸

Countries shown in the left-hand panel have generally a significantly higher ratio of ICT-related applications per million inhabitants than the EU average (the reader should note the difference in the vertical scales). The figure also provides US and aggregate EU data for comparison purposes.

In the left-hand panel, the number of ICT applications per million inhabitants for Finland is always much higher after 1991 than both the EU average and US values: Finland's ratio was 37 ICT applications per million inhabitants in 1990, it then increased rapidly to 169 in 2001 before slowing down, while the US ratio was 48 in 1990 to reach a first peak of 104 in 2000 and a second higher peak of 116 in 2005. Germany closely followed the US ratio during the whole period, except between 2001 and 2004 when its ratio remained high while the US ratio dropped during the dot-com crisis. The Netherlands and Sweden also have ratios close to the US one, but the ratio for Sweden dropped below the US one after the year 2001. Austria showed a sustained increase since 1996, exceeding the EU average after 2001; in absolute terms ICT applications with Austrian inventors more than doubled between 1997 and 2001, while the Austrian population only slowly increased during the period under consideration.¹²⁹

Figure 7-6: ICT applications per million inhabitants – inventor criterion



Source: JRC-IPTS calculations based on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States National Patent Offices and the USPTO. Inventor criterion.

¹²⁷ Figure 7.6 is established on the basis of the same methodology as the earlier Figure 7.3.

¹²⁸ The applications are attributed per country, following the inventor criteria. Using the applicant criteria leads to identical results.

¹²⁹ At this stage, there is no clear evidence explaining this large increase.

In the right-hand panel, the ratios of the UK and France remain above the average EU level in the considered period, while those of Belgium, Italy and Spain remain below the EU average.

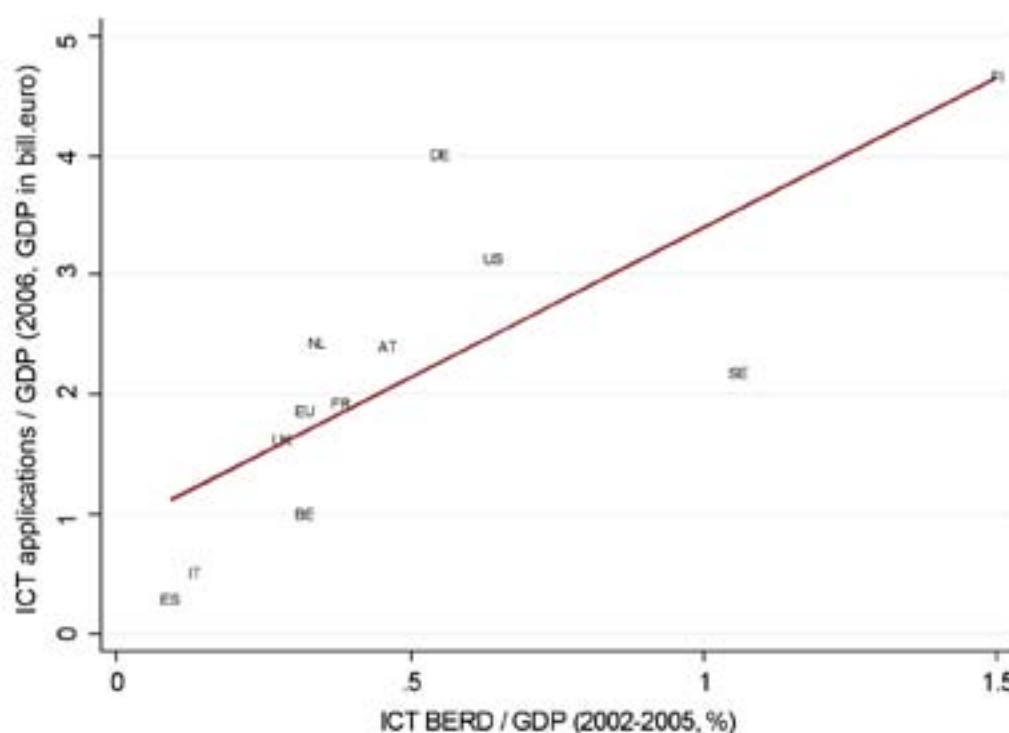
7.3.5 ICT patenting activity in comparison to business R&D expenditures

The results of patenting activities in the ten 'most ICT patenting' EU countries and in the US described in the previous sections provide a picture of the outputs of R&D activities in ICT. This section analyses a possible correlation between inputs to R&D activities in ICT and the observed patent applications, which can be considered as a *proxy* indicator of the output of such activities. R&D expenditures, such as BERD, can be considered as proxies of input resources

in such a function. This approach is in line with the approach considering patents as the output of a production process which transforms a series of input resources.¹³⁰

Figure 7-7 presents results for the ten countries with the highest number of ICT-related applications in 2006. It shows the relation between ICT patent applications in 2006 and ICT BERD, both variables being normalized by GDP. ICT BERD/GDP values are calculated as an average over four years, from 2002 to 2005, to account for the time lag between R&D investment and filing for patents. ICT patent applications/GDP are the values reported in Table 7-1 above. The red line plots the prediction results calculated by means of a linear regression, thus showing what the relationship between the two variables looks like.

Figure 7-7: ICT applications/GDP vs. ICT BERD/GDP. Top 10 ICT patenting EU Countries and the US. Inventor criterion, 2006



Source: JRC-IPTS calculations based on data from Eurostat, OECD, EU KLEMS and national statistics (million euro), and on PATSTAT data (April 2009 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices and the USPTO. Inventor criterion.

130 Refer to, among others, Baumol (2002).

Figure 7-7 shows the presence of a positive correlation between R&D investment in ICT and filing for patents, as countries with a higher ICT BERD intensity also tend to have higher ICT patenting activity.

In 2006, Finland has a high application intensity relative to GDP and also a high ICT BERD intensity. Finland, France and the UK follow the trend shown by the regression line, while Germany, the Netherlands and Austria, together with the US, show an apparently higher ICT 'patent productivity'. By contrast, patent productivity for Sweden, Belgium, Italy and Spain seem to be lower than the trend. Sweden, in particular, shows an average ICT patenting intensity in spite of a relatively high ICT BERD intensity.

However, two important caveats must be taken into account, when analysing the data presented in Figure 7-7:

- A first is the fact that, on the one hand, ICT patents can be developed by firms from both ICT and non-ICT sectors, while on the other hand, ICT BERD refers to business R&D expenditures exclusively in the ICT sector of the economy (see Chapter 2). The two concepts differ, and differences may be country-specific, for example a country could have many firms developing ICT technologies in non-ICT sectors – such as embedded systems - and thus would result in having many ICT patents relative to the size of its ICT sector, or vice-versa.
- The second is that many factors influence the very complex relation between R&D expenditure and observable inventive output, such as patent applications.

The analysis proposed in this section is therefore very rudimentary and, though it is useful as a first reflection on the linkages between inputs and outputs of R&D activities in ICT, it must be taken with extreme caution.

7.4 Conclusions

In this chapter, data based on patent applications have been used as proxy measures of countries' inventive capability. In comparison with the 2009 report,¹³¹ inclusion of patent applications submitted to USPTO allowed for wider and more consistent analysis and for comparison of EU and US performances. Moreover, an improved methodology has been applied, thus making it possible to analyse a much larger amount of data.

The analysis confirms the significant increase in the EU's ICT share in total patenting throughout the 1990s, its peak in 2000 and its stabilisation since then.

When considering patents application across all technologies, EU-based inventors file a larger number of patents applications than US-based inventors; when only ICT patent applications are taken into account, then US inventors file a significantly higher number of applications than EU inventors. The share of ICT patent applications in all technology applications is consistently much higher for the US than the UE. For example, in 2006 almost one in two applications filed by US inventors was for an ICT patent, while it was only one in five for applications filed by EU inventors. US inventors also file more than twice the number of ICT patent applications per million inhabitants than EU inventors.

When considering ICT technology classes, Computers and Office Machinery increased its shares in both the EU and the US over time (1990-2006), while Telecommunications slightly reduces its own. During the considered period, the share of US ICT patents in Computers and Office Machinery is significantly higher than the EU share, while the share of EU ICT patents in Telecommunications is above the US share, reflecting regional industrial strengths.

131 Turlea et al., 2009.

At the EU level, inventors from Germany, France and the United Kingdom filed 75% of all EU ICT patent applications in 2006. In the same year, Finland-based inventors filed 4% of all EU ICT patent applications; this represents, however, 148 ICT applications per million inhabitants, the highest ratio of the EU. For Germany, this ratio was 113 and for the US, it was 110. The EU average was only 44 in the same year.

The share of ICT applications in total applications of the Netherlands and Finland is similar to that of the US. Germany and France are generally in line with the EU average. Most other EU Member States are characterised by small shares of ICT patent applications.

A rudimentary attempt to investigate the relation between input and output of R&D in the ICT sector, by comparing the level of ICT BERD intensity (ICT BERD/GDP) to ICT patenting

intensity (ICT applications/GDP), provides some evidence of the fact that countries with higher expenditure have greater prowess in patenting. There are anyway some exceptions, like Germany, which has higher ICT 'patenting productivity' than the average for the 10 most ICT-patenting EU countries, and, the opposite, Sweden that combines high BEDR intensity with average patenting intensity.

Finally, it is worth recalling that patent applications are only a *proxy* for inventive activities. Nevertheless, the availability of a huge amount of data, the increasing speed and accuracy with which data are available and the number of countries covered make patents a powerful indicator. To allow useful comparisons at country level, in-depth analysis of country specificities must, however, be carried out, in order to take into account the specific behaviours and performance that patent analysis can reveal.

PART 2: Thematic Analysis: Trends in the Internationalisation of R&D in ICT

Part 1 of this report analysed and compared the inventive performance of individual companies, countries or regions. In contrast, this part of the report analyses how R&D, particularly ICT R&D, is taking place across various regions of the world within an increasingly internationalised environment. In other words, it analyses the dynamics of the R&D internationalisation process, i.e. the process of conducting R&D-related activities in other region than a company's country of origin (Kuemmerle, 1997). The most obvious ways of internationalising R&D are, for example, the creation of overseas R&D sites, mergers and alliances with local companies and cooperation with local universities.

The reasons for taking up the subject of internationalisation of ICT R&D activities are manifold. This analysis is partly driven by the following three concerns:

First, the scarcity of data illustrating the developments in ICT R&D activity creates a challenge for informed policy making. In particular, the process of ICT R&D internationalisation challenges the available tools for measuring inventive performance. As seen in Part I, BERD data and company data are used to track the inventive activity. However, as such data is typically assigned to a particular geographical location or company, it fails to capture the full dynamics of the inventive process that is increasingly taking place across national or regional borders. This, of course, puts the decision making process at risk by giving a partial view of the reality. Better grasping the internationalisation process and the corresponding data might help to disentangle such dynamics.

Second, following the internationalisation of their production activities, large multinational ICT companies are increasingly internationalising their R&D activities (Kuemmerle, 1997). If most international R&D activities of EU firms still seem to take place within the EU and between the EU and the US (UNCTAD, 2005), there also seems to be an emerging internationalisation trend towards Asian countries (Van Der Zee, 2006). The increasing role of developing countries, in particular in Asia, may create additional competition for R&D resources and may lead to a reduction of the amount of R&D investments in the EU. Policy makers are concerned that the location of EU company R&D facilities in non-EU countries might have a negative impact on domestic R&D expenditures and employment and on the domestic knowledge base.

Third, another concern is that internationalisation of R&D is primarily taking place in knowledge intensive industries, such as the ICT, chemical or pharmaceutical sectors - in other words, in industries seen as essential to advanced economies. It is perceived that the potential loss of local inventive capacity in these industries to other regions might harm the competitiveness of these industries and undermine the state and development of the knowledge economy in Europe.

However, the internationalisation of R&D may also have positive effects on the EU economy. For example, by accessing a wider pool of knowledge, EU companies may benefit from positive spill over effects at home which can improve their competitiveness (Branstetter, 2006; Todo, 2006). Furthermore, by building up research facilities abroad, firms get access to potentially relevant knowledge located outside

of their original location (Kuemmerle, 1997). Similarly, because firms need to increase the pace at which they bring products to the markets, they need to be close enough to react and adapt to local market needs. Thus, these knowledge flows might positively affect the overall knowledge creation balance and the inventive capacities of individual countries.

To address the concerns and complexities resulting from R&D internationalisation outlined above, it is necessary to follow the developments of the global knowledge creation network, with particular attention to the complexity of the knowledge creation process and company strategies for deciding the location of R&D sites. To this end, this analysis attempts to

create a snapshot of the current status of R&D internationalisation and to investigate the position of EU companies' ICT R&D in this process.

Part 2 of the report is organised as follows: Chapter 8 discusses the concept of R&D internationalisation and aspects such as drivers and barriers to this process. This discussion serves as a framework and as a starting point for a set of empirical analyses of R&D internationalisation in the ICT sector in Chapter 9. In particular, Section 9.1 investigates the geographical distribution of ICT R&D sites and Section 9.2 describes the empirical evidence of internationalisation of EU inventive activity in ICT based on patent statistics. Section 9.3 summarizes the main results and offers some conclusions.

■ 8 The concept of the internationalisation of inventive activity

8.1 Internationalisation of economic activity

8.1.1 Internationalisation of production

Over the last few decades, an intensive process of redistribution of production across the world has been observed (van der Zee, 2006; OECD, 2009e). This process is an illustration of how the allocation of production resources responds to disparities in regional conditions of production (Massey, 1979). The outcome of these flows is an increasing internationalisation of the environment in which companies operate. Trade, foreign direct investment (FDI) and the off shoring of manufacturing have been the most visible forms of this internationalisation.

There are both macro- and microeconomic causes for the international redeployment of resources (Massey, 1979). At the macroeconomic level, one of the main drivers of internationalisation of economic activity has been the growing openness of the international trading system, with reductions in duties and the gradual lowering of non-tariff barriers. The liberalisation of capital movements has additionally increased the level of international integration, eliminating the restrictions on FDI. In addition, the development of modern transport and communication technologies has drastically reduced the costs of moving goods, people, and information across the world and has made the integration of markets across borders easier.

At the microeconomic level, there have been three elements concerning the economic and production process that have facilitated a spatial division of labour and the internationalisation of production. First, the growing vertical and horizontal dimensions of firms and increases in

their size have been responsible for a number of considerable changes in organisational forms of firms. Examples of such organisational changes include the separation and decentralisation of technical, control, and management functions and the division of the production process into separately functioning stages. This, in turn, has allowed firms to spatially divide the value chain and distribute distinct stages across different locations. Second, growing competition has increased the pressure to cut labour costs and increase productivity, which in turn accelerated the process of product standardisation, automation of production, and the introduction of ICT-based processes in manufacturing. Combined with modularisation of production, the increasing trend of product standardisation has further allowed for a geographical separation of different phases in the production process. Third, parallel to the changes in the organisation of economic activity and production, the structure of the economies in the developed countries has changed. New sectors, such as electronics or telecommunications, are playing an increasingly important role. One of the common characteristics of these industries is the type of competition, which is based on fast speed of technological change. The exposure to constantly changing conditions increases the relative importance of research and development in the national employment structure and reduces the reliance on the workforce involved in the manufacturing activities.

As a result of the above discussed changes, the transformations in the production process and the structure of economy have accelerated the process of spatial redistribution of labour according to the requirements of each activity and the pattern of regional conditions. This, in turn, has lead to the internationalisation of production.

8.1.2 Internationalisation of R&D

As part of the process of spatial division of economic activity, a new trend seems to have emerged over the last few years. A number of large corporations have slowly moved away from the strategy of locating only production facilities outside of their home country in order to manufacture products developed in their home country at a lower cost and, instead, have begun to seek new knowledge opportunities worldwide (Bartlett and Ghoshal, 1990; Dunning, 1994). The new breed of 'meta-national' companies is increasingly building a new kind of competitive advantage by discovering, accessing, mobilising, and leveraging knowledge from a number of locations across the globe (Doz, Santos and Williamson, 2001). This means that more and more, firms are locating R&D outside of the country where the company is headquartered. This type of spatial division of labour reflects the increasing transfer of sophisticated, knowledge-intensive activities to other locations than companies' domestic markets. Such behaviour contrasts with the traditional approach of projecting home-country experiences to other locations and keeping high value-added activities such as R&D, marketing, and strategy at headquarters.

Regarding the demographics of firms that internationalise their R&D activities, large multinational companies (MNCs) are the unquestionable leaders (Doz, Santos and Williamson, 2001; see Section 9.1). This does not come as a surprise considering that typically about 80% of business R&D activities are concentrated in large firms with 10,000 or more employees (Patel and Pavitt, 1991). A United Nations survey of world trade activities reaches a similar conclusion (UNCTAD, 2005). Consequently, it is mainly large multinational firms that seem to drive the process of R&D internationalisation. The fact that SMEs may also be involved in global value chains does not seem to influence the leadership of MNCs in a significant way.

Another important observation of the available studies on R&D internationalisation

is that this process remains apparently limited to a small number of developing countries and economies in transition (UNCTAD, 2005). R&D-related investment flows remain concentrated mainly within and between the highly developed countries: the US, Japan and EU countries. This, however, is forecasted to change over time (OECD, 2005). As the process of changing the geography of technology-intensive industry continues, Asian countries are becoming an essential link in the global value chain and their importance and attractiveness as locations for higher value-added firm activities such as R&D are growing. There are already signs that Asia is becoming the target for new collaborations in innovative efforts, both within Asia, and between OECD countries' ICT firms and Asian partners (OECD, 2009e). This observation is supported by findings presented in Chapter 9 of this report.

Despite the fact that the topic of R&D internationalisation has already attracted considerable attention, there is still relatively little empirical evidence of the outcomes of this type of activity, e.g. a significant number of international patents (see Section 9.2). For example, in one of the pioneer studies on the subject, by analysing the patenting activity of U.S firms, Patel and Pavitt (1991) found that the technological activities of multinational firms are concentrated in their home country. More recent studies do not show significant changes with respect to the internationalisation of R&D activity either (Picci, 2008; Di Minin, 2006). In other words, the observed output of international inventive activity apparently remains low. Similarly, Ariffin and Figueiredo (2006) report results that run counter to some existing generalisations concerning the direction of knowledge and expertise flows between developed and developing countries. By studying a number of selected firms in the electronics industry in Malaysia and Brazil, they find that these firms have managed to develop significant levels of innovative technological capabilities without external stimulus.

