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The 2011 Report on R&D in ICT in the European Union

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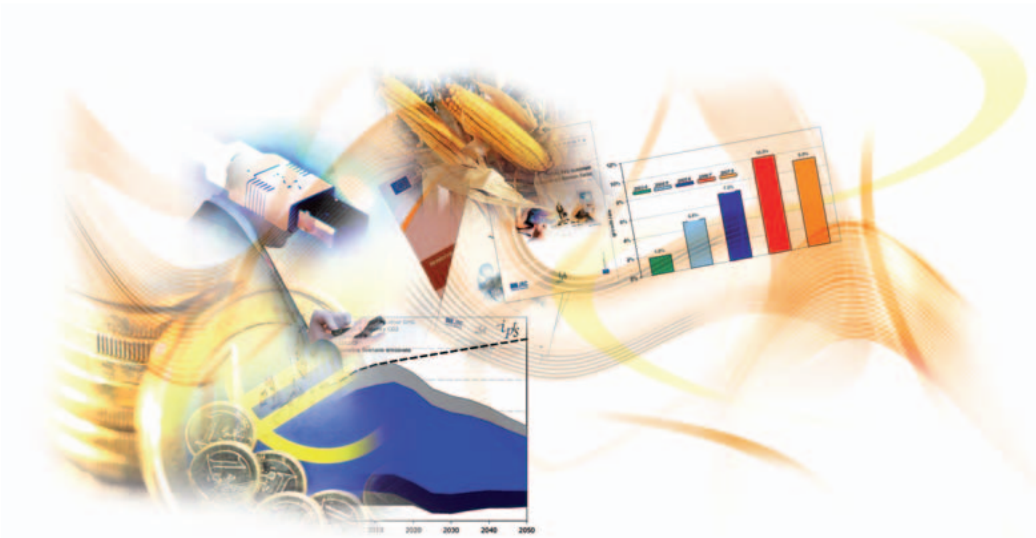

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1 IPTS is one of the seven research institutes of the European Commission's Joint Research Centre (JRC).

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Executive summary

Introduction

This report provides an analysis of EU R&D investments in the Information and Communication Technology industry sector (ICT sector[2]). The research and analysis was carried out by the Information Society Unit at JRC-IPTS[3] in the context of PREDICT,[4] a research project co-financed by IPTS and the Information Society & Media Directorate General of the European Commission.

This report combines in a unique way three complementary perspectives: national statistics, company data, and technology-based indicators such as patent data. 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 2008.[7] This is the fourth report of a series published annually.[8] This year's edition covers the period of ICT sector growth up to the beginning of the recent financial and economic crisis. PREDICT's multiannual analysis allows us to confirm the consistency of the data over time and it offers a wide view of the major ICT R&D trends across those years (2002 – 2008). In summary, the major trends observed in this year's report are the following:

- The structure of the EU ICT sector is strongly oriented towards ICT services. The ICT services share is still growing as compared with the ICT manufacturing share, helped in part by declining relative prices of ICT manufactured products (see Chapter 2).
- The 2008-2009 financial crisis had a strong impact on the ICT sector worldwide. However, the negative effects appeared to have waned by the end of 2010, though recovery dynamics differed across ICT sub-sectors (see Chapter 3).
- Although European ICT companies make substantial and increasing R&D investments, the EU is still lagging behind its main competitors, especially the US, in this regard. This lag seems to be largely due to the smaller number of large European ICT companies, rather than to a lower R&D intensity[9] of individual EU companies: EU

2 The ICT sector includes five NACE Rev.1.1 classes, also called sub-sectors:
• Three ICT manufacturing sub-sectors (IT equipment; 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 "Prospective insights on R&D in ICT".

5 Namely the following sources:
• For ICT sector data: STAN (OECD), National Accounts, Price and GDP data (Eurostat).
• For R&D data: STAN (OECD), R&D Statistics (Eurostat), the EU industrial R&D Investment Scoreboard (JRC-IPTS), and companies' financial reports.
• For supporting data: EUKLEMS database (Groeningen University), PATSTAT (European Patent Office), Amadeus database (Bureau Van Dijck) 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, 2008 figures were the latest available in autumn 2010 when the report was prepared; for patent data, latest year available was 2007. The analysis of impact of the financial crisis on the ICT sector uses data up to 2010.

8 Previous reports are available at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

9 Company R&D intensity is measured by the ratio of R&D investment over sales.

companies show similar R&D intensities per ICT sub-sector to those of their US competitors (see Chapter 4).

- In 2007, the number of ICT patent priority applications worldwide by inventors from the EU was significantly below those by inventors from Japan, Korea, China or the US. Applications by inventors from Germany, France and the UK accounted together for 80% of all applications by EU-based inventors; with Germany-based inventors alone generating half the total ICT applications for the EU (see Chapter 5).
- Although ICT R&D is still predominantly local, the EU and the US are important locations for foreign ICT R&D investment. International cooperation in R&D is, however, evolving from a dominant EU-US relation to global networking. Since the early 2000s, the share of foreign ICT inventions owned by US firms and invented in Asia has increased. US firms own significantly more foreign ICT inventions than EU firms do, and US firms, as an aggregate, appear therefore to be better able than EU firms to take advantage of the process of internationalisation of ICT inventive activity (see Chapter 6).

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 Europe 2020 Strategy.[10] The *Digital Agenda for Europe*, one of seven 'flagship initiatives' under the Europe 2020 strategy, aims to "contribute significantly to the EU's economic growth and to spread the benefits of the digital era to all sections of society".
- 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 has been reiterated in the Europe 2020 Strategy.

These characteristics have provided the rationale for the PREDICT research work since gaining a deeper understanding of the dynamics of research in the ICT industrial sector can provide important policy insights and options.

This year, for the first time, some of the main themes of the PREDICT report have been complemented by a series of further reports. These provide more detailed analyses on R&D investment by top ICT R&D companies worldwide, performance of ICT R&D analysed through ICT patenting, and internationalisation of ICT R&D.[11]

Main findings of this report

This executive summary aims to highlight the most important findings of this year's report. These are fully elaborated in the subsequent chapters.

– **The ICT sector has a smaller weight in the EU economy than it does in other major economies, and it has a dominant service component**

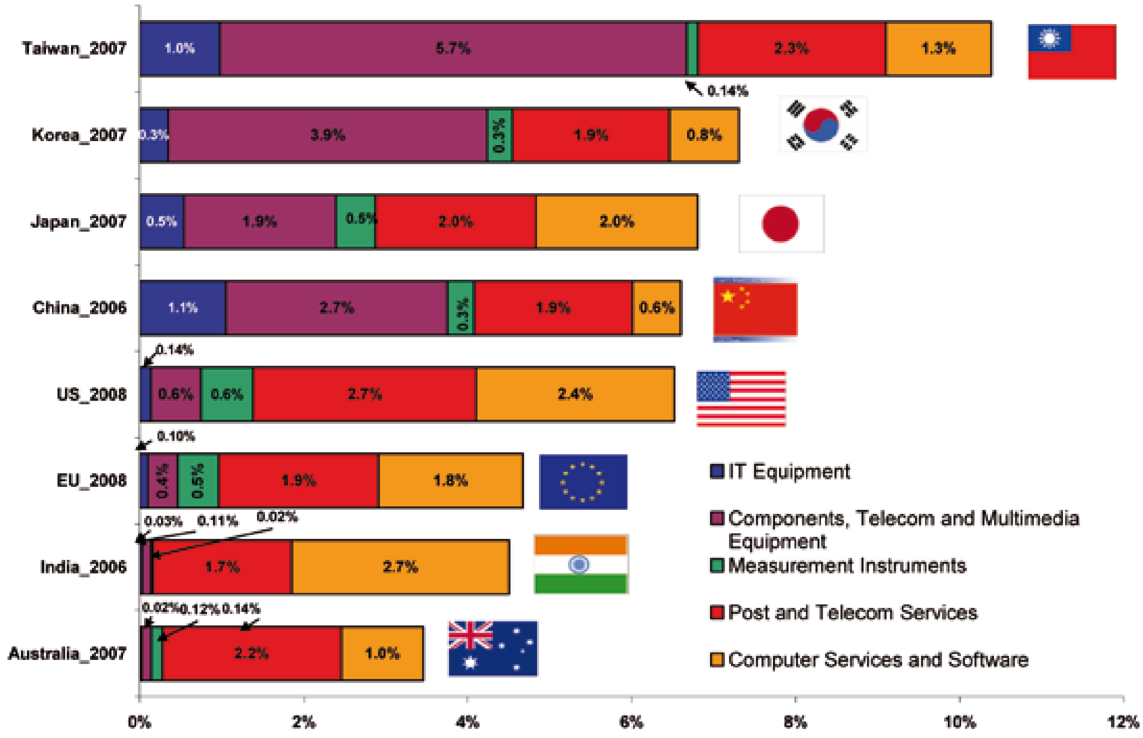
With a value added of 4.7% of GDP, the relative economic weight of the ICT sector in the EU was significantly smaller in 2008 than it was in the US (6.4%), China (6.6 %[12]), Japan (6.9%),

10 http://ec.europa.eu/eu2020/

11 These reports are available at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html (some are still forthcoming at the date of publication of this report).

12 In 2006, most recent year available.

Figure 1: Economic weight of the ICT sector, % of sector's value added in GDP, 2008 or latest data available



Source: JRC-IPTS based on data from EUROSTAT, OECD, EU KLEMS, and IPTS.[13]

Korea (7.2%) and Taiwan (10.5%), as is shown in Figure 1.

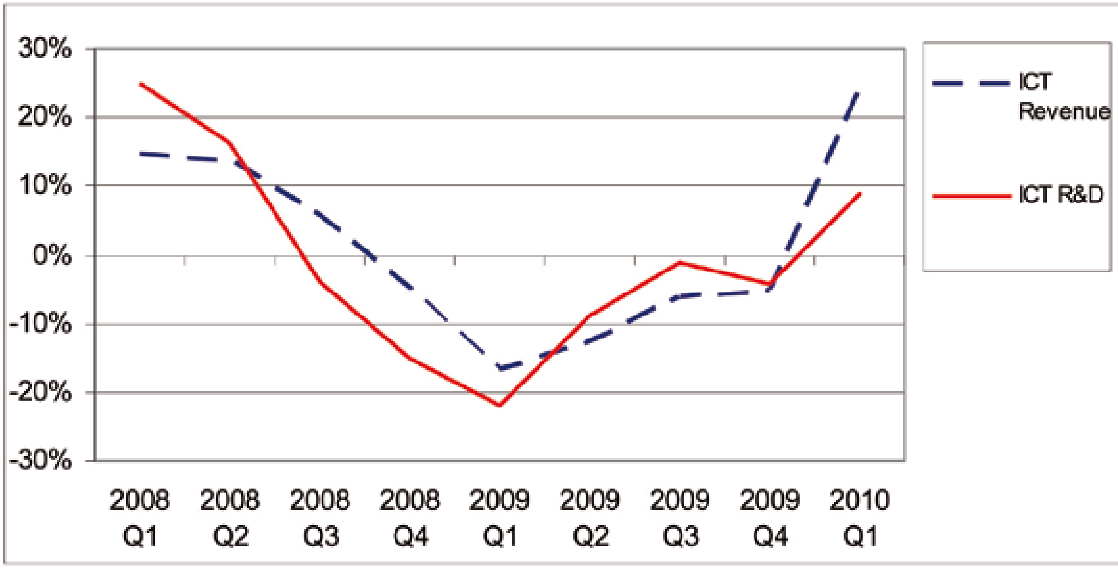
Furthermore, it is striking that the structure of the ICT sector is fairly similar in the EU and the US, but very different from what it is in Japan, Korea or Taiwan. The Asian countries have a comparatively much bigger ICT manufacturing sector. Japan's share of ICT manufacturing relative to GDP is three times bigger than the EU's and China, Korea and Taiwan all have a share in GDP of ICT manufacturing higher than Japan's.

The share of ICT services in the EU ICT sector continued to increase in 2008, reaching 80% of value added and 71% of employment. This increase was driven by the Computer Services and Software ICT sub-sector that alone represents 46% of ICT employment. Stagnating, or even declining, value added and employment in the ICT manufacturing sub-sectors and in Telecom services, may however not necessarily reflect a declining volume of activities but instead declining relative prices in ICT Manufacturing. Dropping prices in ICT manufactured products result from declining hardware prices which in turn result from technological innovation. In Telecom Services increased price competition followed liberalisation of telecoms.