Most of currently available studies conclude that, in general, features of the R&D process, such as multidisciplinary and tacit knowledge inputs and commercial uncertainties surrounding outputs, create considerable challenges to the management of globally dispersed R&D activities (Bo, 2006). In addition, as illustrated by an empirical analysis of the determinants and barriers of R&D internationalisation, both geographical and cultural distance inhibits international collaboration between researchers (see Section 8.2.1). Consequently, tangible outputs of international inventive collaboration remain scarce. Nevertheless, there is also broad agreement that the process of R&D internationalisation will intensify over time. This is particularly true for ICT R&D, which seems to be more prone to internationalisation than other technologies. The analysis of international ICT patents presented in Section 9.2 of this report, illustrating the level of internationalisation of R&D output, confirms this observation.

8.2 Characterisation of internationalised R&D

In order to better understand the process of internationalising of R&D activities, this section discusses the drivers and barriers to locating R&D units abroad. A presentation of firms' strategies of knowledge flow between overseas units and their headquarters is also included.

8.2.1 Drivers and barriers to R&D internationalisation

Although there are many aspects that a firm takes into account when making a choice for R&D-related investment, recent studies on R&D investment show that three main criteria determine the final decision (Dunning, 1988; Dunning, 1994; Tübke, 2009). The first criterion is the access to resources that, in most cases, are non-transferable and location-specific. Furthermore, access to these resources must be perceived as vital to a firm's activities. Examples

of such resources include inputs to R&D activity, e.g. scientists and universities, or the knowledge about customers and markets. As a result, in general, firms are more likely to locate their foreign R&D units close to existing production facilities or institutions that contribute to a firm's activities. The second criterion is related to the macroeconomic environment of the host country and includes, for example, a reliable legal framework for R&D and macroeconomic and political stability. Cost seems to be the third criterion for choosing a location for a new R&D unit. This issue is particularly important in the context of moving R&D units to developing countries. In such cases, firms expect to benefit from lower labour costs and/or government incentives, including exemptions from certain taxes. Firms are paying more attention to the cost consideration as knowledge spreads around the world and as technological tasks become easier to separate, modularise, and divide into distinct phases (Brusoni, et al., 2001). These changes allow firms to allocate different parts of R&D projects to various R&D units, depending on their expertise and cost advantage.

Another possibly important driver of R&D internationalisation is the rise of the open innovation model (OECD, 2008c). To match the demand for innovation, firms have begun to look for external sources of inspiration, including people, institutions and other companies. The main characteristic of open innovation is the organisation of innovative activities across firm boundaries through various governance mechanisms. Examples of such mechanisms include, for example, partnerships with external parties or acquisition or sale of knowledge. This way of accessing knowledge is particularly important in industries characterised by rather short technology life cycles, such as the ICT sector (OECD, 2008c).

When making a decision concerning the creation of a foreign R&D unit, a location's advantages have to be weighed against its disadvantages. Geographical separation remains one of the main

Drivers and barriers to the internationalisation of ICT inventive activity

An analysis of the determinants of the internationalisation of ICT inventive activity reveals that:

- Physical (geographical) proximity is the main determinant of the strength of bilateral ties in the process of innovative collaboration. In addition, cultural differences negatively affect international collaboration.
- On the question of how important intellectual property protection is in the internationalisation of inventive activity, the analysis did not find unambiguous evidence supporting the hypothesis that strong IPR protection is vital to doing research abroad.
- Similarly, no unambiguous effect of FDI on R&D internationalisation was found.

In conclusion, the results of this study confirm that, despite some similarities, the internationalisation of productive activities and R&D are still two quite distinct sides of the globalisation coin.

barriers to R&D internationalisation (Dachs, 2008; Picci, 2008). The central issue here seems to be the difficulty to transfer tacit knowledge. Despite the availability of modern communication technologies, the lack of direct interactions hampers the exchange of knowledge and expertise. Furthermore, differences in national and regional business environments might create some incompatibilities or conflict of interests between home and host country. The sources of such incompatibilities include the national educational system, industrial relations, technical and scientific institutions, policies, and many other national institutions that are fundamental to economic and innovative activities (Freeman, 1995). For example, differences in institutional arrangements might be an obstacle to the creation of a common framework for governing cross-border business activities (Carlsson, 2006). Thus, the combination of the differences and similarities between countries might play a role in stimulating or dampening the progress of R&D internationalisation.

The box above summarises the results of an empirical analysis of drivers and barriers to the internationalisation of ICT inventive activity.¹³²

8.2.2 R&D internationalisation strategies

One way of looking at the internationalisation of R&D activity is to focus on the exploitation of home base-generated knowledge versus the exploitation of external sources of knowledge (Kuemmerle, 1997; see also Niosi, 1999 and Gassmann and von Zedtwitz, 2002). The former is called *asset-exploitation* strategy and the latter *asset-seeking* strategy.

Regarding *asset-exploitation* strategy, it is argued that the process of building knowledge creation units abroad is the natural step a firm makes after having established its presence through either export or production activities in a new market (Niosi, 1999; Boutellier, Gassmann and von Zedtwitz, 2008). By creating learning capacities in these regions or countries, companies seek ways to acquire knowledge about these markets. This allows them to, for example, customize their products to better serve customer needs, and hence increase their revenues. Companies are likely to follow this strategy in developing markets, such as the European Union

132 This analysis is based on "The internationalization of ICT inventive activity: A gravity model using patent data" (Picci, 2008). For further details regarding the methodology, data used and an extensive presentation of the results, please refer to the original work.

and Asia, to adapt their products to meet local requirements. In other words, the expertise on foreign markets *extends the knowledge* that was generated at headquarter. In this case, firms focus in their knowledge acquisition process mostly on the 'D' element of R&D (Kuemmerle, 1997).

The *asset-seeking* strategy reflects another reason why companies locate R&D activities abroad - to gather *knowledge and expertise that is new* to them. Setting up an R&D site to tap into the resources of a particular location serves to augment the home base knowledge. In this case, knowledge supply factors are more important than simply learning about the characteristics of a new market. By following the asset-seeking strategy, firms explicitly aim to tap into resources abroad because they are either of good quality or not expensive, or both. Here, location factors such as the quality, size, and specialization of the knowledge-base determine the location decision. An example of this strategy is to follow cutting-edge technologies and customers that are usually located in the developed regions, such as North America, Japan and Europe. In order to gain access to this cutting-edge knowledge, firms send their own researchers to participate in the research that takes place in these locations (Boutellier, Gassmann and von Zedtwitz, 2008).

Despite the abundance of the literature discussing the importance of knowledge

acquisition by tapping onto foreign resources, there is, in fact, little evidence to support the hypothesis that this is really taking place. On the contrary, with respect to the knowledge creation by foreign R&D units, empirical studies show that firms tend to focus the work of their foreign technology sites on those domains in which they are strong at home (e.g. Patel and Vega, 1999). The aim of this strategy is to adapt products, processes, and materials to suit foreign markets and to provide technical support to offshore manufacturing plants. In other words, there is still little evidence of asset-seeking activities and even the most internationalised firms rarely go abroad to seek new expertise opportunities.

To sum up, access to new knowledge and transfer of knowledge between various locations are driving the internationalisation of R&D activities. These reasons together with rapid innovation and strong market adaptation needs are driving the process of R&D internationalisation in knowledge-intensive sectors, such as the ICT industry. However, there is only limited available evidence of companies doing R&D internationally. Thus, taking this into account, the following chapter aims to identify and quantify the position of the EU ICT sector in the process of R&D internationalisation.

■ 9 Empirical evidence of internationalisation of ICT R&D

This chapter builds on the discussion presented in Chapter 8 and aims to assess the size and importance of the internationalisation of ICT inventive activity by looking at it from various perspectives. First, by using the *JRC-IPTS ICT R&D Location Database*, it analyses the input side of the inventive process, i.e. location of ICT R&D sites in Section 9.1. By creating a global map of ICT R&D sites with respect to location of companies' headquarters, this first section aims to show what the global distribution of ICT R&D activities looks like or, in more concrete terms, to find out how major ICT companies internationalise their R&D.¹³³ Second, by carrying out an extensive analysis of international patent applications, i.e. of inventive output, Chapter 9 provides some evidence of the level of internationalised ICT R&D output across various regions of the world (Section 9.2). This analysis casts some light on the differences in the internationalisation levels of ICT and other technologies inventions and the differences in the levels of international R&D collaboration between the EU, the US and Asia.

9.1 Global distribution of ICT R&D sites

9.1.1 Introduction

The following analysis attempts to create a map of ICT R&D sites of major ICT companies and, on this basis, to assess the internationalisation of their R&D infrastructure. In particular, Section 9.1.2 tackles two questions: first, what does the regional distribution of ICT R&D sites (of the considered companies) look

like? Second, where do companies from different regions of the world locate their R&D sites? In other words, the analysis focuses on explaining where ICT sector knowledge is being produced and what the geographical origins of companies owning these ICT knowledge production sites are. Section 9.1.3 compares the average degree of R&D sites internationalisation across companies from various regions. The main findings are summarized in Section 9.1.4.

The analysis in this section is based on information included in the *JRC-IPTS ICT R&D Location Database*. This dataset includes location information for over 1,800 R&D sites that, in 2007 and 2008, belonged to 80 multinational companies that are considered to be major *semiconductor influencers*. Among the companies included in the sample are, for example, Microsoft, IBM, Sony and Siemens. Despite the small sample size, companies included in the analysis are representative of the ICT sector. For example, in 2008, these companies accounted for more than 30% of all patent applications to the USPTO. Moreover, the sub-group of 40 companies for which information was matched with the *ICT Scoreboard* database (see Chapter 6) spent nearly €70 billion on R&D. This represents 53% of the 2008 R&D budget of all ICT companies included in the *ICT Scoreboard* or over 19% of the total R&D investments of all the *Scoreboard* firms. The list of companies included in the Location Database can be found in Annex 9. The methodological box below describes in detail the creation process of this dataset.

It has to be noted that the results presented below are only descriptive evidence that does not provide insights into the type, size, quality or scientific complexity of activities performed in these R&D sites. In other words, the mere number of R&D sites may be misleading when

¹³³ Theoretically, there are a number of ways of analysing inventive input, e.g. firms' investments in research and development. However, such data hardly exist and, until now, efforts to map cross-country industry R&D expenditures have been not very conclusive (see, for example, UNCTAD, 2005).

JRC-IPTS ICT R&D Location Database

The JRC-IPTS ICT R&D Location Database contains information on over 1,800 ICT R&D sites that belong to 80 ICT companies (see Annex 9). Companies included in the database are considered to be the major 'semiconductor design influencers' and therefore essential industrial actors in the ICT value chain. It has to be noted that the selection of companies included in the JRC-IPTS ICT R&D Location Database was based on expert knowledge and does not cover the entire ICT industry, but instead, attempts to cover companies which are considered to have the most impact on the ICT value chain.

In addition to the basic information on R&D sites, such as OEM name, R&D site name and location, the dataset includes very detailed information on the type of activity conducted at nearly every site and, to a limited extent, its size.

Part of this information was collected by iSuppli on behalf of JRC-IPTS during the period 2007-2008.¹³⁴ Information about companies' geographical origins was in general extracted from the EU Industrial R&D Investment Scoreboard dataset.¹³⁵ When necessary, the Goliath database¹³⁶ of the Gale Group and the Amadeus database¹³⁷ of the Bureau van Dijk were also used to identify the country of origin of companies.

Regarding the regional coverage, the dataset includes over 40 countries and allows us to assign them to one of the four major regions that play the most important role in the development and production of ICT products. These regions are:

- **Americas Region:** North, South, and Central America, Caribbean countries,
- **Asia-Pacific and Central Asia (APAC) Region:** India, Southeast Asia, China, South Korea, Taiwan, the Philippines, Australia, New Zealand, Indonesia, Indian Ocean and Pacific Ocean countries,
- **EMEA Region:** Europe, Russia, the Middle-East to the India border, and Africa,
- **Japan.**

trying to draw conclusions on the importance of firms' presence in a particular location. As argued in Chapter 8, there are various reasons for conducting R&D abroad and, as a result, the amount of effort and resources invested by companies in various R&D sites may vary. Therefore, the evidence presented here should be interpreted with caution.

9.1.2 Global distribution of ICT R&D sites

The analysis starts with a first look at the global distribution of ICT R&D sites across the

four major world regions listed in the above box, i.e. Asia and the Pacific, Americas, Europe and the Middle East, and Japan. It also looks at where the headquarters of companies owning these sites are located. Then it examines where ICT companies from different regions locate their R&D sites.

Global distribution of ICT R&D sites by location and ownership

Table 9-1 reveals some patterns of global distribution of ICT R&D sites. First, by including a breakdown by site location in one of the four world regions, it shows companies' preferences for location selection for conducting R&D activities. Second, the information in the second part of the table indicates to whom these R&D sites belong.

¹³⁴ See at: <http://www.isuppli.com/>

¹³⁵ See at: http://iri.jrc.ec.europa.eu/research/scoreboard_2007.htm

¹³⁶ See at: <http://goliath.ecnext.com/>

¹³⁷ See at: <http://www.bvdep.com/en/amadeus.html>

Table 9-1: Global distribution of ICT R&D sites by location and ownership, 2007/08, in %

ICT R&D sites by ...		
	... location	... ownership
APAC	22	10
Americas	30	36
EMEA	24	20
Japan	24	35
Total	100	100

Source: JRC-IPTS calculations, N=1808.

Concerning **location of ICT R&D sites**, Table 9-1 indicates that almost one third (30%) of 1,808 ICT R&D sites belonging to the major influencers of semiconductor design is located in the Americas region. The EMEA region and Japan each host 24% of ICT R&D sites. 86% (382) of the R&D sites located in the EMEA region are in the EU countries. Finally, 22% of all ICT R&D sites are in the APAC region, which is only 2% less than in the entire EMEA area.

Regarding **ownership of R&D sites**, Table 9-1 indicates that firms with headquarters in the Americas region own 36% of all ICT R&D sites. Japan has 35% of all R&D sites, and is therefore the second largest owner. Companies from the EMEA region have twice as many R&D sites as their APAC counterparts, which own only 10% of all ICT R&D sites.

A simple comparison of the information concerning the location and ownership of ICT R&D sites reveals that only the Americas region

and Japan can be considered as *net exporters* of ICT R&D sites. That is, the number of R&D sites owned by companies from these regions is greater than the number of sites located there. By the same token, the APAC and EMEA regions are *net importers* of R&D sites.

Where are ICT R&D sites located and who owns them?

Table 9-2 shows the regional distribution of ICT R&D sites and the region of origin of companies owning them in 2007/08.

ICT R&D sites located in the EMEA region:

Out of 442 ICT R&D sites located in the EMEA region, 45% of them are owned by EMEA companies and 32% belong to companies with headquarters in the Americas region. The remaining 23% are distributed between companies headquartered in Japan (16%) and the APAC region (7%).

Table 9-2: Distribution of ICT R&D sites by company HQ location, 2007/08, in %

Table 1.2: Breakdown of R&D sites by company HQ location, 2001-2010					
Location of R&D sites					
		APAC	Americas	EMEA	Japan
Location of headquarters	APAC	29%	4%	7%	1%
	Americas	31%	69%	32%	3%
	EMEA	18%	13%	45%	3%
	Japan	22%	14%	16%	92%
Total		100%	100%	100%	100%
Number of R&D sites		399	536	442	431

Source: JRC-IPTS calculations, N=1808.

ICT R&D sites located in the APAC region:

Likewise, out of 399 ICT R&D sites located in the APAC region, 29% of them are owned by APAC companies and 31% belong to companies with headquarters in the Americas region. The remaining 40% of R&D sites located in the APAC region are nearly equally distributed between companies headquartered in the EMEA and Japan region.

The APAC region is the only one where the share of R&D sites belonging to companies from another region (Americas: 31%) is higher than the share of R&D sites owned by local firms (APAC: 29%). Furthermore, it should be noted, that it is American companies that own the highest number of sites in the ICT R&D in the APAC region, i.e. 31% vs. 22% for Japan and 18% only for EMEA. Thus, this observation tends to confirm the strong position of American companies in the Asian region in terms of both production and research activities.

In all of the remaining regions, local companies own the highest share of R&D sites. However, there are considerable differences. For example, whereas the EMEA region hosts a very high share of foreign-owned R&D sites (55%), only one third of the R&D sites located in the Americas region are controlled by foreign companies. Regarding the Japan region, local companies own the lion's share of R&D sites, i.e. over 90%, and R&D sites of firms from the other regions are nearly nonexistent.

As seen above, the largest share of foreign R&D sites located in the EMEA region is controlled by American companies (one third). This might suggest that, like the APAC region, the considerable presence of American companies in Europe is positively correlated with the inventive output measured by the number of patented inventions that American researchers develop together with their EU counterparts (see Section 9.2.5).

Where do ICT companies locate their R&D sites?

Table 9-3 shows the location of ICT R&D sites with respect to the place of origin of company headquarters. This data allows us to cast some light on companies' decisions concerning the location of their R&D sites in one of the four world regions.

R&D sites owned by companies headquartered in the EMEA region: Out of 353 R&D sites owned by companies headquartered in the EMEA region, 57% were located in the EMEA region. The other most frequent locations for R&D activities among the firms headquartered in the EMEA region were the countries from the APAC (20%) and Americas (19%) regions. Only 4% of R&D sites owned by EMEA companies were located in Japan.

R&D sites owned by companies headquartered in the APAC region: Likewise, out of 174 R&D sites owned by companies

Table 9-3: Location of R&D sites by company HQ location, 2007/08, in %

		Location of headquarters			
		APAC	Americas	EMEA	Japan
Location of R&D site	APAC	67%	19%	20%	14%
	Americas	13%	57%	19%	12%
	EMEA	17%	22%	57%	11%
	Japan	3%	2%	4%	63%
Total		100%	100%	100%	100%
Number of R&D sites		174	649	353	632

Source: JRC-IPTS calculations, N=1808.

headquartered in the APAC region, 67% of their R&D sites were located in the APAC region. The other most frequent location for R&D activities among the firms headquartered in the APAC region were the countries from the EMEA (17%) and Americas (13%) regions. At the same time, only 3% of R&D sites owned by APAC companies were located in Japan.

Other regions: The pattern of locating R&D activity close to a company headquarters is very common among firms from other regions as well. However, the data shows that whereas companies from the Americas and EMEA regions have over 40% of their R&D sites in other regions, their Japanese counterparts maintain over 60% of their R&D sites in Japan. Although this level of domestic ownership of R&D sites located in a particular region is only slightly lower than in the APAC region, it confirms the generally low level of internationalisation of Japanese firms.

As of 2008, American ICT firms seemed to consider the EMEA countries as most attractive for locating R&D sites. 22% of all American research sites are located in the EMEA region. However, despite the long-standing R&D collaboration between US and EU firms and researchers, as illustrated by the level of joint patents (see Section 9.2.4), the data indicates that the APAC region is almost as attractive to American companies for establishing R&D sites as the EMEA one. In 2007/08, the APAC region hosted only 3% fewer American R&D sites than the EMEA region. In addition, for Japanese firms, the EU countries were the least attractive for conducting R&D activities. Only 11% of all the R&D sites owned by Japanese firms were located in the EMEA region.

The analysis of the data in Table 9-3 allows us to draw some first conclusions on the patterns of R&D investments in the major world regions. Overall, it confirms the existence of strong linkages between the US and Europe in scientific and technological cooperation and mutual investments in R&D

activities. However, it also clearly shows the increasing attractiveness of the APAC region as a destination for R&D investments. Companies from all major economic regions seem to share this view and, as the data reveals, the most frequent locations for EMEA ICT R&D activity are the emerging Asian economies.

9.1.3 Internationalisation of R&D sites

The following section presents the analysis of the levels of internationalisation of R&D sites for companies from different regions. Two indicators were computed, based on information on the number and location of R&D sites, by region of origin and also by country of origin of their mother companies:

- **Average share of international R&D sites at country level** represents the average percentage of R&D sites located in countries other than those where the companies' headquarters are located.
- **Average share of international R&D sites at regional level** represents the average percentage of R&D sites located in regions other than those where the companies' headquarters are located.

The above defined indicators help to describe the relative importance of the number of R&D sites located in other countries or regions in the overall composition of firms' R&D infrastructure and, in addition, allow us to compare the internationalisation of R&D sites across different regions.

It should be noted that R&D sites located abroad are likely to be, on average, smaller than sites in the home country. Furthermore, as indicated in Section 9.1.1, this data does not give information on the type and scientific complexity of activities performed in these R&D sites. Nevertheless, the above defined indicators provide an indication of R&D internationalisation of firms from different regions.

Table 9-4: Share of international R&D sites at country and region level, 2007/08, in %

		Share of international R&D sites at...	
		... country level	... regional level
Location of headquarters	APAC	65	33
	Americas	50	43
	EMEA	76	43
	Japan	37	37
	Average	52	40

Source: JRC-IPTS calculations, N=1808.

Table 9-4 shows the average levels of R&D site internationalisation among companies from the four regions. As indicated above, the share of international R&D sites at country level reflects the average percentage of R&D sites located in countries other than those where the companies' headquarters are located. The other indicator shows the same value at the regional level.

According to Table 9-4, at the country level, on average 52% of all R&D sites are located in countries other than the companies' headquarters. Companies from the EMEA and APAC regions have the most internationalised distribution of R&D sites. The percentages of international R&D sites at country level for companies from these regions reach, on average, the highest scores: 76% of R&D sites owned by EU companies and 65% of R&D sites owned by Asian companies are located in countries other than those in which the companies are headquartered. Not surprisingly, the lowest level of internationalisation measured by this indicator is for Japanese companies. On average, only 37% of R&D sites owned by a Japanese company are located outside of Japan.

The high values of R&D site internationalisation at country level for companies from the APAC and EMEA regions may result mainly from the large number of countries included in the definition of these regions (see above the methodological box on *JRC-IPTS ICT R&D Location Database*). For example, the German R&D sites of companies headquartered in the UK are counted as 'international sites'

by this first indicator. Thus, the average share of international R&D sites at regional level is also examined in a second indicator.

As can be expected, the average percentage of international R&D sites measured at regional level is significantly lower than the percentage of international R&D sites measured at country level. As reported in Table 9-4, the total sample average of R&D sites located in regions other than the regions in which the companies are based is 40%, compared to 52% for the previous, country-level, indicator. Values for individual regions are considerably smaller as well. This is consistent with the discussion of distance as a barrier to R&D internationalisation in Section 8.2.1. For example, the share of international R&D sites for the APAC companies is 33%, the smallest in the sample.

R&D sites belonging to companies from the EMEA and Americas regions are the most internationalised. The levels of international R&D sites at regional level for companies from these regions reach 43%. In other words, nearly half the ICT R&D sites owned either by EU or American companies are located outside the region in which these companies are headquartered.

9.1.4 Summary of main findings

The above analysis provides a number of insights with respect to the global distribution of ICT R&D sites and their ownership based on 2007/2008 data. The most important findings can be summarised as follows:

- First, the largest share (30%) of the nearly two thousand R&D sites included in the analysis is located in the Americas region. Although Japan hosts an equal share of ICT R&D sites to the EMEA region (24%), the latter covers a number of countries, whereas the former consists only of one country. Furthermore, there are nearly four hundred R&D sites in the APAC region, representing a share of 22%, only 2% less than in the entire EMEA area. Consequently, hosting such shares of ICT R&D sites can be interpreted as a considerable advantage for both the US and the Asian region, including Japan, compared to the EU.
 - Second, regarding the ownership of ICT R&D sites, American and Japanese firms own two thirds of all ICT R&D sites from the analysed sample worldwide. Thus, when taking into account the number of R&D sites owned by companies from these regions and the number of sites located there, they can be considered as *net exporters* of ICT R&D sites. Using the same criterion, the APAC and EMEA regions emerge as *net importers* of ICT R&D sites.
 - Third, independently of the region of a firm's headquarters, most of the firms tend to locate most of their R&D sites in the region in which they are based. The APAC region is the only exception in this respect. In the APAC region, the share of R&D sites owned by firms from the Americas region is higher than the share of R&D sites owned by local firms.
 - Fourth, although most of the ICT firms included in the analysed sample tend to locate their sites in their home country or region, the above analysis revealed some significant differences between firms from the four regions. For example, when considering only cross-regional R&D site locations, companies from the APAC region have the least internationalised distribution of R&D sites, whereas American and EU ICT firms have the most internationalised R&D site distribution.
 - Lastly, although it has been confirmed that there are very strong linkages between the triadic countries, i.e. Japan, the US and the EU, the APAC region seems to be very attractive as a location for R&D sites for ICT companies from every region. For example, although for American firms, EMEA countries seem to be most attractive for locating R&D sites abroad, the APAC region hosted only 3% less American R&D sites than the EMEA region. At the same time, EMEA countries seem to be the least attractive for Japanese firms for locating their R&D activities. Companies from the EMEA area also seem to favour the APAC region over the remaining two regions. These results indicate the increasing attractiveness of the Asian countries as a location for not only production or service facilities but also for R&D-related investments as well.
- Again, as a word of warning, it has to be noted that these data do not provide information on the quality and technological and scientific advancement of the research conducted in any of these R&D sites. The evidence presented here, and the above conclusions, should therefore be interpreted with caution, taking into consideration the nature of the analysed data (i.e. only the number of R&D sites) and characteristics of the sample of ICT companies analysed.

9.2 Empirical evidence of internationalisation of EU inventive activity in ICT based on patent statistics

The previous section provided a mapping of the global distribution of ICT knowledge production infrastructure. This mapping allowed us to analyse the internationalisation of ICT inventive activity by looking at it from the input side of inventive activity. In contrast, the following section attempts to measure and identify inventions that have been developed as a result of international collaboration by analysing patent data.

Several researchers have already exploited in various ways the information contained in patent data (see, among others, Patel and Pavitt, 1991; Patel and Vega, 1991, and Le Bas and Serra, 2002). However, while most previous studies have considered the patent portfolios of firms, here patents are attributed to countries, by exploiting the fact that patent data provide separate information on the places of residence of the inventors and the applicants.¹³⁸ Thus, it is possible to track the output of inventive activity conducted by actors residing in different countries and regions.

As in Chapter 7, the source of the data here is also the European Patent Office Worldwide Patent Statistical Database (PATSTAT). The methodological box below describes the approach this study has taken to the analysis of the internationalisation of ICT inventive output by using patent statistics.¹³⁹ It has to be noted that

this ICT inventive output is not only produced by the ICT sector, as defined in Part 1 of the report, but also by other sectors of the economy, such as automotive, aeronautics, etc. Further details concerning the methodology can be found in Annexes 8 and 10.

The remainder of the chapter is organised as follows: Section 9.2.1 describes the level of internationalisation of EU ICT inventive activity. Section 9.2.2 compares the internationalisation levels of ICT and other technologies. Section 9.2.3 compares the internationalisation level of the EU and the US. Section 9.2.4 assesses the level of inventive collaboration between the EU and the US. Section 9.2.5 compares the levels of collaboration between the EU and Asia and between the US and Asia. Section 9.2.6 summarises the main findings.

138 The notions of inventor and of applicant in patent application procedures are defined in Chapter 7 and in OECD (2008a).

139 To identify ICT patent applications, the taxonomy of the International Patent Classification (IPC) technology classes proposed by the OECD is adopted (OECD, 2008a): 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.

9.2.1 The internationalisation of the EU ICT inventive activity

The current analysis starts with a general assessment of the internationalisation of the ICT inventive activity of EU companies and EU-based researchers for the period 1990 to 2006. Figure 9-1 presents the levels of international collaboration between EU and non-EU inventors (blue line), co-ownership of inventions by EU and non-EU applicants (dotted green line) and cross-border ownership of inventions (red line and dotted pink line). All four measures of internationalisation of ICT inventive activities presented in Figure 9-1 are based on the concepts of internationalisation defined in the following methodological box.

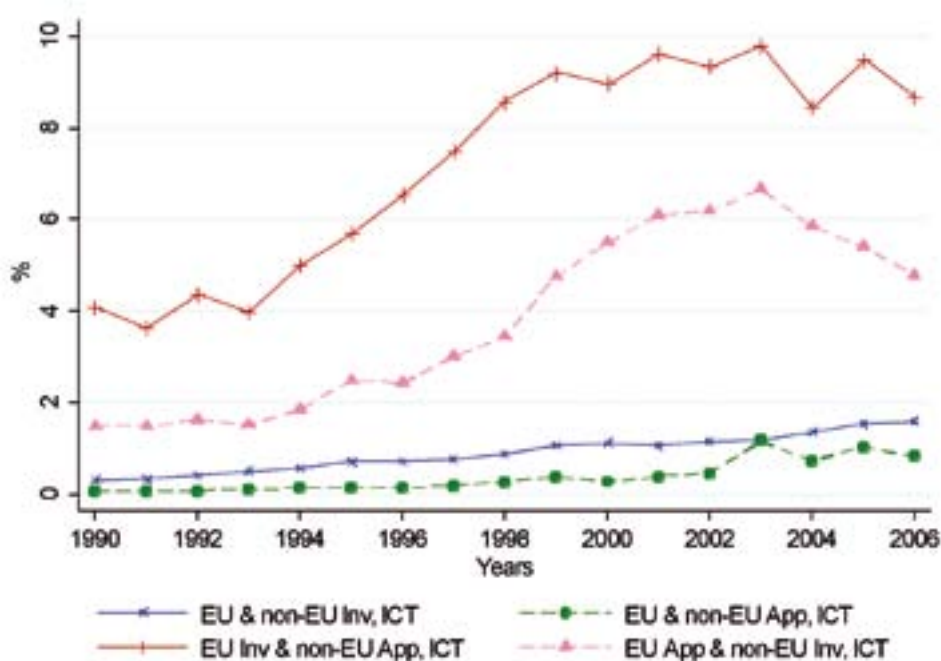
Figure 9-1 shows that the level of collaboration between EU and non-EU inventors

on ICT inventions (blue line) is quite low. By 2006, the level of this measure had not reached 2% of the total number of EU ICT inventions. The level of co-ownership of ICT inventions remained even lower (dotted green line).

With respect to the levels of cross-border ownership of ICT inventions, Figure 9-1 shows that, between 1990 and 2006, the share of non-EU ICT inventions owned by EU applicants in the total number of EU ICT inventions (dotted pink line) grew from 2% to around 5%. In the same period, the share of EU ICT inventions owned by non-EU applicants grew from 4% to almost 9% of the total number of EU ICT inventions (red line).

An analysis of this data allows us to draw the following conclusions. First, there are significant differences among the levels of the four alternative

■ Figure 9-1: Shares of collaboration between EU and non-EU inventors, co-ownership and cross-border ownership of inventions in the total number of EU ICT inventions, 1990-2006



Notes: Priority patent applications filed at European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU & non-EU Inv, ICT: % of ICT inventions with EU and non-EU inventors in the total EU ICT inventions (according to the inventor criterion).

EU & non-EU App, ICT: % of ICT inventions with EU and non-EU applicants in the total EU ICT inventions (according to the applicant criterion).

EU Inv & non-EU App, ICT: % of ICT inventions with at least one EU inventor and non-EU applicant in the total EU ICT inventions (according to the inventor criterion).

EU App & non-EU Inv, ICT: % of ICT inventions with EU applicant and at least one non-EU inventor in the total EU ICT inventions (according to the applicant criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

Measures of internationalisation

Each patent application has a list of inventors, i.e. the people who developed a particular invention; and a list of applicants, i.e. the people who own the property rights over this invention. Our analysis uses measures of internationalisation that are based on the presence of inventors and/or applicants residing in different regions of the world among the list of people who file a patent application (for details see Annex 10). An international patent application is defined in the analysis presented here as a patent application with people and organizations residing or located in different countries or regions, e.g. in the US and the EU. It is, however, important to note that, intra-EU patent applications are *not* considered here as international patents. For example, a patent application having only a German inventor and/or applicant and a French inventor and/or applicant, is *not* considered here as international.

Four concepts of internationalisation of a given patent are used in the analysis:

Inventor international collaboration: a patent with at least two inventors residing in different countries or regions, e.g. a patent with an EU and a non-EU inventor. This concept captures international co-inventions and is used to construct a relative measure of *international collaboration between inventors*. This measure is defined as the share of a country's inventions with inventors residing in the country and inventors residing outside of the country, in the country's total number of inventions (according to the inventor criterion).¹⁴⁰

International co-ownership of inventions: A patent with at least two applicants residing in different countries, e.g. a patent with an EU and a non-EU applicant. This concept is used to construct a measure of *international co-ownership of inventions*. This measure is defined as the share of a country's inventions co-owned by applicants residing in the country and applicants residing outside of the country, in the country's total number of inventions (according to the applicant criterion).

Cross-border ownership of inventions: There are two concepts associated with this type of internationalisation that capture the notion of cross-border ownership of patents:

- 1) A domestic invention is owned by a foreign applicant. This concept captures *foreign ownership of domestic inventions*. It is used to construct a relative measure of foreign ownership of domestic inventions. This measure is defined as a share of a country's inventions owned by applicants residing outside of the country, in the country's total number of inventions (according to the inventor criterion).
- 2) A domestic applicant owns a foreign invention. This concept captures domestic ownership of foreign inventions. It is used to construct a relative measure of *domestic ownership of foreign inventions*. This measure is defined as a share of a country's ownership of foreign inventions in the country's total number of inventions (according to the applicant criterion).

The above defined measures of internationalisation are computed by using data from the EPO Worldwide Patent Statistical Database (also known as EPO PATSTAT).¹⁴¹ This database compiles raw patent data from over 80 countries. In the following analysis, the data from the April 2009 database release is used. Indicators were computed for the period 1990 to 2006.

The analysis is carried out using a methodology that considers all priority applications filed at all 27 EU national patent offices, at the European Patent Office (EPO), and at the United States Patent Office (USPTO).

¹⁴⁰ See Annex 8 concerning inventor and applicant criteria.

¹⁴¹ See at: <http://www.epo.org/patents/patent-information/raw-data/test/product-14-24.html>

metrics, with the two measures of cross-order ownership of inventions being well above the measures of inventor collaboration and co-ownership of inventions. Second, there is a clear gap between the two measures of cross-border ownership of inventions, which gives a hint of the importance of the role of foreign firms in EU inventive activity. The fact that the share of EU ICT inventions owned by non-EU applicants (red line) is higher than the share of non-EU ICT inventions owned by EU applicants (dotted pink line) indicates the relatively high importance of extra-EU applicants in the EU inventive activity. The typical case reflected by these data is a non-EU firm owning

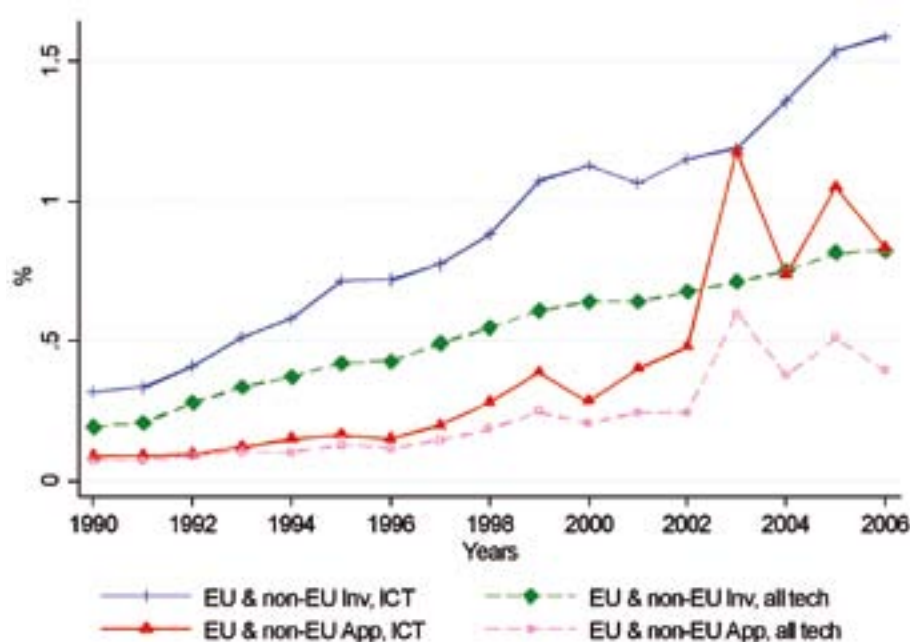
a R&D lab in Europe and filing patent applications either in Europe or in the US. Third, these data show that, in general, the degree of internationalisation in the production of technology has increased since the early nineties, but is still rather low.