Within the EU in 2008, the four largest economies (Germany, France, the UK and Italy) produced together two thirds of the EU ICT sector

13 Dr Shin-Horng Chen, Dr Pei-Chang Wen and Dr Meng-chun Liu (2011), Trends in Public and Private Investments in ICT R&D in Taiwan, JRC Technical Note – JRC 63993. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/documents/ICT2_CR_Taiwan_1Novformattedjpsjan13.pdf
Malik P., Vigneswara Ilavarasan, P. (2011), Trends in Public and Private Investments in ICT R&D in India, JRC Technical Note – JRC 64578. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/documents/ICT2RandDIndiafinal18012011.pdf;
Ling Wang, Shiguo Liu (2011 forthcoming), Trends in Public and Private Investments in ICT R&D in China. JRC Technical Note. Institute for Prospective Technological Studies, Joint Research Centre, European Commission.

Figure 2: Quarterly change in R&D expenditure and total revenue for top 200 ICT firms worldwide



Source: OECD, 2010, OECD Information Technology Outlook 2010.

value added. Despite the fact that the ICT sector has an important weight in the economies of Finland, Ireland, Hungary and Sweden, these countries produced together less than 7% of EU ICT sector value added in 2008 (i.e., roughly the same contribution as Spain alone).

– **Impact of the recent economic crisis on ICT R&D: a strong decrease, followed by a recent recovery**

The 2008-2009 economic crisis had a profound impact on the revenues of ICT companies and on ICT R&D expenditures worldwide. As can be seen in Figure 2, the effect for the ICT sector worldwide was a steep downward trend in R&D expenditure growth from a 25% growth in the first quarter of 2008 to a 22% decline in the first quarter of 2009. Growth in both revenues and R&D expenditures remained negative in 2009, but started to show signs of recovery. The first quarter of 2010 was marked by positive growth rates in both revenues (approaching 25%) and ICT R&D expenditure (approaching 10%).

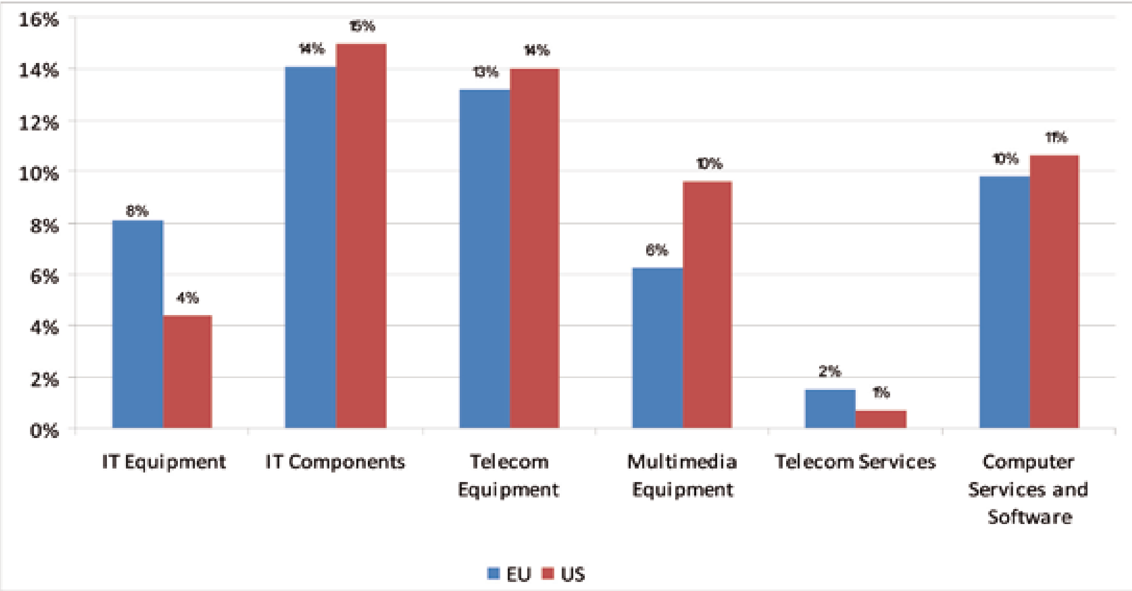
By the end of 2010, the negative effect of the crisis on the ICT sector appeared to have largely waned but recovery dynamics have differed across the ICT sub-sectors. While some of the ICT industries experienced only a minor reduction in growth rates (e.g., Internet, Software), others such as Computer Services or Telecom Equipment were struggling in 2010 to recover pre-crisis levels of growth.

– **Top R&D investing ICT companies from the EU and the US have similar ICT R&D intensity levels (R&D investment / net sales) - but there are many more US firms than EU firms in the worldwide group of top R&D-investing ICT companies**

In 2008, total R&D investments by EU *ICT Scoreboard*[14] companies amounted to € 27 billion, as compared to € 65 billion for US *ICT Scoreboard* companies. Thus, as observed in previous years, EU ICT firms as a whole invested far less in R&D than their US counterparts. However this is not necessarily because individual US companies were more R&D intensive than EU ones. Instead, as shown in Figure 3, R&D intensity (measured by

14 The *ICT Scoreboard* includes the 428 ICT companies with the largest R&D budgets globally. It is extracted from the 2009 EU industrial R&D Investment Scoreboard, available at http://iri.jrc.ec.europa.eu/research/scoreboard_2009.htm; see Chapter 4.

Figure 3: R&D intensities (R&D investment / net sales) in EU and US ICT Scoreboard companies (2008)



Note: the ICT Scoreboard is an extract of ICT companies from the 2009 EU industrial R&D Investment Scoreboard.

the ratio R&D investment / net sales) varied more according to sectors than to regions. This suggests that the ICT R&D investment gap between EU and US ICT companies is mostly due to the fact that there is a bigger number of large top R&D-investing ICT companies from the US than from the EU. Indeed, in 2008 more than half the top global R&D-investing ICT companies listed in the *ICT Scoreboard* were from the US, while only 15% of them were from the EU.