9.2.2 Internationalisation of EU ICT and other technologies inventions

ICT versus other technologies: collaboration between inventors and co-ownership of inventions

Figure 9-2 compares the levels of inventor collaboration and co-ownership of ICT inventions

Figure 9-2: Shares of inventor collaboration and co-ownership of inventions in the total number of EU ICT and all technologies inventions, 1990-2006¹⁴²



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU & non-EU Inv, ICT: % of ICT inventions with EU and non-EU inventor in the total EU ICT inventions (according to the inventor criterion).

EU & non-EU Inv, all tech: % of inventions with EU and non-EU inventor in the total EU inventions (according to the inventor criterion).

EU & non-EU App, ICT: % of ICT inventions with EU and non-EU applicants in the total EU ICT inventions (according to the applicant criterion).

EU & non-EU App, all tech: % of inventions with EU and non-EU applicants in the total EU inventions (according to the applicant criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

142 The PATSTAT data has proved to suffer from some limitations with respect to the accuracy of the most recent data. This is a result of the very intensive process of feeding the dataset with information from all countries that are covered. The peak in the shares of cross-border ownership of inventions, i.e. EU & non-EU App, ICT and EU & non-EU App, all tech, in 2003 illustrated in this figure, may be an example of such inaccuracy. Fortunately, this does not seem to affect the general trend.

versus all technologies for the period 1990 to 2006. The level of inventor collaboration for ICT technologies is illustrated by the blue line and for all technologies by the dotted green line. The level of co-ownership of inventions for ICT technologies is illustrated by the red line and for all technologies by the dotted pink line.

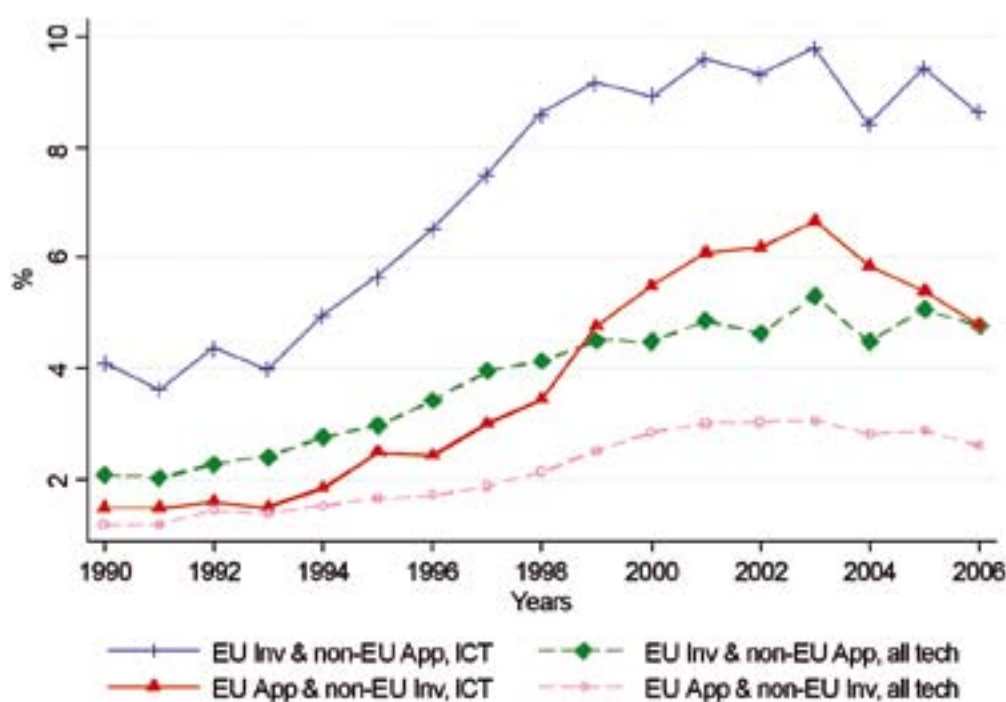
According to Figure 9-2, both the level of inventor collaboration and the level of co-ownership of ICT inventions (blue line and red line) are higher than the averages for all technologies (dotted green and dotted pink line). For example, in 2006, the share of ICT inventions with international inventors was over 1.5%, while the average for all technologies was below 1%. In the same period, the level of invention co-

ownership for ICT technologies was around 1% and for the all technologies average below 0.5%.

ICT versus other technologies: cross-border ownership of inventions

Figure 9-3 illustrates the level of cross-border ownership of inventions for ICT versus all technologies for the period 1990 to 2006. The blue line and the dotted green line represent the shares of EU inventions owned by applicants from outside the EU for ICT and for all technologies in the total number of EU inventions respectively. The red line and the pink line represent the shares of non-EU inventions owned by EU applicants for ICT and for all technologies in the total number of EU inventions respectively.

Figure 9-3: Shares of cross-border ownership of ICT vs. all technologies inventions, EU, 1990-2006



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU Inv & non-EU App, ICT: % of ICT inventions with at least one EU inventor and non-EU applicant in the total EU ICT inventions (according to the inventor criterion).

EU Inv & non-EU App, all tech: % of inventions with at least one EU inventor and non-EU applicant in the total EU inventions (according to the inventor criterion).

EU App & non-EU Inv, ICT: % of ICT inventions with EU applicant and at least one non-EU inventor in the total EU ICT inventions (according to the applicant criterion).

EU App & non-EU Inv, all tech: % of inventions with EU applicant and at least one non-EU inventor in the total EU inventions (according to the applicant criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

Figure 9-3 shows that, over the entire period of analysis, the level of foreign ownership of EU ICT inventions (blue line) has been significantly higher than the average for all technologies (dotted green line). The same is true for EU ownership of foreign ICT inventions (red line). That is, the level of EU ownership of foreign inventions is considerably higher for ICT inventions than the average for all technologies.

The above observations lead to the conclusion that, compared to other technologies' inventions, ICT inventions are more often owned by applicants residing in regions other than the ones where the inventors reside. It is also worth mentioning that, as in the previous analysis of the shares of cross-border ownership of ICT inventions, the foreign ownership of EU inventions across all technologies is significantly higher than the share of EU ownership of foreign inventions. Again, these observations probably reflect the important role of non-EU companies in the EU inventive activity that seems to exist across all types of technologies. The analysis indicates that this trend is more pronounced for ICT inventions, than it is for other technologies inventions.

A consideration of the results presented by Figure 9-2 and Figure 9-3 leads us to make an interesting observation: ICT inventions appear as considerably more internationalised than the average for all technologies. This result confirms the general argument that ICT economic activity is characterised by a series of specificities in terms, for example, of early and fast internationalisation. This would probably be true for its R&D activity also.

9.2.3 The internationalisation of the EU and the US inventive activity

Collaboration between inventors and co-ownership of inventions: a comparison between the EU and US

Figure 9-4 illustrates the levels of inventor collaboration and co-ownership of inventions for ICT inventions for the EU and the US for the

period 1990 to 2006. The degree of collaboration between EU and non-EU inventors is represented by the blue line and between US and non-US inventors by the dotted green line. The level of collaboration between EU and non-EU applicants is represented by the red line and between US and non-US applicants by the dotted pink line.

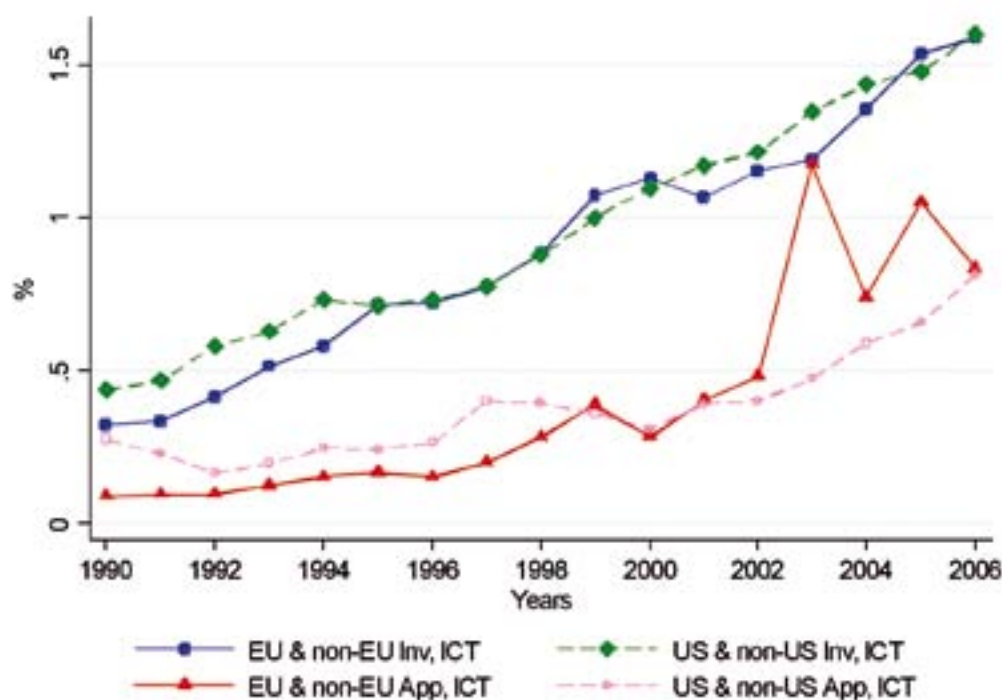
According to Figure 9-4, the degree of inventor collaboration and co-ownership of inventions in the US and the EU has been very similar over the period considered in this analysis. For example, in 2006, the share of ICT inventions with both EU and non-EU inventors in the total number of EU ICT inventions (blue line) was roughly equal to the share of ICT inventions with both US and non-US inventors in the total number of US ICT inventions (dotted green line), i.e. 1.5%. Furthermore, in both regions the degree of inventor collaboration is higher than the level of co-ownership of inventions. Note that the above shares are still quite low. They are however rising.

Cross-border ownership of inventions: a comparison between the EU and US

Figure 9-5 illustrates the level of EU and US cross-border ownership of inventions for ICT inventions for the period 1990 to 2006. The level of EU inventions owned by foreign entities is represented by the blue line and the level of US inventions owned by non-US firms by the dotted green line. The level of non-EU inventions owned by EU firms is illustrated by the red line and of non-US inventions owned by US firms by the dotted pink line.

According to Figure 9-5, in 2006, around 9% of EU ICT inventions were owned by foreign applicants (blue line). In contrast, in the same year, less than 4% of US ICT inventions were owned by non-US applicants (dotted green line). The reverse pattern can be observed for the share of foreign inventions owned by EU and US entities. In 2006, only around 5% of EU-owned ICT inventions were developed by foreign inventors (red line). In the same year, more than 7% of all inventions

Figure 9-4: Shares of inventor collaboration and co-ownership of inventions, EU vs. US, ICT inventions, 1990-2006¹⁴³



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU & non-EU Inv, ICT: % of ICT inventions with EU and non-EU inventor in the total EU ICT inventions (according to the inventor criterion).

US & non-US Inv, ICT: % of ICT inventions with US and non-US inventor in the total US ICT inventions (according to the inventor criterion).

EU & non-EU App, ICT: % of ICT inventions with EU and non-EU applicants in the total EU ICT inventions (according to the applicant criterion).

US & non-US App, ICT: % of ICT inventions with US and non-US applicants in the total US ICT inventions (according to the inventor criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

owned by US applicants were the result of foreign inventive activity (dotted pink line).

The comparison of the data presented in Figure 9-5 reveals the presence of an important difference: in the US, there are significantly more US applicants filing patent applications including foreign inventors, than in the EU. In contrast, many EU inventors file patent applications with foreign firms. Thus, compared to the US, the

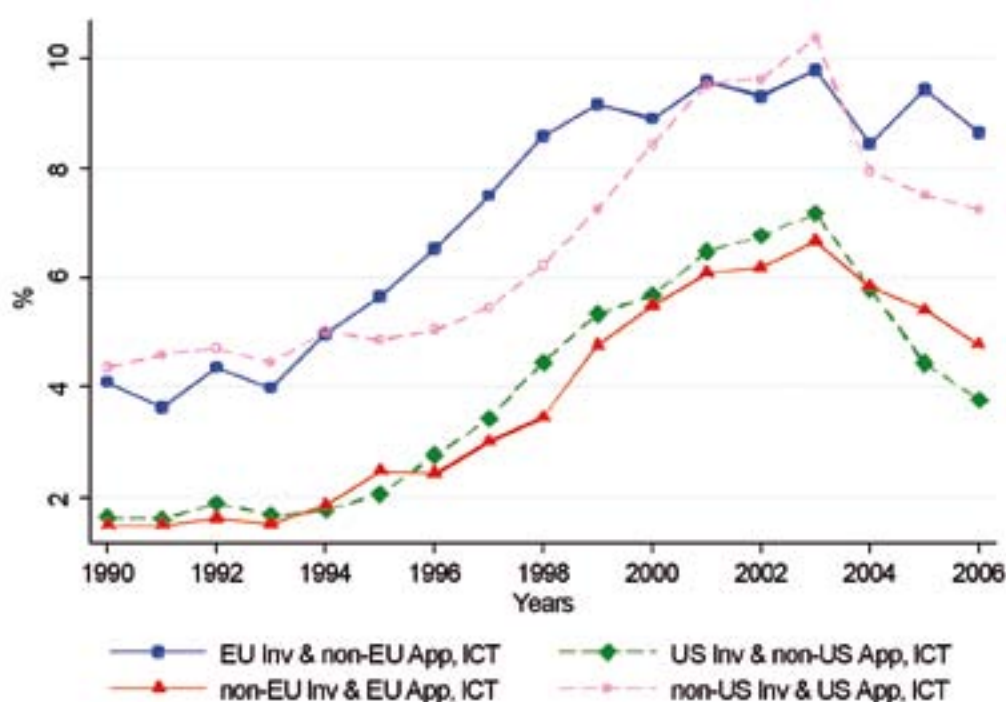
share of foreign ownership of EU ICT inventions is much higher than the share of EU ownership of foreign ICT inventions. In other words, the above analysis reveals that US companies are more likely to own both US and non-US ICT inventions, than EU companies.¹⁴⁴

The analysis of the results of Figure 9-4 and Figure 9-5 leads to the following conclusion: whereas the degree of inventor collaboration and co-ownership of inventions in the EU and the US are similar, the levels of cross-border ownership of inventions are very different. The

143 The PATSTAT data has proved to suffer from some limitations with respect to the accuracy of the most recent data. This is a result of the very intensive process of feeding the dataset with information from all countries that are covered. The pick of the shares of cross-border ownership of inventions, i.e. EU & non-EU App, ICT, in 2003 illustrated in this figure, may be an example of such inaccuracy. Fortunately, this does not seem to affect the general trend.

144 These indicators need to be interpreted with caution, as the filing practices to the USPTO and EPO or EU national patent offices are slightly different. In this particular case, it needs to be taken into account that, at the USPTO, the inventor is the applicant filing a patent application.

Figure 9-5: Shares of cross-border ownership of ICT inventions, EU vs. US, 1990-2006



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU Inv & non-EU App, ICT: % of ICT inventions with at least one EU inventor and non-EU applicant in the total EU ICT inventions (according to the inventor criterion).

US Inv & non-US App, ICT: % of ICT inventions with at least one US inventor and non-US applicant in the total US ICT inventions (according to the inventor criterion).

non-EU Inv & EU App, ICT: % of ICT inventions with at least one non-EU inventor and an EU applicant in the total EU ICT inventions (according to the applicant criterion).

non-US Inv & US App, ICT: % of ICT inventions with at least one non-US inventor and an US applicant in the ES total ICT inventions (according to the applicant criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

share of foreign ICT inventions owned by US applicants is higher than share of foreign ICT inventions owned by EU applicants. Thus, US strength in internationalising the process of inventive activity seems to stem from both a higher propensity to own inventions developed in overseas locations and from more intensive collaboration with foreign researchers.