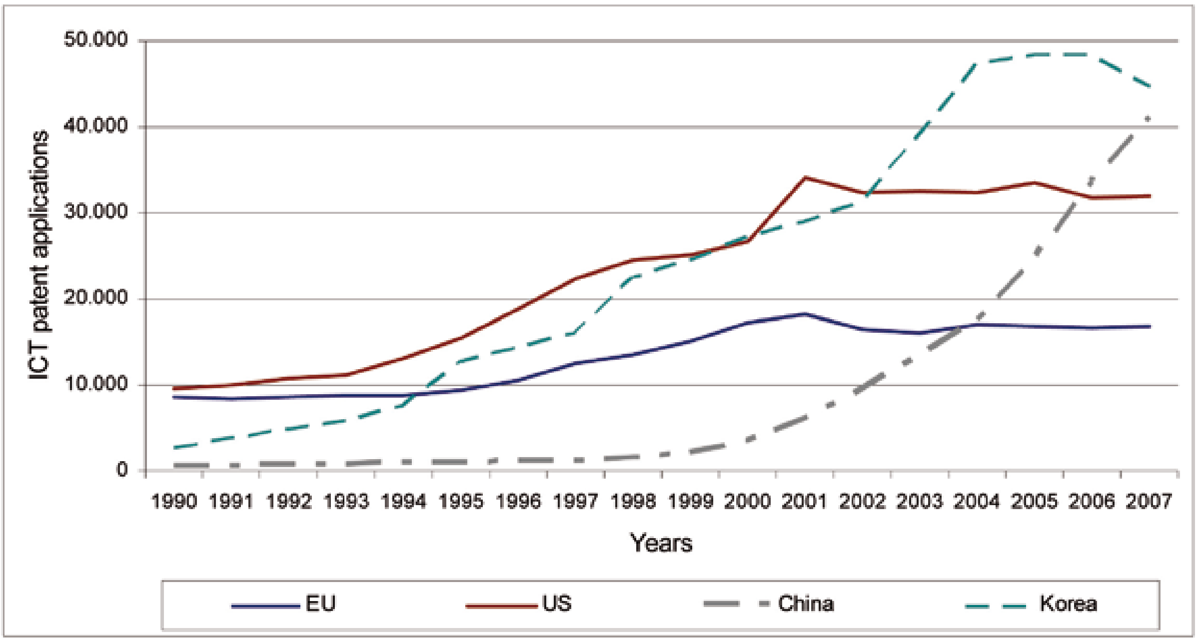
In 2008, EU companies' R&D investments were concentrated in Telecom Equipment and Telecom Services, whereas R&D investments by US companies were strong in IT Components, Computer Services and Software, and also Telecom Equipment. Japanese companies made significant R&D investments in IT equipment, IT Components, and particularly in Multimedia Equipment where they lead over companies from other regions. Companies from the rest of Asia essentially had a strong presence in IT Components, but with lower aggregate investments than companies from the US or from Japan.

– **ICT R&D investments by firms from Asia as a whole are rising more rapidly than those by firms from the EU or the US - but are still comparatively lower**

Top R&D-investing ICT companies from Asia increased their R&D investments from 2005 to 2008 by 14%, while the growth rate for EU and US-based firms was 10% and 11% respectively. For the same period, the R&D investment growth rate of Japanese companies was the lowest (3%).[15] Total R&D investments of *ICT Scoreboard* Asian companies amounted in 2008 to 'only' € 12 billion (of which more than € 10 billion were invested by Korean and Taiwanese companies) as compared to total R&D investments of € 27 billion for EU companies. The innovation capacity of emerging Asian economies is growing and these countries are increasingly present in the ICT R&D global landscape. For India, however, the level of investment in ICT R&D is still low and it remains modest for China.

15 Japan is analysed in this report as a single 'region', like the US or EU. It is therefore not included in the analysis of the Asia region.

Figure 4: ICT priority patent applications by EU, US, China and South Korea-based inventors (1990-2007)



Notes: Based on priority patent applications to the EPO, the 27 Member States' national patent offices, the USPTO, the JPO, and 29 further patent offices worldwide. Inventor criterion. EPO PATSTAT database - April 2010 release.

– **While ICT patenting by EU and US-based inventors has remained stable in recent years, ICT patenting by China-based inventors has boomed**

The annual number of ICT priority patent applications by inventors based in the EU has remained almost constant since 2001 with 17 000 ICT priority patent applications in 2007, i.e., about half the 32 000 ICT priority patents applied for by US-based inventors[16] (see Figure 4). The number of ICT patent priority applications by China-based inventors has strongly increased since 2000, overtaking the EU in 2004 and the US in 2006, and approaching South Korea in 2007 with more than 40 000 applications. ICT applications by inventors from South Korea kept on increasing until 2004 and have slightly decreased since. The number of ICT applications by inventors from Japan (not shown on the figure) has also slightly decreased in recent years, but in absolute values it remains by far the highest: in 2007, it was three times the number of ICT applications by US-based inventors.

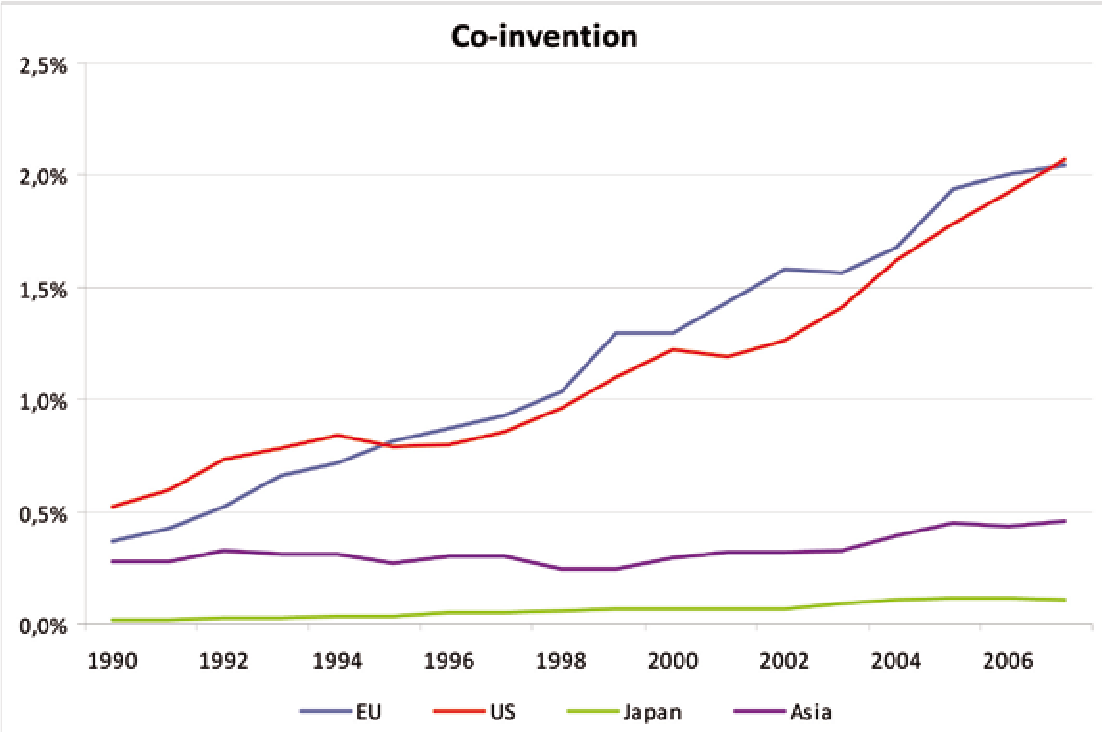
– **ICT patenting in the EU is led by a small number of Member States**