9.2.4 Inventive collaboration between the EU and the US

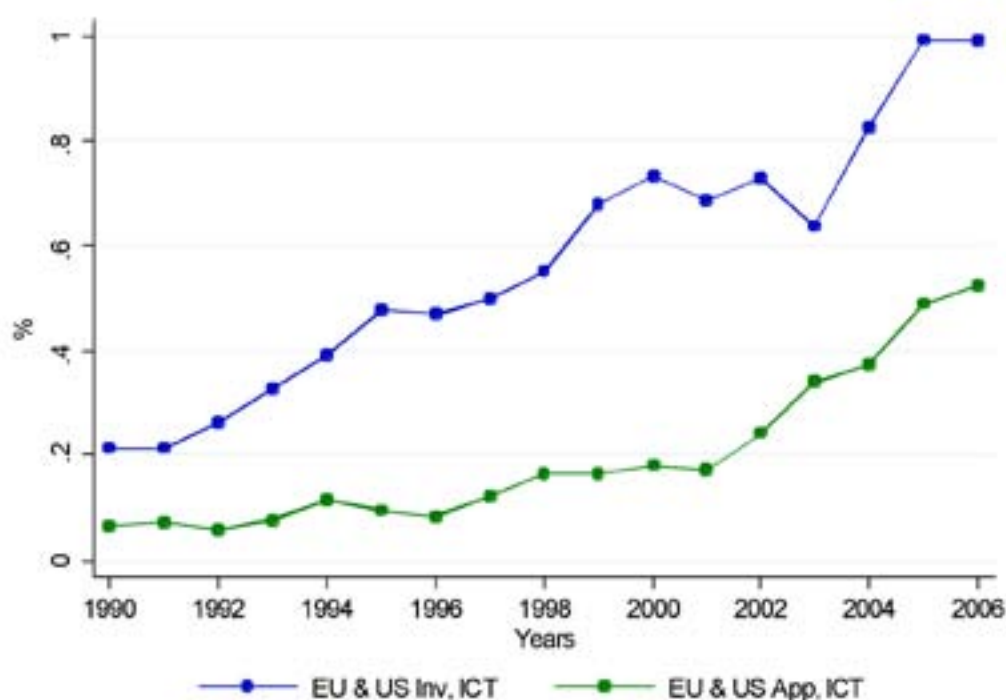
So far, only the level of internationalisation of inventive activity of a given country or region, irrespective of the identity of the collaborating countries, was considered. In the following, the

mutual relations that exist between countries or regions are analysed. This section examines the collaboration between the EU and the US. Next, Section 9.2.5 presents equivalent measures for the collaboration between EU and Asian inventors and applicants and between US and Asian inventors and applicants.

Collaboration between EU and US inventors and EU-US co-ownership of inventions

Figure 9-6 illustrates the level of collaboration in developing ICT inventions between EU and US-based inventors (blue line) and the level of EU-US co-ownership of inventions (green line). The period covered is 1990 to 2006.

Figure 9-6: Shares of international inventions with EU and US collaboration, ICT inventions, 1990-2006



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU & US Inv, ICT: % of ICT inventions with an EU and an US inventor in the total EU ICT inventions (according to the inventor criterion).

EU & US App, ICT: % of ICT inventions with an EU and an US applicant in the total EU ICT inventions (according to the applicant criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

According to the results presented in Figure 9-6, the values of the measures of collaboration between EU and US inventors and of EU-US co-ownership of inventions are very low. In the period of analysis, they remain below 1% of the total number of EU ICT inventions, although they have increased significantly since the early nineties.

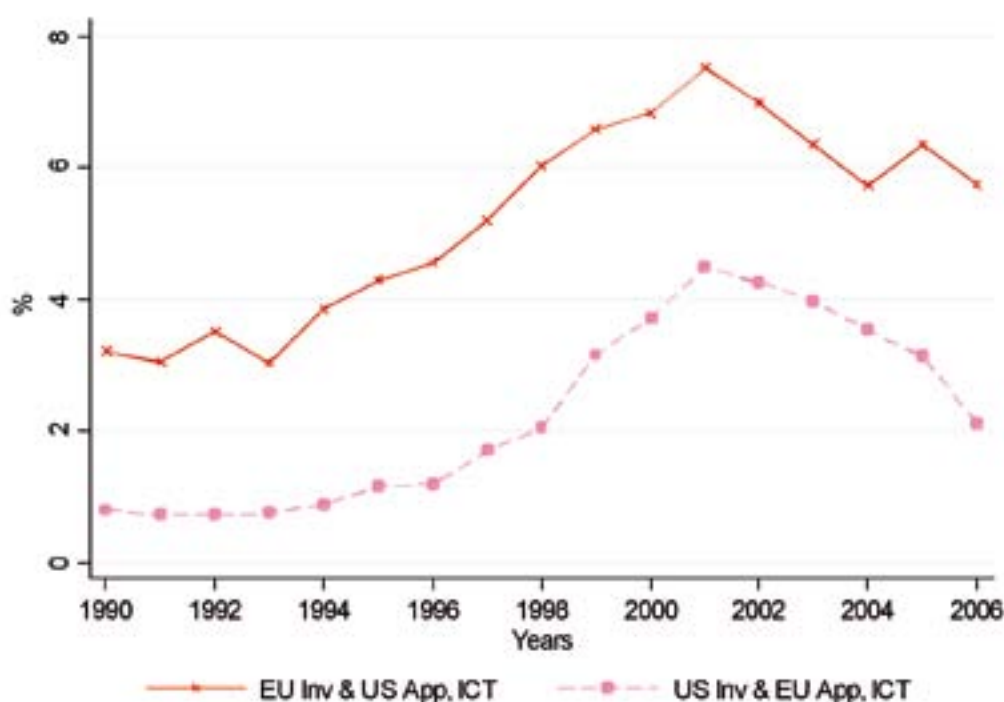
These small numbers have to be seen in a broader perspective. As indicated in Section 9.2.1, the overall levels of international patents is very low and, as shown in the forthcoming section, collaboration levels between researchers and applicants from other regions are even lower. Thus, although very low in absolute numbers, the level of inventor collaboration or co-ownership of inventions between the EU and the US is among the highest observed in the current analysis.

Cross-border ownership of inventions by EU and US applicants

Figure 9-7 compares the share of EU patent filings that include applicants from the US (red line) to the share of US patent filings that include applicants from the EU for ICT inventions (dotted pink line) for the period 1990 to 2006.

According to the results presented in Figure 9-7, over the entire period of analysis there have been two to three times as many US applicants filing patents with EU inventors, as vice versa. For example, in 2006, nearly 6% of all EU inventions were owned by US applicants (red line). In the same year, only around 2% of American inventions were owned by EU applicants (dotted pink line).

Figure 9-7: Shares of cross-border ownership of ICT inventions, EU and US, 1990-2006



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU Inv & US App, ICT: % of ICT inventions with an EU inventor and US applicant in the total EU ICT inventions (according to the inventor criterion).

US Inv & EU App, ICT: % of ICT inventions with an US inventor and EU applicant in the total US ICT inventions (according to the inventor criterion).

Source: JRC- IPTS calculations based on PATSTAT data.

An analysis of the data reported in Figure 9-7 shows that the gap in cross-border ownership of inventions between the EU and the US has remained unchanged over the entire period of the analysis. This observation may indicate that it could have some structural causes. A possible explanation may be a high preponderance of US firms in producing internationalised (ICT) patents. Alternatively, it may be a confirmation of the importance of US firms in the EU inventive process, which was observed earlier (see Section 9.1.2).

9.2.5 Collaboration between the EU and Asia and between the US and Asia

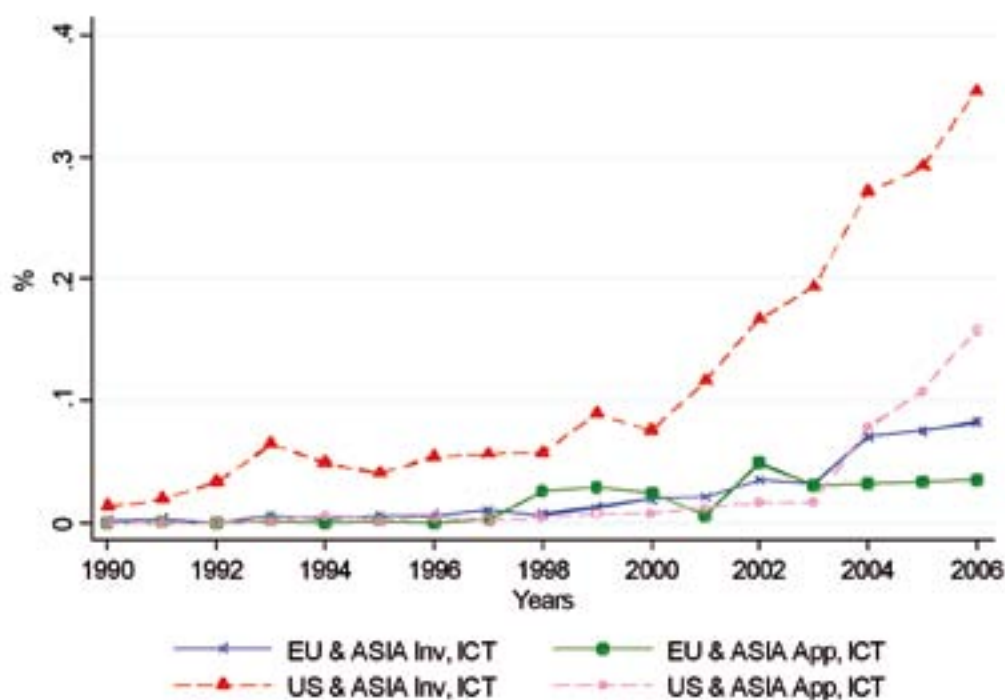
While the relations, at all levels, between the EU and the US have been historically intense in all fields, including the domain of R&D

activities, Asia, with the exception of Japan, has only relatively recently appeared as an important partner. Thus, the following section analyses the internationalisation of EU and US inventive activities with respect to the Asian region.

Collaboration between inventors and co-ownership of inventions EU-Asia and US-Asia

Figure 9-8 illustrates the level of collaboration in developing ICT inventions between EU and Asian inventors and applicants and between US and Asian inventors and applicants for the period 1990 to 2006. In particular, the strength of the innovative collaboration between EU and Asian inventors is given by the blue line and between US and Asian inventors by the dotted red line. The degree of co-ownership of inventions by EU and Asian applicants is represented by the green line

Figure 9-8: Shares of inventor collaboration and co-ownership of inventions, EU-Asia versus US-Asia, ICT inventions, 1990-2006



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU & ASIA Inv, ICT: % of ICT inventions with an EU and an Asian inventor in the total EU ICT inventions (according to the inventor criterion).

EU & ASIA App, ICT: % of ICT inventions with an EU and an Asian applicant in the total EU ICT inventions (according to the applicant criterion).

US & Asia Inv, ICT: % of ICT inventions with at least one US inventor and one Asian inventor in the total US ICT inventions (according to the inventor criterion).

US & Asia App, ICT: % of ICT inventions with at least one US applicant and one Asian applicant in the total EU ICT inventions (according to the applicant criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

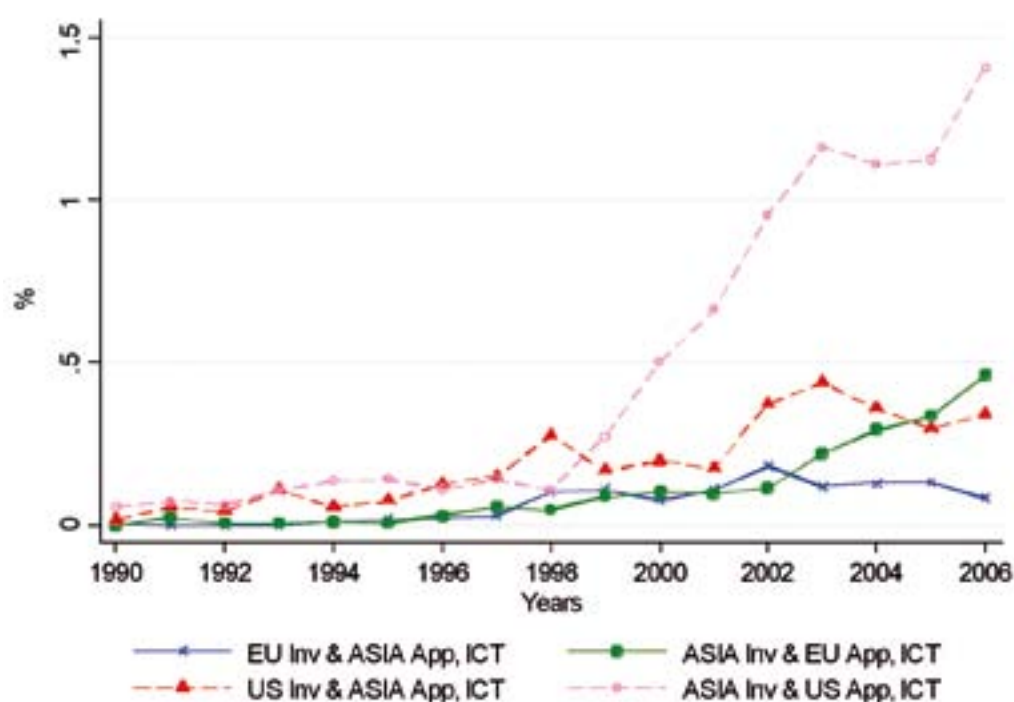
and the level of co-ownership of inventions by US and Asian applicants by the dotted pink line.

The results reported in Figure 9-8 show that the levels of collaboration between EU and Asian researchers and between American and Asian researchers and the levels of co-ownership of inventions are still very low. For example, in 2006, less than 0.4% of all US ICT inventions were developed by US and Asian inventors in cooperation (dotted red line). For Europe, the value of the same indicator was even lower and did not go above the 0.1% mark (blue line). Although the levels of co-ownership of inventions for both the EU-Asia (green line) and the US-Asia (dotted pink line) are also very low, the

collaboration between US and Asian applicants is more pronounced than between EU and Asian applicants.

Despite the overall low levels of inventor collaboration and co-ownership of inventions between EU and Asia and between US and Asia, there are some notable trends in the development of the indicators. First, there has been after 2000 a steep increase of the fraction of inventions developed jointly by US and Asian inventors, but a much lower increase of the fraction of inventions developed jointly by EU and Asian inventors. Second, after 2003, there has been a sharp increase in the level of patents co-owned by US and Asian applicants. At the same time, the

Figure 9-9: Shares of cross-border ownership of international ICT inventions, EU-Asia versus US-Asia, 1990-2006



Notes: Priority patent applications filed to European national patent offices, at the EPO, and at the USPTO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.

EU Inv & ASIA App, ICT: % of ICT inventions with at least one EU inventor and an Asian applicant in the total EU ICT inventions (according to the inventor criterion).

ASIA Inv & EU App, ICT: % of ICT inventions with at least one Asian inventor and EU applicant in the total Asian ICT inventions (according to the inventor criterion).

US Inv & ASIA App, ICT: % of ICT inventions with at least one US inventor and an Asian applicant in the total US ICT inventions (according to the inventor criterion).

ASIA Inv & US App, ICT: % of ICT inventions with at least one Asian inventor and US applicant in the total Asian ICT inventions (according to the inventor criterion).

Source: JRC-IPTS calculations based on PATSTAT data.

level of patent applications co-owned by Asian and EU applicants remained steady.

EU-Asian and US-Asian cross-border ownership of inventions

Figure 9-9 shows the levels of EU-Asian and US-Asian cross-border ownership of ICT inventions for the period 1990 to 2006. The level of EU ownership of Asian ICT inventions is given by the green line and of US ownership of Asian ICT inventions by the dotted pink line. The degree of Asian ownership of EU ICT inventions is represented by the blue line and the level of Asian ownership of US ICT inventions by the dotted red line.

The results presented in Figure 9-9 indicate that the measures for both EU and US ownership of Asian inventions have increased steadily since the early 1990s, though they started at a very low level and remained low in 2006. Even the highest value of the measure for the degree of US ownership of Asian ICT inventions is below 1.5% (dotted pink line). Regarding Asian ownership of EU and US inventions, both figures also remain very low (green line and dotted pink line).

However, the comparison of the degrees of internationalisation between the EU and Asia versus the US and Asia indicates the presence of an important difference. After 2000, there has been a rapid increase in the number of US

applicants filing patent applications including at least one Asian inventor. In contrast, the share of EU applicants filing patent applications including at least one Asian inventor has remained low over the same period. Consequently, in 2006, the share of Asian inventions owned by EU applicants was three times smaller than for the US. Furthermore, over the last few years, the rate of US inventions owned by Asian applicants has been increasing more rapidly than the equivalent EU measure. As a result, today, Asian applicants own more inventions developed by American inventors than by EU inventors.

The above observations cast some light on the recent development in the US-Asian relationship. The growth of US ownership of Asian inventions can be interpreted as representing an increase in patent filings where the applicant is resident in the United States, and inventors are from Asia. Despite the fact that the value of the level of internationalisation discussed is still very low, this may be an early sign of an increasingly intense collaboration between Asia and the US.

These observations, together with the results reported in Figure 9-8, allow us to conclude that, in the last few years, there has been a fast increase –albeit starting from very low levels– in the share of inventor collaboration between the US and Asia and the share of inventions co-owned by US and Asian applicants. At the same time, both types of collaboration between EU and Asian researchers and applicants remained at the same very low levels. At least to some extent, this may be explained by the relatively large number of US R&D sites in the Asian region (see a detailed discussion Section 9.1.2).

9.2.6 Summary of main findings

The above analysis aimed to track the patterns of inventive output internationalisation by analysing patent statistics and was primarily focused on: the internationalisation of EU firms' ICT inventive activity, the comparison of the degree of inventive collaboration between the EU

and the US, and the examination of cross-regional collaboration between the EU, the US and Asia. In addition, the preceding section included a comparison of the internationalisation of ICT with other technological inventions. Altogether, four types of internationalisation measures were used to capture the following means of international collaboration in inventive activity: collaboration between inventors, co-ownership of inventions and cross-border ownership of patents. The main points can be summarized as follows:

- First, although the output of international ICT inventive activity has steadily increased since the early nineties, ICT research is still highly local and the level of international collaboration, proxied by the number of international inventions measured by patent applications, remains very low. For example, in 2006, the share of ICT inventions developed in the course of joint cooperation between EU and non-EU inventors was around 2% of the total number of EU ICT inventions. Measures capturing the level of cross-border ownership of inventions are however more pronounced. In 2006, the share of EU ownership of foreign ICT inventions reached 5% of all EU-owned ICT inventions and the share of EU ICT inventions owned by non-EU applicants was 9% of all EU ICT inventions. Consequently, although Europe might be considered by other regions as an attractive source of innovations, EU firms exhibit a lower propensity to search for new knowledge and expertise abroad, compared to, for example, their US counterparts.
- Second, when compared to all technologies, the level of internationalisation of ICT inventive activities appears to be significantly higher. For example, in 2006, the share of ICT inventions developed by inventors from different countries was three times higher than the average for all technologies. This observation does not come as a surprise considering the early and fast internationalisation of ICT production. It is

very likely that what happened to the ICT value chain in terms of global production distribution is slowly making its way into the organisation of ICT inventive activity as well.