In 2007, the most patenting EU countries in ICT were Germany, France and the UK, accounting together for 80% of all ICT priority patent applications by EU-based inventors. Germany-based inventors alone generated half of all ICT applications for the EU that year. When the number of ICT priority patent applications is weighted by number of inhabitants, Finland, Germany and Sweden are the top three performers in the EU.

Among western EU Member States, ICT patenting by Portugal, Italy, Greece and Spain remained low, especially when weighted by capita or GDP. However, ICT patenting by inventors from Greece and Portugal has notably increased since

16 Based on number of priority patent applications to the EPO, the 27 Member States' national patent offices, the USPTO, the JPO, and 29 further patent offices worldwide. Inventor criterion. EPO PATSTAT database - April 2010 release.

Figure 5: Shares of co-invention between world regions in the total number of ICT inventions of each region (1990-2007)



Notes: Based on priority patent applications to the EPO, the 27 Member States' national patent offices, the USPTO, the JPO, and 29 further patent offices worldwide. Inventor criterion. EPO PATSTAT database - April 2010 release.

2000. Among eastern EU Member States, ICT patenting rose (compared to 2000) particularly in Estonia, Bulgaria, the Czech Republic, and Slovenia, but decreased in Hungary, Romania, Latvia and especially Poland.

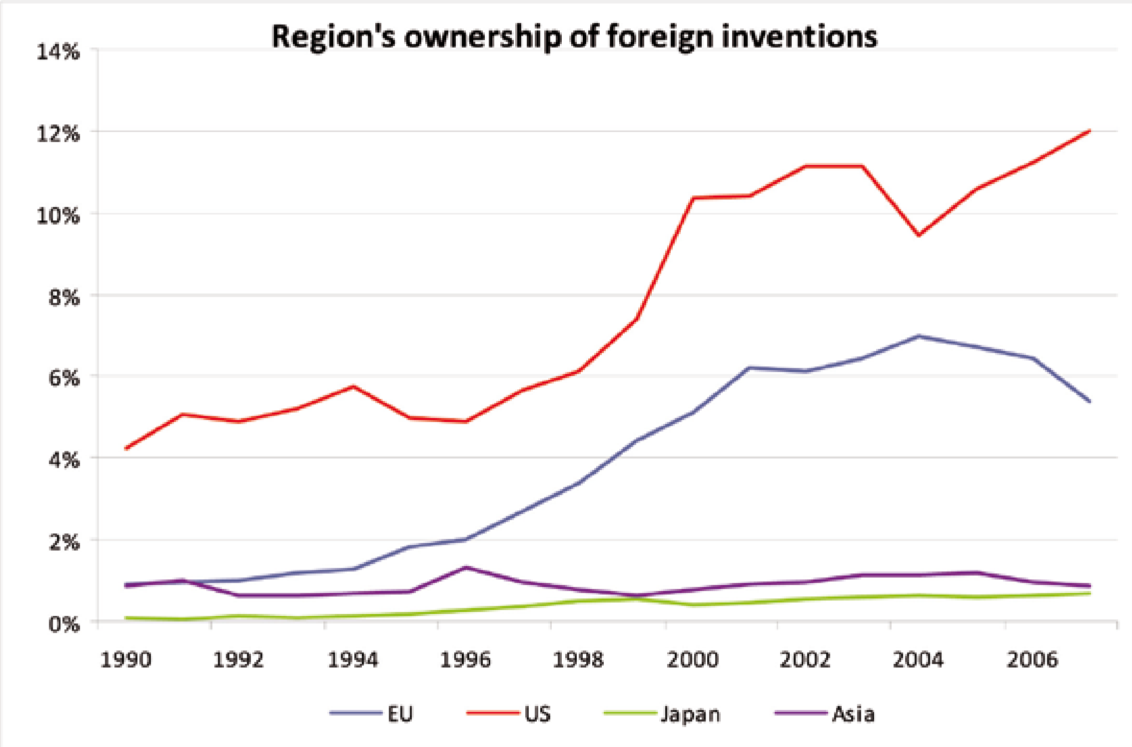
– **International collaboration between EU ICT inventors and inventors from other regions increases, but is still very low**

As shown in Figure 5, although the output of EU international ICT inventive activity has steadily increased since the early 90s (blue line), ICT research and innovation is still highly local and the level of international collaboration beyond EU borders, remains very low. For example, in 2007, 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 (proxied by the number of ICT patent priority applications involving EU and non-EU inventors). Similarly, the share of ICT inventions collaboratively developed by US and non-US inventors in 2007 was also around 2% of the total number of US ICT inventions (red line in Figure 5).