- Third, regarding the comparison of the EU and the US, the current analysis reveals some interesting patterns in firms' internationalisation activities in both regions. Although, the levels of inventor and applicant collaboration in the US and in the EU have been very similar over the entire period of analysis, there is an important difference with respect to the level of ownership of foreign inventions. US firms own significantly more patents including foreign inventors than EU firms do and, at the same time, more EU inventors file patent applications with foreign firms than US inventors do. In other words, although the degree of inventor collaboration and co-ownership of inventions in both regions are nearly identical, the share of US-owned foreign ICT inventions is significantly higher than the corresponding measure for the EU. Furthermore, this gap has persisted over the last few years, suggesting that it may have structural causes. A possible interpretation is that the US may better benefit from the process of internationalisation of inventive activity because it captures inventions developed in overseas locations more successfully and also because of the relatively higher levels of collaboration with foreign researchers.
- Lastly, the above analysis casts some light on the position of the Asian region as a destination and source of ICT innovative output and the collaboration of EU and US firms with their Asian counterparts. In general, the level of inventive collaboration with Asian economies in developing ICT inventions was still very low in 2006, though increasing over time. However, over the last decade, there have been some important developments with respect to the intensity of US-Asia collaboration.

In particular, since 2000, there seems to have been a steep increase in the fraction of patent applications with US and Asian inventors, whereas the level of collaboration between EU and Asian researchers and applicants seem to have remained stagnant. Furthermore, US firms seem to be much more active in applying for patents on inventions developed by Asian inventors than their EU counterparts and, what is equally interesting, Asian firms seem more likely to patent an invention with an American than with a EU inventor. These two last observations may be an early sign of a US first-mover advantage in tapping the inventive resources of the Asian region, on the one hand, and of the Asian countries developing inventive collaboration with primarily US partners, on the other hand.

9.3 Conclusions

Building on the theoretical discussion presented in Chapter 8, Chapter 9 analysed empirically ICT R&D internationalisation and the position of EU companies in this process. In order to address the complexity of this topic, the analysis used a framework that disentangled the innovation value chain and divided it into two stages. According to this approach, the first stage covers the input side of the inventive process or, in more concrete terms, the geographical distribution of R&D sites. The second stage covers the output of international inventive activity measured by the number of patents.

The analysis delivered a puzzling picture of R&D internationalisation in the ICT sector. On the one hand, based on the analysed sample, it was seen that up to 43% of ICT firms' R&D sites can be located in regions different from the ones in which companies have their headquarters. On the other hand, however, when the output of internationalised ICT inventive activity (measured as the number of patented inventions developed between inventors from different regions) is

examined, very low levels of international inventive collaboration can be verified.¹⁴⁵

These puzzling results can be explained by the complexity of the inventive process and the variety of motivations behind the decisions to locate R&D sites away from the home country. For example, as argued in Section 8.2.2, not all international R&D sites are created with a view to delivering new inventions that can then be patented and transferred to other locations. Instead, some of them are meant to adapt existing products and technologies to new markets and consumer preferences. This might explain why, for example, a strong concentration of American and EU R&D sites in Asian countries does not result in a large number of patents developed by these companies together with domestic researchers. Also, it takes time for research activities to result in patent applications and, hence, many recently established R&D centres abroad may not be 'visible' yet when looking at available patent statistics.

The ICT sector in general and its R&D activities are subject to very dynamic conditions and constant changes. Thus, like the quickly changing distribution of ICT production facilities across the world, the ICT knowledge creation network is in the process of constant transformation. In other words, firms are responding very quickly to disparities in regional conditions of both production and knowledge creation and are allocating their resources accordingly.

In conclusion, the preceding analysis contributes to the understanding of the ICT R&D internationalisation process in a number of ways. First of all, it confirms that, when studying the phenomenon of inventive activity internationalisation, it is necessary to address its complexity by, for example, disentangling various stages of the process. As shown in the above analysis, one possible way of looking at it is to separate the input side of inventive activity from the output or product of such efforts. Second, it delivers a considerable amount of evidence on the internationalisation of various stages of inventive activity in the ICT sector and allows us to assess the position of EU ICT companies and of EU ICT R&D in this process. Lastly, however, it shows that the phenomenon at hand is far from being fully understood and there are still a number of open questions. For example, it is still not clear what the implications of ICT R&D activity internationalisation at firm and country level are. It is worth asking how the geographical expansion of R&D activities affects a firm's performance and its inventive capabilities. At the country or regional level, there is the question of what is the overall effect of ICT R&D activity migration on local production and inventive capacities. Consequently, as the process of R&D internationalisation has significant implications for the countries or regions in which new R&D activities are being set up, or from which these activities are being withdrawn, it would be worth spending some more effort on better understanding this phenomenon and its consequences.

¹⁴⁵ It must be noted that results presented in Section 9.1 and 9.2 are not strictly comparable, since ICT inventive output as measured by ICT patent applications is not only produced by the ICT sector but also by other sectors of the economy, such as the automotive or the aeronautics sector.

■ 10 Conclusions

This report provides a unique analysis of R&D investments in the EU ICT sector, combining three complementary perspectives: national statistics (covering both private and public R&D expenditures), company data, and technology-based indicators such as patent data. It also benchmarks the EU's performance in terms of R&D investment with that of its main competitors.

This last chapter presents the most important conclusions of the report and makes several broader observations.

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

The report confirms that the ICT sector is a major R&D actor in the EU economy. In spite of its relatively small size, the ICT sector is far ahead of the other sectors of the economy in terms of R&D expenditure and researcher employment, and is a major contributor to the EU knowledge economy.

Total employment in ICT service activities grew significantly in the past decade, while it shrank in ICT manufacturing: it took six years (from 2001 to 2007) for total ICT sector employment to recover from the effects of the dot.com crisis, with an important redistribution of jobs from manufacturing to services.

The number of researchers in the ICT sector grew by almost 15% from 2002 to 2007. In 2007, the Computer Services and Software sub-sector became the ICT sub-sector employing the highest number of researchers, above the number working in the Component, Telecom and Multimedia subsector. Whilst the majority of R&D spending takes place in ICT manufacturing, the sustained growth in Computer Services and Software observed in recent years may indicate

that this sub-sector could become a strong asset for future development in the EU ICT sector.

10.2 International perspective

Over the 2002-2007 period, ICT business R&D expenditure grew more than the economy-wide inflation in most of the developed countries. However, following high growth rates in 2005 and 2006, growth slowed down significantly in 2007.

When comparing the EU ICT sector with its main competitors, for example in the US, Japan, or Korea, an important gap in business R&D expenditure in relation to GDP (BERD/GDP) can be observed. The US in particular invests more than twice as much as the EU in ICT R&D. This gap is caused by a combination of a relatively smaller EU ICT sector (measured by the ratio of Value Added over GDP), and a lower R&D intensity (where R&D intensity is measured by the ratio of BERD over Value Added). However, the R&D investment gap is not necessarily due to lower levels of R&D investments by individual EU companies, as indicated by analysis of company data (see Section 10.4).

Japan's higher overall ICT BERD intensity is due to the ICT manufacturing sector, which in relation to GDP, is twice as large as it is in the US and nearly three times as large as it is in the EU.

10.3 ICT R&D by Member State

EU R&D in the ICT sector is relatively concentrated in a few large Member States, notably Germany, France and the UK. Employment data show that the UK – and Spain – have oriented their research much more towards ICT services than France, Italy, and especially Germany.

In 2007, ICT BERD intensity (ICT BERD/ICT Value Added) remained highest in the Nordic countries and north western Member States, where Finland and Sweden led a group of seven Member States that were above the EU average; and lowest in the southern and new Member States. Some new Member States have seen considerable increases in ICT BERD intensity (e.g., Estonia, the Czech Republic, and in the last few years, Romania and Bulgaria), others have experienced drops (e.g., Slovenia and Slovakia).

In 2007, public funding of ICT R&D (estimated through GBAORD) was distributed in the EU similarly –but not exactly– to ICT BERD, with Finland, Spain and Sweden leading in ICT GBAORD intensity (ICT GBAORD/GDP).

The relative weight of the ICT sector in national economies remained much larger than the EU average in Finland, Hungary, Sweden [and Malta], where this is due to large Semiconductor and Telecom Equipment industries, and in Ireland, where the IT Equipment sub-sector is strong. Finland and Ireland are however the two Member States where the share of the ICT sector in the economy decreased most from 2002 to 2007, indicating a reduction in structural disparities.

10.4 ICT sector company R&D

EU ICT sector companies make very substantial R&D investments, and show similar R&D intensities¹⁴⁶ to those of their US competitors. At an aggregate level, however, they invest less in R&D than companies from the US, and they represent a smaller share of total R&D in the EU than ICT R&D represents elsewhere.

The analyzed sample of top R&D-investing ICT sector companies¹⁴⁷ therefore confirms the

existence of a gap between the EU and the US in terms of total ICT R&D investments. However, this gap is not necessarily because individual US companies have higher R&D intensity ratios than EU ones.

The analysis shows that companies' R&D intensity ratio is instead more likely to be sector-specific than region-specific. In other words, this ratio is more an industrial and market characteristic, than a national one (at least in the comparison between US and EU companies).

This suggests that the observed company-level ICT R&D gap is, in fact, mostly due to the presence of a larger number of top R&D-investing ICT sector companies in the US than in the EU. This is perhaps the most striking and important observation based on company data – that more than half the top global R&D-investing ICT companies are from the US. Furthermore, these companies are usually larger than those from the EU.

The analysis also indicates that, in absolute terms, the already dominant US companies further increased their R&D investment lead (in volume) over the observed period (2004-2007).

Worldwide, the most important ICT sub-sector in terms of R&D investment is IT Components. In terms of size and R&D dynamics, it is followed by Computer Services and Software and by Telecom Equipment. These three sub-sectors show a strong presence of US firms with high R&D investments and growth.

The top EU R&D-spending companies are pre-dominantly in Telecom Equipment, but also in IT Components and Telecom Services. Asian companies, on the other hand, hold very strong R&D positions in IT and Multimedia Equipment and also in IT Components.

The Software and Internet segments of the Computer Services and Software sub-sector were the most dynamic ones in terms of R&D investment, displaying high R&D intensities

146 Company R&D intensity is measured by the ratio of R&D investment over sales.

147 Composed of the 453 ICT sector companies with largest R&D budgets globally in 2007.

as well as high growth rates. On the positive side, the top EU R&D-investing companies in Computer Services and particularly in Software increased on average their R&D investments relatively faster than their US counterparts (mostly due to the rising R&D investment of SAP). On the other hand, the absolute R&D investments and investment growth figures of EU companies remain very much lower than those of US companies. The US Internet industry also hosts some young companies with high and rapidly growing R&D investments, such as Google and Yahoo, while among the 453 ICT companies with largest R&D budgets globally, there was not in 2007 a single EU Internet company.

Finally, it must be noted that the number of relatively young, large and rapidly growing R&D investing companies in California is strikingly high. Most of these companies are clustered in the San Francisco Bay area (Silicon Valley).

10.5 ICT patents in the EU

Data on patent applications submitted to EU and US patent offices is used in the report as proxy measures of inventive capability. The analysis confirms the significant increase in ICT patenting in the EU since the early 1990s. Inventors based in the US, however, file more than twice the number of ICT patent applications per million inhabitants than EU-based inventors. Inventors from Germany, France and the United Kingdom file 3/4 of all EU ICT patent applications.

It is worth recalling that patent applications are only a *proxy* for inventive activities. Nevertheless, the availability of a large amount of data, the increasing speed and accuracy with which data are available and the number of countries covered make patents a powerful indicator. To allow useful comparisons at country level, in-depth analysis of country specificities must, however, be carried out, in order to take into account specific behaviour and performance patterns that patent analysis can reveal.

10.6 Internationalisation of ICT R&D

This edition of the report includes for the first time a thematic section on internationalisation of ICT R&D. Building on a discussion of recent literature on the topic, the report analyses empirically ICT R&D internationalisation between the EU and other regions of the world and the position of EU companies in this process.

The analysis delivers a puzzling picture. On the one hand, it shows that ICT R&D is indeed an international endeavour that is widely distributed globally, with a large percentage of ICT companies' R&D sites located in regions different from the ones in which they have their headquarters (based on the analysed sample). On the other hand, when the output of internationalised ICT inventive activity, measured by number of patent applications, is examined, low levels of international inventive collaboration can be verified - although they are increasing.

The analysis shows that the EU remains an important location for ICT R&D – for both EU and non-EU companies - but it is also noted that Asia is gaining importance in this respect. International patent analysis also indicates that US companies have taken a 'first mover' advantage in developing ICT R&D collaborations with Asia.

Internationalisation of ICT R&D is a phenomenon that is still far from being fully understood. A number of open questions remain. For example, it is still not clear what the different implications at firm and country levels are. It is worth asking how the geographical expansion of R&D activities affects a company's performance and its inventive capabilities. At the country or regional level, there is the question of what is the overall effect of ICT R&D activity migration on local production and inventive capacities. Consequently, as the process of R&D internationalisation has significant implications for the countries or regions in which new R&D activities are being set up, or from which these activities are being withdrawn, it is worth

spending more effort on better understanding this phenomenon and its consequences for the EU.

10.7 Broader observations

Our analyses show that EU ICT R&D investment is less than half that of the US. Moreover, due to its prominence in overall R&D investments, the ICT investment 'gap' accounts for a substantial part of the difference between EU and US R&D investment. A number of possible contributory factors are elaborated in the paragraphs below.

Issues of economic and industrial composition

As this series of reports have indicated, the economic structure (size of the ICT sector in the total economy), the composition of the industry (share of each ICT sub-sector), and the overall size and number of ICT companies (and particularly the scarcity of large, globally operating EU companies - with the exception of Telecom Services sector) largely explain the investment differences. However, our analysis also shows that EU ICT companies' R&D investments are roughly equivalent to those made by comparable US firms in comparable sub-sectors.¹⁴⁸ These investments are driven by an industrial logic where, in order to remain competitive, the companies have to make an equivalent investment in R&D.

Issues of growth

Company data analysis indicates that the EU does not generate as many large new and innovative ICT companies as the US (and may additionally be threatened by emerging competitors from China and India). This appears particularly true in a key growth segment: Computer Services and Software. The US R&D investments have grown from virtually nothing to about €2.5 billion/year

in Internet-related businesses, and, moreover, this growth can largely be attributed to only two relatively recently created companies: Google and Yahoo. The lack of large innovation clusters in the EU may partly explain these difficulties, but market fragmentation, difficult access to financial capital, and other market rigidities are often cited¹⁴⁹ as other possible causes. The lack of large ICT companies in high growth sectors and slower industrial growth clearly have a negative impact on the R&D investment indicators.

Issues in international R&D cooperation

Europe is an important place for ICT R&D, but as shown in this report, globalisation leads to internationalisation of R&D activities embedded into emerging economies. In the ICT sector, US companies have opted for a more rapid internationalisation of their R&D activities than their EU counterparts and have progressively targeted Asian countries, benefiting from a first-mover advantage in the respective markets.

Issues of ICT R&D in non-ICT sectors of the economy

Substantial ICT R&D is carried out in other sectors of the economy (for example, automotive or aeronautics). The size of this additional ICT R&D expenditure cannot be readily measured with current statistics. However, the OECD has estimated that the ICT R&D carried out in other sectors than the ICT sector itself may count for an additional 30% R&D activity.¹⁵⁰ Further statistical analysis and estimation, taking this additional R&D into account may eventually deepen our understanding of the nature of the gap in R&D investment (EU-US). More importantly, it may also

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

149 See also: Information and Communication Technologies, Market Rigidities and Growth: Implications for EU Policies at <http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1508>.

150 Czech Republic, Denmark, Norway, Finland, Japan (OECD, 2008 b).

further underpin the pervasive impact of ICT and ICT R&D investment on the overall economy.¹⁵¹

Issues of publicly-funded ICT R&D

It is inherently difficult to access data on public funding of ICT R&D. However, available (incomplete) data indicates a substantial 'gap' where again the EU is a long way behind the US in terms of R&D public procurement¹⁵² and never adopted fully dual-use research.¹⁵³

Issues of statistics

As stated elsewhere in this report, official statistical data is processed on an on-going basis by the relevant international organisations with a view to improving data quality and comparability at international level. The recently revised data for the US raises their annual business ICT R&D investment by some 20%. Notwithstanding these changes, our analysis helps to develop understanding and further improvement in

analysis methods, and particularly to analyse trends and opportunities.

Issues of policy

The pervasive impact of ICT, its inherent R&D magnitude and intensity, its innovation performance and global dynamics, confirm the central role ICT plays in the world economy, the EU economy and the EU's economic recovery. This report further indicates that the current under-investment in ICT R&D is a complex issue that has a multitude of contributory factors, including Europe's economic and industrial structure. New measures will therefore require a coordinated policy mix that includes, but also goes beyond, ICT R&D and innovation policies. In particular, a policy mix needs to favour industrial restructuring to high-tech, high-growth, high added-value sectors fuelled by ICT-enabled innovations. The report also points to potentially important trends (threats and opportunities) in terms of internationalisation of ICT R&D.

151 JRC-IPTS is currently investigating this issue further.

152 See December 2007 EC Communication on pre-commercial procurement, COM(2007) 799, available at: http://ec.europa.eu/information_society/tl/research/priv_invest/pcp/documents/pcp_brochure_en.pdf

153 Dual-use research refers to tools or techniques, developed originally for military or related purposes, which are commercially viable enough to support adaptation and production for industrial or consumer uses. The United States Department of Defence (DOD) has an important dual-use research program. Adapted from: <http://www.answers.com/topic/dual-use-technology>.

■ 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 classification¹⁵⁴ rev 1.1. in two versions: the comprehensive definition and the operational one.

154 NACE refers to Nomenclature générale des Activités 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 discussed in the corresponding subchapters of this report.

In this report, we use for international comparisons the operational NACE definition. For EU country benchmarking, and as far as data availability allows, we identify and use data corresponding to the following subgroups: NACE/ISIC 642 (telecom services) NACE/ISIC 321 (electronic valves and tubes and other electronic components), NACE/ISIC 322/323 (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 332 / ISIC 3312 (Instruments and appliances for measuring, checking, testing, navigating and other purposes except industrial process equipment), NACE 333 / ISIC 3313 (Industrial process equipment).

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

2. Main limitations of the definition

With the conceptual and methodological standard premises described above, both international and 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 a 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, a mismatch is generated 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.

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. However, a similar redistribution of employment, VA or sales on a product or activity basis is not simultaneously available. In order to ensure maximum coherence across the statistical system, the reporting on principal activity was adopted as standard by both the OECD and Eurostat. Over the time span of the PREDICT project, not all the countries have approached this issue in the same way. The full harmonisation is on the way, but differences between national practices still exist. Some countries still collect and submit product field data (Finland, Sweden, the United Kingdom, Belgium and France).

It is not clear to what extent, or how, the product adjustment at the level of R&D figures impacts on the overall competitiveness analysis at detailed sectoral level. Official statistical data is produced on an ongoing basis by the relevant international organisations (Eurostat, OECD, US National Science Foundation

(NSF)). It is normal to observe minor adjustments in the available data from one year to another. US R&D data has been nevertheless subject to a major revision by the NSF which was published by OECD in late 2009 (OECD 2009a). The revision follows the decision of the NSF to change its method for classifying industrial R&D, beginning with reference year 2004. The major impact of this revision is a 40% increase in the amount of R&D allocated to the manufacturing sector (i.e. in pharmaceuticals and ICT), mainly at the expense of the wholesale trade industries. Therefore R&D data for the US presented in this report is not directly comparable with the statistical data used in previous editions of the report. The current revision does not affect the overall trends observed before, or the relevance of our previous conclusions (see Annexes 3 and 6).

Still, it remains a fact that data collected on country or company level results in an inaccurate registration of R&D ICT. While it makes sense to assume that R&D in ICT sectors is R&D that is 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. Ongoing research on statistical registration of embedded systems, which so far excludes 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 compétitivité* etc., which are probably registered within NACE 73, Research and Development services.¹⁵⁵ Trying to amend the current ICT sector definition would be outside

¹⁵⁵ In fact, through the actual methodology, figures on public support for private research bodies performing research in ICT are accounted for within the total (see Section 2.3.), but not the figures on business funding for the same institutions, because these research bodies are not normally registered in the ICT sectors as defined by NACE.

of the scope of the PREDICT study. It remains, nevertheless, interesting and useful to gain as much knowledge as possible on the issues related to the statistical treatment of entities performing ICT R&D (other than companies

and public R&D institutes) in order to estimate the size of the potential bias on statistical estimation of overall ICT R&D, but mainly to appreciate these entities' role as part of the surrounding ICT sector innovation system.

■ Annex 2 – Description of R&D intensity indicators

This 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 this 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:

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

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

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

- R&D Intensity at company level:

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

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 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.:

- *Total R&D personnel (or Researchers) / 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 (national statistics, 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

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 2002 to the most recent year available. The last year for which data is available in both Eurostat and the OECD (as at the beginning of 2010) is 2007, with a very limited number of countries publishing data for 2008.

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, more precisely in the ANBERD2009 database. Whenever available, we employed the Eurostat data.

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 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 years¹⁵⁶ 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.¹⁵⁷

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

156 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.

157 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. Annexes 6 and 7 and the literature referred to therein describe in detail our sources of BERD data and company level data, making clear the limits of their compatibility.

■ 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 are taken, when possible, from the EU KLEMS project. The methodology for data collection in the EU KLEMS project is described in Marcel Timmer, Mary O'Mahony and Bart van Ark, in *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 value added according to the NACE

classification for EU25 countries (i.e., not including Bulgaria and Romania) and 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. The most recent publication of EU KLEMS presents EU data at a level of aggregation that is too high for our needs. We complemented with Eurostat National Accounts data, with which the EU KLEMS dataset is highly compatible.

■ Figure 1, Annex 4: Valuation of value added

Value added at Factor costs	1. This table draws on concepts outlined in both the 1968 and 1993 version of a <i>System of National Accounts</i> (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).
+ 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	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.
+ taxes, less subsidies, on imports	3. These consist of taxes (and subsidies) payable per unit of some good or service produced, such as turnover taxes and excise duties.
+ Trade and transport costs	
+ Non-deductible VAT	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.
= Value added at Market prices ⁴	

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

Data for Romania and Bulgaria are extracted from a dedicated research project and for Australia from the OECD. VA from these countries would be expressed at factor costs or basic prices. When possible, these data were corrected with

a coefficient calculated as $\text{GDP/Total Economy VA}$ 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.

■ 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 those referred to 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).

Like the R&D expenditure estimation work done by JRC-IPTS, and partly based on it, gaps in official sources for ICT employment industries were filled, producing an estimate of EU R&D

employment (total and researchers) for each of the ICT sub-sectors at NACE two digit level for the years 2002 to 2007. The gaps were filled, wherever possible, by using 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 in some cases making conjectures on the dynamics of sub-sector composition, and 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. They were also used 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 or large year-on-year changes, and ‘suspicious’ movements across industries. The figures obtained were coherent with the JRC-IPTS series for expenditure at country and industry cell level.

■ Annex 6 – Methodology for GERD and GBAORD data

1. Definitions

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)

- Forthcoming JRC Scientific and Technical Report on “Public Expenditures in ICT R&D” (European Commission, 2010)

3. Geographical scope and time coverage

Due to serious shortcomings on availability of GBAORD data, time coverage for this calculation is restricted to 2005. Geographical coverage is the EU Member States and the US 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 the box below.

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: <ul style="list-style-type: none"> Foreign enterprises <ul style="list-style-type: none"> - 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

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

$$\begin{array}{ccccccc}
 & & \text{BERD} & & & & \\
 & \swarrow & & \searrow & & & \\
 \text{GERD} = & \text{BERD} & \begin{array}{l} \text{Financed by} \\ \text{Businesses} \\ \text{Performed by} \\ \text{Businesses} \end{array} & + & \text{BERD} & \begin{array}{l} \text{Financed by} \\ \text{Government} \\ \text{Performed by} \\ \text{Businesses} \end{array} & + & \text{GOVERD} & \begin{array}{l} \text{Financed by} \\ \text{Government} \\ \text{Performed by} \\ \text{Government} \end{array} \\
 & & & & & \underbrace{\hspace{10em}} & & & \\
 & & & & & \text{GBAORD} & & &
 \end{array}$$

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. Data for 2007 is published as well using the new classification and it is used as such beginning with this Report. 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 funded by other sources than GUF”. The remaining part of the former ‘Non-oriented research’ is distributed between the rest of the categories. Most of the data are collected now at one digit level. There is general correspondence between the previous and the current categories, although differences might exist for some countries.

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.

An important development in the current report is the introduction of the first estimates of the ICT R&D within the previous NABS1992 category 02 Infrastructure and general planning of land-use (currently NABS2007 class 04 Transport, telecommunication and other infrastructures). Therefore from the current Report we use the following NABS 2007 categories:

- *Exploration and exploitation of the earth (objective 01)*
- *Transport, telecommunication and other infrastructures (objective 04)*
- *Industrial production and technology (objective 06)*
- *Research financed from general university funds (GUF) (objective 12)*
- *Defence (objective 14)*

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 JRC Scientific and Technical Report on “Public Expenditures in ICT R&D” (European Commission, 2010 – 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 2008 EU industrial R&D scoreboard (European Commission 2008d¹⁵⁸) (henceforth the *Scoreboard*) in which R&D investment and other 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 2007.¹⁵⁹

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), 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 2470 (*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.

■ Table 1, Annex 7: *Summary of the major methodological differences between Scoreboard and national BERD data*

	BERD data	Scoreboard data
Data collection	Surveys according to the Frascati Manual (e.g. including capital expenditure in BERD)	Firms' annual reports and accounts according to accounting standards (IAS) (only including yearly amortization of capital expenditures)
Analyzed companies	Large companies plus representative samples of small ones	Top 1,000 R&D investing companies in the EU and 1000 companies outside the EU, covering about 80% of the R&D financed.
Money flows	Expenditures for R&D performed (regardless of source of funding)	R&D financed (regardless of where performed)
Economic sectors	ISIC/NACE	ICB (translated to ISIC/NACE in this paper, using correspondence tables)
R&D intensity denominator	Value added (used here)	Net sales
Geographical allocation	R&D attributed to country (and sector of performance) for business enterprises (including e.g. local subsidiaries)	R&D attributed to parent company

Notes: There are several other differences such as the entity collecting the information (national statistical offices vs. company accounts) and the time period (calendar year vs. financial years). Note also that Scoreboard figures are nominal and expressed in Euros with all foreign currencies having been converted at the exchange rate of 31 December 2007.

Source: Adapted mainly from Azagara and Grablowitz (2008).

158 http://iri.jrc.ec.europa.eu/research/docs/2008/Scoreboard_2008.pdf

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

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 data is therefore not directly compatible with data from national statistics (e.g., BERD).**

The table below summarises some of the major methodological differences between Scoreboard and national BERD data.

Scoreboard figures are nominal and expressed in Euros, and all foreign currencies have been converted at the exchange rate of 31 December 2007. For example, a €1 = \$1.46 exchange rate has been used, not only for 2007, **but for all previous years as well.** 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 could consider recalculating *Scoreboard* data based on some purchasing power parity model. At this stage, no such recalculation has been made.

R&D intensity is calculated as the ratio between R&D investment and net 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 2007, the R&D investment threshold for the EU-1000 group was about € 4.3 million and that for the non-EU 1000 group about € 24 million. 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 highest (i.e., non-EU) threshold. This comprises a group of 402 EU companies, 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 refer to as 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 453 ICT companies (out of 1,402).

A final note concerns determining age of the companies. Annual reports, company information and Wikipedia have been used as sources for determining the birth date of the companies. Age is stated as 2010 minus the birth year. In many cases determining the birth year is not a straight forward activity, for instance:

1. when the company is a spin-off from another company (such as NXP from Philips)
2. when the company is a result of merger (such as ST Microelectronics)
3. when the company changed its main activity (such as Nokia and Texas Instruments) (for

example entering into the ICT sector from another sector, or moving between sub-sectors)

Depending on the purpose of the analysis, different guidelines could be applied. The following choices have been made, for the purposes of this report. In the first case, we have tried to identify the start of business activity inside the parent company, which later was spun-off. For instance, Philips started its semiconductor business 1953, while NXP was not spun-off until 2006. In this case we used 1953 as the year of birth.

In case of mergers, the age of the main or oldest ancestor is given. For example, for STM, 1957 - the foundation of the oldest merging

company, SGS, is given, rather than 1987, which the formation year of STM.

In the case of change of main business activity, we have not taken this into consideration. For instance, the birth of Nokia is considered to be 1865 although it was not until 1960 the company diversified into ICT.

In case of a choice an alternative date is has also been proposed and documented, in order to allow for alternative analyses. To exemplify, for the example of STM above, the year 1987 (the formation of STM) is provided as an alternative to 1957 which is the year used in the report.

■ Annex 8 – Methodology for patent data

A brief description of the PATSTAT database

The results presented in Chapters 7 and 9 are based on analysis performed on a subset of the PATSTAT database, which is the European Patent Office (EPO) worldwide patent statistical database and provides a snapshot of the EPO's 'master bibliographic database DocDB'.

A brief description of main methodological aspects is proposed here. For a more complete and detailed description of the methodology followed, please refer to Chapter 8 of the 2009 Report (Turlea et al., 2009), and to Picci (2009).

Priority applications

The process of patenting an invention passes through a number of steps, starting when the application is first filed at a Patent Office by an applicant seeking patent protection and is then assigned a priority date (in case of first filing in the world) and a filing date. Once the subject, the novelty, the non-obviousness and the industrial applicability of the invention have been examined, the patent application is granted in case no reasons for refusal emerged, and a date of grant is assigned to the patent. Otherwise, the application is refused. The analysis takes into account patent applications, rather than granted patents. This choice is in line with the common practice in current literature on patents. Thus, when referring to 'patents', reference is actually made to 'patent applications'. Moreover, this analysis only takes into account 'priority applications': only the first filing of an invention is considered and all the possible successive filings of the same invention to different Patent Offices are discarded. This approach is best suited to building a measure of the inventive capability

of a country, rather than of the productivity of a given patent office. Priority patent applications identified in this way can be considered a more suitable proxy measure of inventing capability, even if a number of shortcomings have been pointed out by the literature (OECD, 2009d; de Rassenfosse et al., 2009).

Data set considered and years covered

The present analysis is based upon the April 2009 release of the PATSTAT database. The dataset considered includes all priority applications filed in any of the Patent Offices taken into account: namely, the EPO, the 27 European National Patent Offices, and the USPTO. Data covers the period between 1990 and 2006. However, it must be underlined that some delays have been detected in the updating procedure of the database. Those delays, possibly connected in some cases to a slow feeding of patent data from the National Patent Offices, could affect the last years taken into account. Therefore, even if it has been decided to include in the analysis years up to 2006 in order to provide insights on the most recent years, the possibility has to be considered of incompleteness of data with regard to the latest years. This is usually mentioned, when relevant, in the analysis.

Assigning patents to countries (or regions)

One further relevant methodological aspect regards the choice of the criterion to apply in order to assign patents to countries. Two alternative criteria are commonly adopted in the literature, either the nationality of the inventor(s) ('inventor criterion') of a patent or, alternatively, of the applicant ('applicant criterion'). According

to patenting rules, the applicant is “the holder of the legal rights and obligations on a patent application”, i.e. the patent owner (see OECD 2009). The applicant is in many cases a company or a university, but it could also be an individual; several applicants could hold rights on a patent application, and they have legal title to be owners of the patent once (and if) it is granted. Several inventors could have taken part in the development process of the invention, and be listed in the patent application. Due to the fact that often patents have inventors (or applicants) with different nationality, a *fractional count* is applied in order to assign patents to countries in such cases. The choice of the criterion to be applied, either based on inventors or on applicants, depends on which point of view on innovative capability is required. In Chapter 7, we use the inventor criterion.

As mentioned above, the dataset includes all priority applications filed at EU patent offices (EPO or national patent offices) or at the US patent office (USPTO). **It must however be made clear that**, in the cases in which the inventor criterion is used, we call:

- **‘EU applications’, those involving at least an EU-based inventor** (or applicant in case the applicant criterion is used), **and not** all applications to EU patent offices (which can involve EU-based or non-EU-based inventors).
- **‘US applications’, those involving at least a US-based inventor** (or applicant in case the applicant criterion is used), **and not** all applications to the USPTO (which can involve US-based or non-US-based inventors).

Applications to the USPTO before 2001

It is worth noticing that applications to the USPTO include, up to 2001, only those which have been later granted as patents. The patent legal framework in force in the US until 2001 is the cause of this difference in the availability of patent

application information for publication. Year 2001 represents a turning point, due to a change in the procedure of USPTO patent application publications.¹⁶⁰ Under the new provision of this act, patent applications are published 18 months after the effective filing date, in order to align with international patent practice and the Patent Cooperation Treaty (PCT) indications.

The count of applications submitted to EPO or any of the 27 MS Patent Offices includes, however for the whole period, all applications whether successful or not in the granting process.

Technology classes

Finally, with regard to the identification of ICT patent applications the same approach adopted in the previous (2009) edition of the report has been followed. Therefore, the taxonomy of the International Patent Classification (IPC) technology classes proposed by the OECD (OECD, 2008a) has been considered. Such a taxonomy links four categories of ICTs to groups of technology classes of the IPC Telecommunications (IPC codes 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 (codes G11B, H03F, H03G, H03J, H04H, H04N, H04R, H04S); Computers and office machinery (codes B07C, B41J, B41K, G02F, G03G, G05F, G06, G07, G09G, G10L, G11C, H03K, H03L); Other ICT (codes G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01R, G01V, G01W, G02B6, G05B, G08G, G09B, H01B11, H01J (11/, 13/, 15/, 17/, 19/, 21/, 23/, 25/, 27/, 29/, 31/, 33/, 40/, 41/, 43/, 45/), H01L). In case of applications referring to more than one technology class, the approach of *fractional counts* has been followed

¹⁶⁰ This change was introduced as a result of the American Inventors Protection Act of 1999 (AIPA), which requires the publication of all US patent applications filed after November 29, 2000.

(see above). It must be specified that the distinction between ICT and non-ICT technologies is therefore not related to the ISIC classification of economic activity or to NACE codes.

Triadic patent families

It is worth mentioning that in literature different methodologies are proposed to build indicators based on patent applications. In particular, Eurostat and OECD,¹⁶¹ among others, make available data concerning *triadic patent*

families. In this case the indicator is built by considering '*triadic patents*', meaning all patent applications filed at least at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO). This triple filing to particularly important patent offices is expensive and is meant to guarantee a wide protection to inventions.

It is worth noting that the annual number of patents applications analysed in this report corresponds to about ten times the annual number of triadic patents applications.

161 For more information, see OECD (2008a).

■ Annex 9 – JRC-IPTS ICT R&D Location Database

Table 1 shows the list of companies included in the *JRC-IPTS ICT R&D Location Database*, created on the basis of the information provided by iSuppli on behalf of JRC-IPTS during the period 2007-2008.¹⁶² An asterisk indicates companies for which information from the iSuppli and EU Industrial R&D Investment Scoreboard datasets¹⁶³ were merged. For the remaining companies, information on the location of company headquarter was extracted either from the Goliath database¹⁶⁴ of the Gale Group and the Amadeus database¹⁶⁵ by Bureau van Dijk.