– **The US seem to be better able to exploit international ICT R&D collaboration than the EU**

The share of non-US ICT inventions owned by US-based patent applicants (red line in Figure 6) is significantly higher than the share of non-EU ICT inventions owned by EU-based applicants (blue line) - proxied by number of ICT patent priority applications. A possible interpretation is that US companies, as a whole, benefit more from the process of internationalisation of inventive activity because they are able to capture more inventions developed in overseas locations than EU firms do, and also because there is a relatively higher level of collaboration between US-based inventors and inventors based overseas (e.g., in the EU or in Asia). This observation should however be interpreted

Figure 6: *Shares of cross-border ownership of inventions in the total number of ICT inventions by world regions (1990-2007)*



Notes: Based on priority patent applications to the EPO, the 27 Member States' national patent offices, the USPTO, the JPO, and 29 further patent offices worldwide. Inventor criterion. EPO PATSTAT database - April 2010 release.

cautiously, since as previously noted, the number of US top R&D-investing ICT companies is much larger than the number of the EU top R&D-investing ICT companies, and the issue at stake is therefore most probably not the ability of *individual* EU or US firms but that of the entire *group* of EU and US firms.

– **ICT R&D internationalisation patterns differ widely across various regions of the world**

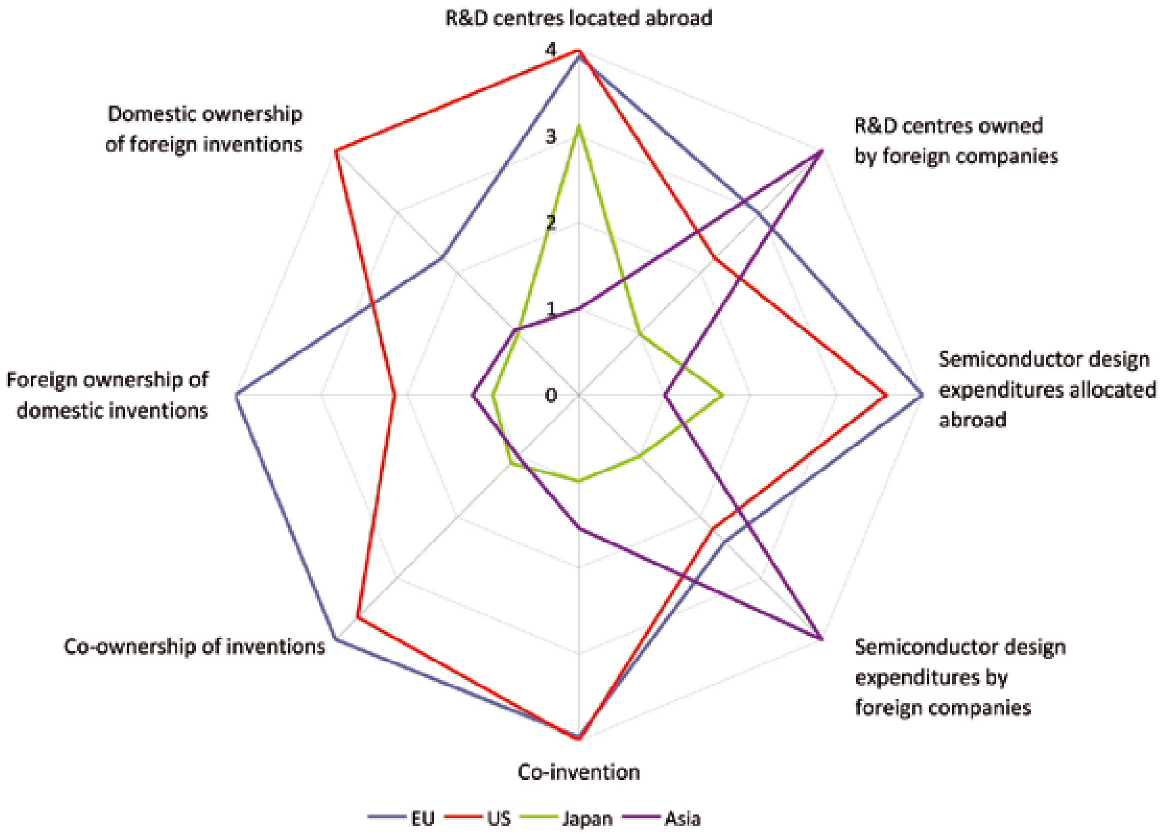
Detailed analysis of the internationalisation of ICT R&D shows that the EU and the US exhibit the highest levels of ICT R&D internationalisation, when compared to Japan and the rest of Asia (see Figure 7).

There are however important differences, even between the EU and US, when different R&D internationalisation measures are taken into account. For example, whereas EU and US firms exhibit similar levels of location of ICT R&D centres abroad and of cross-border allocation of product design expenditures, these regions show very different patterns with respect to, for example, cross-border ownership of inventions (as was also pointed out above in Figure 6).

There are even more important differences when considering Japan vs. the rest of Asia. Whereas Japan exhibits higher *outward* ICT R&D internationalisation (e.g., in terms of the location of Japanese firms' R&D centres abroad) and lower *inward* internationalisation (e.g., in terms of location in Japan of ICT R&D activity of foreign firms), the reverse can be observed for the rest of Asia.

These observations would seem to indicate that internationalisation of R&D activities depends on both the ICT R&D internationalisation 'path' (and policies) followed by each region and the actual strategies and capabilities of companies

Figure 7: Eight dimensions of ICT R&D internationalisation across world regions



Notes: The figure displays on different axis the relative positions of different world regions (EU, US, Japan, and the rest of Asia) with respect to eight specific ICT R&D internationalisation measures. Values are normalized on a scale from 0 to 4, where 0 represents the lowest value and 4 the highest value of each measure. Last available year for each measure is used.

from different regions to develop ICT R&D activities on a global level.

Broader observations

Our analysis shows that EU ICT R&D investment was (less than) half that of the US during the whole observed period. Moreover, due to the prominence of ICT R&D investment in overall R&D investment both in the EU and in US, this ICT investment 'gap' accounts for a substantial part of the difference between EU and US R&D total investment. Therefore, understanding the current and future dynamics of EU ICT R&D investment is crucial for reaching the R&D and economic goals presented in the EU 2020 Strategy.

Issues of economic structure and industrial composition in a global economy

For several years, our analysis, in line with that developed by other Commission[17] and academic bodies,[18] has shown that:

- The comparison of the economic structure of the EU and the US (size of the ICT sector in the total economy), of the composition of their ICT industries (share of each ICT sub-sector), and of the overall size and number of their ICT companies (and particularly the scarcity of large, globally-operating EU

17 Such as for example the Industrial scoreboard issued by the Knowledge for Growth Unit of the JRC-IPTS. See at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3819

18 Such as, for example: http://aei.pitt.edu/14847/

companies - with the notable exception of Telecom Services sector companies) largely explains why there is an ICT R&D investment gap between the US and the EU.

- Individual EU ICT companies' R&D investments are roughly equivalent to those made by comparable US firms in comparable sub-sectors. These investments are driven by an industrial logic where, in order to remain competitive, the companies have to invest in R&D, taking into account the behaviour and competitive assets of their competitors, worldwide.[19]

- The globalisation process has transformed the industry and its markets across all regions. The last decade has been marked by the emergence of strong ICT activities in Asian countries, affecting both of the above points: industrial structure and company strategies.[20]

Hence, to deepen our understanding of ICT R&D statistics, it is necessary to elaborate on the above structural differences. Four possible contributory factors are described in the paragraphs below.

– ***The re-composition of the ICT industry in advanced economies***

The reallocation of ICT manufacturing from mainly the EU and the US to Asia has been taking place for several years, and it is likely that manufacturing activities remaining in the EU and the US will need to position themselves in niche markets and in high value-added, cutting-edge technological activities. But it is also the case that cheaper ICT products manufactured in Asia fed the worldwide demand for ICT goods,[21] including the growing demand in the EU and the US, and created the conditions for the consequent accelerated development of ICT services and ICT-enabled products[22] in our advanced economies.

On the world markets, the competitive battle in ICT between the most advanced economies - the EU, the US and Japan - is therefore taking place in the fields of advanced technology in ICT hardware, in Computer Services and Software and in specific ICT-enabled products. Availability and quality of Telecom services is also seen as a prerequisite, a basic enabling infrastructure (strongly correlated with GDP) which allows the ICT business to expand and ICT to be integrated into the products of other industrial sectors. This justifies the policy emphasis on the deployment of infrastructure such as ultra high speed broadband, and the adoption of national broadband plans by advanced economies worldwide.

In this competitive battle, EU ICT Manufacturing still has a good performance, active mainly in the Components, Telecom Equipment and Instrumentation industries, but often heralding only few large companies.[23]

Production from Computer Services and Software in the EU, the US and Japan is still much bigger than it is in Asia. Competitive pressure is pushing companies from the advanced economies towards strategies that ensure they keep the edge on international markets. Over the last few years, these strategies have included the promotion of innovative services and the reintegration

19 See Chapter 4.
20 See Chapter 6 and JRC-IPTS reports on Asia at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/AsiaICT.html
21 China has become the 1st largest country producing ICT products.
22 We refer here to embedded ICT in Transport, Energy, Health etc. - related solutions.
23 Such as ST Microelectronics in Components, Nokia or Alcatel-Lucent in Telecom Equipment, etc.

of customised hardware and software into services hubs (e.g., smart phones and apps stores; cloud computing).

The ICT industry in Europe continues to depend on both Manufacturing – still an important engine of productivity growth - and Services, a strong locus of innovation and revenues. But it has also shown weaknesses on both sides: in the competition with Asia in Manufacturing and with the US in Services.

– ***Innovative waves and changing ICT industrial ecosystem***

The US have confronted the recent crisis with a Computer Services and Software sector 1.4 times bigger than the EU's, and a faster R&D investment growth trend for several years, as noted in this and earlier PREDICT reports. In US Internet-related businesses alone, R&D investments have grown from virtually nothing to about € 2.5 billion/year in just a few years.

This sub-sector has definitely demonstrated its contribution to the high rates of revenue growth of the US ICT industry during the crisis years. It has allowed the US industry to surf on the latest innovation wave – that of smart phones and apps stores - while showing the way forward to a renewed industrial ecosystem where roles and revenues are redistributed between hardware and software, telecoms equipment and services, software development and internet companies, and between the EU and the US. The iPhone platform wrested smart phone leadership from Nokia's Symbian platform. This also moved the centre of the smart phone eco-system from the EU to the US. Then, the Google Android platform opened the door for other smart phone hardware suppliers (Nokia's competitors) to compete with the iPhone eco-system. Similarly, one can expect that the current cloud computing innovation wave will further boost US hardware and software companies and their financial results.

It is essential to understand why European companies have missed these successive innovation waves,[24] even more so as those innovation waves build upon widely recognised European strengths such as mobile devices and wireless telephony.

– ***Revised role vis-à-vis the emerging economies***

As we have seen in earlier editions of this report, and again this year, while Europe and the US remain essential locations for ICT R&D, globalisation is leading to the reorientation of ICT R&D to emerging economies. These economies are perceived not only as huge potential markets but also, progressively, as sources of original domestically-produced knowledge. US companies seem to have opted for a more rapid internationalisation of their R&D activities, benefiting from a first-mover advantage in Asian markets.[25] It remains to be seen whether US companies will repeat this fast move in the remaining BRICS countries: Brazil, Russia, South Africa, etc. First observations indicate, however, that companies from the Asian countries themselves, particularly China, are taking a large share of these markets.[26]

Besides the access-to-market motivation, it is also essential to understand that the innovative capacity of Asia, and China in

24 The JRC-IPTS is currently running two research projects which aim to answer these questions. The first project integrates the findings of the seven ICT innovation reports of the COMPLETE project (http://is.jrc.ec.europa.eu/pages/ISG/COMPLETE.html), and the second sets out to compare US and EU industrial policies, paying particular attention to their impact on the growth of small companies into large global ones.
25 See Chapter 6.
26 See Simon J. P. (2011 forthcoming), BRIC Report 1 (Brazil, India and China), JRC Scientific and Technical Report, Institute for Prospective Technological Studies, Joint Research Centre, European Commission.

particular, is developing, and that its large companies and market are rapidly evolving. Though the statistics (value added, revenues, BERD, etc.) still look modest, the overall industrial and innovative capacity is growing very rapidly, supported by strong ambitions and policies (demand as well as supply oriented). Major examples of domestically developed innovations and standards are already emerging in the telecom sector, Indian telecom operators have introduced a major business innovation: the budget telecom model or 'bottom of the pyramid' (BOP) model. Mobile rates are the lowest in the world. Apple's iPhone illustrates the shift by Taiwanese ICT Firms from end-product manufacture to component manufacture to form an ICT hub in the global value chain. Additionally, these very large emerging markets have leapfrogged fixed lines and rely on infrastructure which supports massively mobile wireless internet.