■ Table 1, Annex 9: *List of companies included in the JRC-IPTS ICT R&D Location Database by region of headquarter origin*

Americas		Japan		APAC		EMEA	
1	Apple*	1	Aisin Seiki	1	Acer	1	Alcatel-Lucent*
2	Cisco Systems*	2	Alps Electric	2	Asustek Computer*	2	Bosch Group
3	Danaher*	3	Canon*	3	AU Optronics*	3	Continental
4	Dell*	4	Casio Computer*	4	Delta Electronics*	4	Ericsson*
5	Delphi	5	Denso	5	Delta Networks	5	Fujitsu Siemens*
6	Eastman Kodak	6	FujiFilm	6	Haier Group	6	Gemalto*
7	EMC*	7	Fujitsu*	7	Huawei Technologies	7	Magneti Marelli
8	Garmin*	8	Hitachi*	8	Lenovo*	8	Nokia*
9	General Electric	9	Kyocera	9	LG Display	9	Philips Electronics*
10	Harman International	10	Matsushita Electric*	10	LG Electronics*	10	Safran
11	Hewlett-Packard*	11	Mitsubishi Electric	11	Lite-on Group	11	Siemens*
12	Honeywell	12	NEC*	12	Pantech Group	12	Sony-Ericsson
13	IBM*	13	Nikon*	13	Samsung Electronics*	13	Thales Group
14	Intel*	14	Nintendo	14	Samsung Techwin		
15	Kingston Technology	15	Olympus	15	TCL		
16	L-3 Communications	16	Pioneer*				
17	Microsoft*	17	Ricoh*				
18	Motorola*	18	Sanyo*				
19	Nortel Networks*	19	Seiko Epson*				
20	Raytheon	20	Sharp*				
21	RIM*	21	Sony*				
22	SanDisk*	22	Toshiba*				
23	Seagate Technology						
24	Sun Microsystems*						
25	Thomson Group						
26	TRW Automotive						
27	United Technologies						
28	UTStarcom*						
29	Western Digital*						
30	Xerox*						

162 See at: <http://www.isuppli.com/>

163 See at: http://iri.jrc.ec.europa.eu/research/scoreboard_2007.htm

164 See at: <http://goliath.ecnext.com/>

165 See at: <http://www.bvdep.com/en/amadeus.html>

■ Annex 10 – Patent data and internationalisation measures

Fractional counting

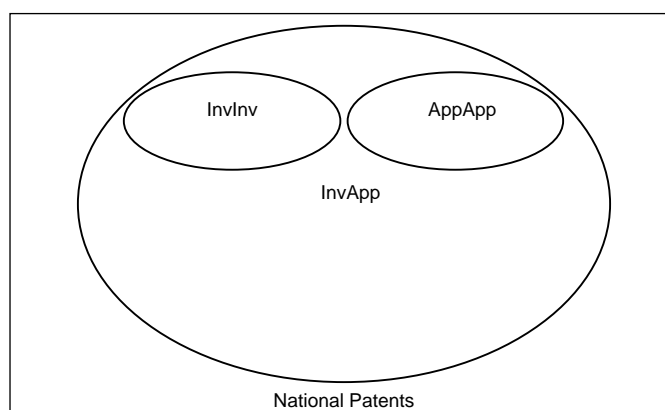
To present the way of assigning patents to countries or regions that is used in this study, first the concept of fractional counting of patents is reviewed (see for example Dernis et al., 2001). To help make the discussion as easy to follow as possible, a simple fictitious example is used. Three countries, United States (US), France (FR), and Germany (DE), are considered that in a given year produce a total of $P=3$ patents. Column I in Table 1 indicates the nationality of the inventors and applicants that contributed to these three inventions.

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 defines the ‘applicant criterion’ and the latter the ‘inventor criterion’. Whenever an application has more than one inventor or applicant, some of them coming from different countries, patent assignment is carried out by resorting to fractional counts. So, for example, patent n. 1 counts as $\frac{1}{2}$ German and $\frac{1}{2}$ American according to the applicant criterion, and $\frac{1}{2}$ American, $\frac{1}{4}$ German and $\frac{1}{4}$ French according to the inventor criterion.

■ Table 1, Annex 10: Fractional counts of three fictitious patents

I	II			III			IV	
	$Inv_{US,p}$	$Inv_{DE,p}$	$Inv_{FR,p}$	$App_{US,p}$	$App_{DE,p}$	$App_{FR,p}$	$\sum_{i=1}^N Inv_{ip}$	$\sum_{i=1}^N App_{ip}$
P=1: Inv: DE, FR, US, US P=1: App: DE, US	0.5	0.25	0.25	0.5	0.5	0	1	1
P=2: Inv: DE, DE, FR, FR P=2: App: FR, US	0	0.5	0.5	0.5	0	0.5	1	1
P=3: Inv: FR, US P=3: App: US, US	0.5	0	0.5	1	0	0	1	0
$Inv_i = \sum_{p=1}^P Inv_{ip}$	1	0.75	1.25					
$App_i = \sum_{p=1}^P App_{ip}$				2	0.5	0.5		

■ Figure 1, Annex 10: Relations among the different types of internationalisation



Legend: Rectangle: all patents; InvApp: all international patents necessarily display (also) Inventor-Applicant internationalisation

Measures of R&D internationalisation

In the following, $Inv_{i,p}$ represents the fraction of patent p attributed to country i according to the inventor criterion, and $App_{i,p}$ the analogous measure according to the applicant criterion. Column II and III of Table 1 report these measures for the three patents. For each patent application, the sum of all the country's contribution according to the inventor criterion has to be equal to 1: for each patent, $Inv_{US,p} + Inv_{DE,p} + Inv_{FR,p} = 1$, where the first subscript indicates the country, and the second the patent. These sums are indicated in Column IV of Table 1.

The total fractional assignment of the three patents to each country is simply equal to the sum of the individual assignments:

$$(1) \quad Inv_i = \sum_{p=1}^P Inv_{ip}$$

and:

$$(1') \quad App_i = \sum_{p=1}^P App_{ip}$$

They are reported in the last two rows of Table 1. For example, Germany produced a total of 0.75 patents according to the inventor criterion, and of 0.5 patents according to the applicant criterion.

Having discussed the general concepts of Inventor, Applicant, and Inventor-Applicant internationalisation, the related measures are defined. For each patent, the strength of the relation between inventors in country i and j is expressed as the product of the attribution of that patent to the two countries:

$$(2) \quad InvInv_{ijp} = Inv_{ip} \cdot Inv_{jp}$$

This measure attributes a greater weight to collaborations where the two countries have more similar weights. So, for example, the collaboration between the US and France is equal to $\frac{1}{2} \cdot \frac{1}{4} = \frac{1}{8}$ in patent n. 1 (where there are 1 French and 2 American inventors) and to $\frac{1}{2} \cdot \frac{1}{2}$

in patent 3 (where the total number of inventors, 2, is equally divided between the US and France. In fact, if i is different from j , $0 \leq InvInv_{ijp} \leq \frac{1}{4}$, where the upper bound is reached when the total number of inventors is equally divided between two countries, and the lower limit applies when a patent is national.

The aggregate strength of the relation between the inventors of two countries is defined as the sum of the above, over all patents:

$$3) \quad InvInv_{ij} = \sum_{p=1}^P Inv_{ijp}$$

Below, the values for all the combinations of the three patents in Table 1 are reported, where for clarity, instead of the indexes i and j , the acronyms of the countries are employed.

$$InvInv_{US,US} = 0.5 \cdot 0.5 + 0 \cdot 0 + 0.5 \cdot 0.5 = 0.5$$

$$InvInv_{US,DE} = 0.25 \cdot 0.5 + 0 \cdot 0 + 0 \cdot 0 = 0.125$$

$$InvInv_{US,FR} = 0.25 \cdot 0.5 + 0 \cdot 0 + 0.5 \cdot 0.5 = 0.375$$

The top part of Table 2 shows the values of these interactions for all three cases. Note that $Inv_{ij} = Inv_{ji}$ (the order of the countries is irrelevant). Using (1), it is easy to see that:

$$(4) \quad \sum_{i=1}^N InvInv_{ij} = Inv_j \quad \text{and} \quad \sum_{j=1}^N InvInv_{ij} = Inv_i$$

For example, as predicted by (4):

$$InvInv_{US,US} + InvInv_{US,DE} + InvInv_{US,FR} = 0.5 + 0.125 + 0.375 = 1 = Inv_{US}$$

These sums are reported for all three countries in the last column and in the last rows of the top part of Table 2, and correspond to the values reported in Table 1. They show that the country patent portfolio, assigned according to the inventor criterion, may be expressed as a sum of pairwise measures of country inventive collaboration ($InvInv_{ij}$).

The measure of applicant internationalisation is constructed along the same lines, and the following formulae hold:

$$(2') \quad App_{ijp} = App_{ip} \cdot App_{jp}$$

$$(3') App_{ij} = \sum_{p=1}^P App_{ijp}$$

$$(4') \sum_{j=1}^N App_{ij} = App_i \text{ and } \sum_{i=1}^N App_{ij} = App_j$$

All computations for this case are shown in the middle part of Table 2. Note that $App_{ij} = App_{ji}$ (again, the order of the countries is irrelevant). Equation (4') allows us to express a country patent portfolio, according to the applicant criterion, as a sum of interactions between applicants in different countries. The values reported in the last column and row of the middle part of Table 2 correspond to those of Table 1.

A measure of Inventor-Applicant internationalisation is constructed similarly. The strength of the collaboration between inventors in country i and applicants in country j , for a single patent p , is defined as:

$$(5) Invapp_{ijp} = Inv_{ijp} \times App_{ijp}$$

Summing over patents provides a measure of the strength of the overall collaboration between country i inventors and country j applicants:

$$(6) Invapp_{ij} = \sum_{p=1}^P Inv_{ijp} \cdot App_{ijp}$$

These measures aggregate to the patent attributed to a country either according to the inventor, or to the applicant criterion, depending on whether the summation is over i , or over j :

$$(7) \sum_{j=1}^N Invapp_{ij} = Inv_i$$

$$(7') \sum_{i=1}^N Invapp_{ij} = App_j$$

The bottom part of Table 2 indicates all computations for our fictitious example. Note that $InvApp_{ij}$ generally differs from $InvApp_{ji}$.

The quantities defined in (3), (3') and (6) are the three measures of internationalisation of

innovative activities. In order to provide a first description of the degree of internationalisation, *relative* measures of internationalisation are used which are expressed as a share of the total number of patents. It is straightforward to construct relative measures of (3) and (3'):

$$(8) Inv_{ij|i} = Inv_{ij} / Inv_i$$

and

$$(8') App_{ij|i} = App_{ij} / App_i$$

$$\text{where } \sum_{j=1}^N Inv_{ij|i} = 1 \text{ and } \sum_{j=1}^N App_{ij|i} = 1.$$

There are in fact two conditional measures of inventor-applicant internationalisation, depending on whether the normalization is carried out with respect to the inventors of country i , or to the applicants of country j :

$$(9) Invapp_{ij|i} = Invapp_{ij} / Inv_i$$

$$(9') Invapp_{ij|j} = Invapp_{ij} / App_j$$

$$\text{where } \sum_{j=1}^N Invapp_{ij|i} = 1 \text{ and } \sum_{i=1}^N Invapp_{ij|j} = 1.$$

The relative measures of internationalisation defined by Equations 8, 8', 9 and 9' are computed by using the same data that were illustrated in Chapter 7, including all priority applications filed at all European national patent offices, at the EPO, and at the USPTO between 1990 and 2006. As we discussed in that chapter, our approach effectively corrects for the 'home bias' with respect to inventive activities taking place in the European Union and in the United States. Consequently, it is suitable to consider inventive collaborations between actors residing within this broad area. On the other hand, any consideration regarding inventive collaborations among actors that at least in part are from outside the European Union or the United States will be possible only with great care and with a good understanding of the consequences of the presence of a form of home bias.

These metrics of relative internationalisation have similarities with those of Guellec and van Pottelsberghe de la Potterie (2001), who adopt three measures that they call SHAI, SHIA, and SHII. The first one is similar to our $Invapp_{ij|i} = Invapp_{ij} / Inv_i$, the second to $Invapp_{ij|j} = Invapp_{ij} / App_j$, and the third to $Inv_{ij|i} = Inv_{ij} / Inv_i$. Our $App_{ij|i} = App_{ij} / App_i$ has no analogue in their paper. There are, however, several differences in the way that the measures are constructed, perhaps the main one being that, here, fractional counts of patents lead to counting as 'more international' those patents where international collaboration is more pronounced. One advantage of our measures is that they are coherent with the concept of fractional counting, in that they allow us to express country patent counts as sums of pairwise internationalisation linkages (equations 4, 4', 7 and 7'). The measures adopted by Guellec and van Pottelsberghe de la Potterie (2001), on the other hand, do not make this distinction, and consider alike all patents where there is at least some international collaboration of a given type. Similar considerations hold for the patent statistics of internationalisation presented in OECD (2008a).

An analysis of any shortcomings of our concepts of internationalisation should be carried out with an eye to the alternatives available. As we mentioned in the introduction, there are two competing approaches to analyzing internationalisation of R&D activities using patents data. One is by assembling a firm's portfolio: Firms are typically selected (also) according to their size, and this leads to problems of sample selection. This method, on the other hand, looks at patents regardless of the size or type of the applicant(s), and resort to an 'automatized' criterion to select international patents. The limits each approach may have ultimately derive from the fact that

patent applications are so numerous and are not amenable to a case-by-case examination.

There are two forms of international inventive effort that our approach may fail to detect. First, imagine that a firm owns an R&D unit in a foreign country, producing an invention with the help of inventors that are all resident in that same location. If, moreover, the applicant of the filing is the foreign subsidiary (instead of the firm's headquarters), or a subsidiary located in the home country, then all the applicants and the inventors would be from the same country and therefore the patent application, according to our taxonomy, would fall into the 'national' category. However, it must be noted that usually multinational firms apply for their patents through their headquarters – thus, the patent in this example would fall into the InvApp type. Another case of internationalisation that would go undetected is when two firms from different countries constitute a joint R&D effort in one of the two countries, or in a third country, and produce an invention where all the inventors are residents of the country where the jointly-owned firm is registered. Arguably, there should not be very many of these cases. Moreover, it is possible that researchers from both countries would team up in the jointly-owned entity, so that their patenting activities would show up as inventor and inventor-applicant internationalisation. Also, there may be patents that we classify as international, which, in fact, are not. For example, a multinational corporation (MNE) could have its legal headquarters in one country, but most of its operations in another. In this case, its patents would automatically display applicant internationalisation. In Picci (2009), a careful analysis of a sample of international patents leads us to conclude that, overall, the number of problematic cases should be quite limited.

Table 2, Annex 10: Computation of measures of internationalisation of three fictitious patents

$InvInv_{ij} = \sum_{p=1}^P Inv_{ijp}$	$j = \text{US}$	$j = \text{DE}$	$j = \text{FR}$	$\sum_{j=1}^N InvInv_{ij} = Inv_i$
$i = \text{US}$	0.5	0.125	0.375	1
$i = \text{DE}$	0.125	0.3125	0.3125	0.75
$i = \text{FR}$	0.375	0.3125	0.5625	1.25
$\sum_{i=1}^N InvInv_{ij} = Inv_j$	1	0.75	1.25	

$AppApp_{ij} = \sum_{p=1}^P App_{ijp}$	$j = \text{US}$	$j = \text{DE}$	$j = \text{FR}$	$\sum_{j=1}^N AppApp_{ij} = App_i$
$i = \text{US}$	1.5	0.25	0.25	2
$i = \text{DE}$	0.25	0.25	0	0.5
$i = \text{FR}$	0.25	0	0.25	0.5
$\sum_{i=1}^N AppApp_{ij} = App_j$	2	0.5	0.5	

$InvApp_{ij} = \sum_{p=1}^P InvApp_{ijp}$	$j = \text{US}$	$j = \text{DE}$	$j = \text{FR}$	$\sum_{j=1}^N InvApp_{ij} = Inv_i$
$i = \text{US}$	0.75	0.25	0	1
$i = \text{DE}$	0.375	0.125	0.25	0.75
$i = \text{FR}$	0.875	0.125	0.25	1.25
$\sum_{i=1}^N InvApp_{ij} = App_j$	2	0.5	0.5	

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Glossary

- ANBERD – Analytical Business Enterprise R&D Expenditure OECD database
- APAC – Asia-Pacific and Central Asia
- BERD – Business Expenditure on Research and Development
- CAGR – Compound Annual Growth Rate
- CIS – Community Innovation Survey
- CSS – Computer Services and Software ICT sub-sector
- EMEA – Europe, Russia, Middle-East and Africa
- EPL – European Patent Convention
- EPO – European Patent Office
- EU – European Union
- EU – 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)
- EU KLEMS – The EU KLEMS Growth and Productivity Accounts Database of the University of Groningen
- FTE – Full Time Equivalent
- 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
- JPO – Japan Patent Office
- JRC – Joint Research Centre, European Commission
- NABS – Nomenclature for the analysis and comparison of scientific programmes and budgets
- NACE – Nomenclature générale des Activités économiques dans les Communautés Européennes

NFBE - Non-financial Business Economy is commonly used as a reference, as it encompasses the *real* part of the 'modern' private economy. It excludes agriculture, public administration and other non-market services, as well as the financial services sector.

OECD – Organisation for Economic Cooperation and Development

PATSTAT – EPO Worldwide Patent Statistical Database

PCT – Patent Cooperation Treaty

PPP – Purchasing Power Parity exchange rate

PREDICT – Prospective Insights on R&D in ICT project

R&D – Research and Development

RDI – Company R&D Intensity (R&D investment over sales)

RoW – Countries from the Rest of the World

SBS – Structural Business Statistics

STAN – Structural Analysis Database of the OECD

USPTO – United States Patent and Trademark Office

VA – Value Added

European Commission

EUR24320 EN – Joint Research Centre – Institute for Prospective Technological Studies

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Abstract

This report is the 2010 edition of a report that is published annually. It presents all the data available on ICT R&D private and public expenditures in Europe, at sector, country and company levels, and from an international perspective (benchmarking). It provides data up to 2007. The second part of the report includes a thematic analysis on ICT R&D internationalisation.

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