From an operational point of view, though dozens of European companies have chosen to ensure their early presence in these markets, it seems that Europe lacks a broad coordinated strategy in its relations with these regions and countries. As a result, EU companies compete on a weaker basis than their US counterparts, which are better supported by US institutions (such as the US Chamber of Commerce) or simply by a clearer agenda.[27]

One should also stress that this new role of emerging economies is accompanied by changes in trade patterns. For instance, the ICT industry illustrates the growing role of China in global production networks. Emerging trade relationships between Asia and Brazil have displaced previous relationships with other regions like the EU and the US. Not only does intraregional trade in Asia affect the global trade streams but it allows Asia to play a growing role in an increasingly sophisticated global value chain, as a supplier of intermediate inputs. For instance, China coordinates assembly networks taking inputs from other countries like India, and ships products, while Taiwan acts as a facilitator for China.

– ***The competitive asset of ICT R&D in non-ICT sectors of the EU economy***

Following up on the above industrial analysis, one has to consider the importance of 'embedded' ICT for the other sectors of the economy. A substantial share of ICT R&D is carried out in other sectors of the economy (for example, in Automotive, Media, Pharmacy, Aeronautics, etc.) but this is not presented here, nor is it measured by currently available statistics.[28]

Deeper sector-level analysis, showing the fundamental role of ICT R&D in the future competitiveness of the European automotive sector,[29] has shown the pervasive impact of ICT-enabled hi-tech products on European industry performance and the EU economy. ICT, complementing the diversity of European industrial activities, play a growing and essential role as key enabling technologies. This complementarity enhances existing goods and services, giving those companies that embed ICT in their products and services

27 For more see at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/AsiaICT.html

28 The JRC IPTS has established an economic methodology allowing a first approach to this issue, and a first estimate for one national economy (Germany). Report available at: http://is.jrc.ec.europa.eu/pages/ISG/documents/FINAL-17March2011.pdf. Earlier, the OECD had 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.

29 Such as Advanced Driver Assist Systems and its software. See more in: Juliussen E., Robinson R. (2010). Is Europe in the Driver's Seat? The Competitiveness of the European Automotive Embedded Systems Industry. JRC Scientific and Technical Report EUR 24601 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3780

the opportunity to develop (or maintain) the competitive edge on a global scale.

Policy issues

The combination of these various aspects creates a new dynamic that goes beyond the ICT sector. The pervasive impact of ICT, its inherent R&D magnitude and intensity, its innovation performance and global dynamics, confirm the central role ICT play in the world economy, the EU economy and the EU's economic recovery. Furthermore, this report indicates that the European comparative under-investment in ICT R&D is a complex industrial issue resulting from a multitude of contributory factors. These factors include the competitive battle for the ICT industry among advanced economies, the innovative tensions affecting the industry ecosystem, the emergence of new large ICT markets and ICT knowledge flows, and the progressive transformation of the ICT industry from an engine of direct growth into a competitive asset as a key enabling technology for other sectors of the EU economy. These factors will shape Europe's economic and industrial ICT structure.

All these aspects call for a policy mix that goes beyond ICT R&D and innovation policies, and favours industrial high-tech, high-growth, high added-value sectors fuelled by ICT-enabled innovations designed for global markets and supported by global research and production value chains. Targeted policies can help creating a strong lead in science and technology, without necessarily picking winners in the form of national champions, but by consistently earmarking support for particular sectors deemed to define the future.

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)[30] under PREDICT,[31] 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 fourth report of a series which is published annually.[32] This year's report provides data up to 2008,[33] and therefore covers a period of ICT sector growth until the beginning of the recent financial and economic crisis started.

The report starts with a presentation of general trends concerning the EU ICT sector in a global perspective and in the EU Member States (Chapter 2), and presents an analysis of the impact of the financial crisis on the ICT sector (Chapter 3). The report then analyses R&D in the ICT sector, using data from the *EU Industrial R&D Investment Scoreboard*,[34] which tracks R&D spending by the biggest EU and non-EU R&D spenders (Chapter 4). Chapter 5 provides an overview of ICT patenting in the European Union and a comparison of ICT patenting performance, by Member State and with other world regions. Chapter 6 presents a set of empirical analyses on internationalisation of R&D in the ICT sector, on which there is still scarce evidence available, particularly with regard to ICT R&D internationalisation with emerging Asian economies. This chapter aims to assess the size and importance of the internationalisation of ICT R&D, building upon and extending the initial analysis presented in last year's edition. Finally, Chapter 7 provides the conclusions of the report. Several methodological annexes can be found at the end of the report.

Contrary to previous editions of the report, the present edition does not include an analysis of ICT R&D expenditures in the EU, since 2008 data on Business Expenditures in R&D (BERD) broken down by sectors of performance are not available for all EU countries.[35]

For the first time, the annual PREDICT report is complemented by a series of reports presenting more detailed analyses of some of the themes included in this report, namely on: R&D investment by top ICT R&D companies worldwide, performance of ICT R&D analysed through ICT patenting, and internationalisation of ICT R&D.[36]

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

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

32 Previous reports are available at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

33 For most of the data, 2008 figures were the latest available in autumn 2010 when the report was prepared; for patent data, latest year available was 2007. The chapter on impact of the financial crisis uses data up to 2010.

34 http://iri.jrc.ec.europa.eu/research/scoreboard_2009.htm

35 Periodicity of R&D data compilation is determined by the Commission Regulation (EC) No. 753/2004 of 22 April 2004 implementing Decision No 1608/2003/EC of the European Parliament and of the Council as regards statistics on science and technology. Under this Regulation, provision of R&D data by EU Member States to EUROSTAT is mandatory every two years. EUROSTAT publishes and disseminates all the data available, even for the years that are not obligatory, but there are countries that do not provide data on those years. This is currently the case for 2008 data for several EU Member States. Since ICT BERD data of some of these Member States have an important weight in the total EU ICT BERD, resorting to estimations would increase uncertainty to a level that would make the analysis unreliable, especially bearing in mind that 2008 was the year at the onset of the financial crisis.

36 These reports are available at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html (some are still forthcoming at the date of publication of this report).

Data sources and methodology[37]

The data used by PREDICT, in terms of collecting, estimating, aggregating, comparing or processing, follows the international standards set in particular by the 2002 edition of the OECD *Frascati Manual*.[38] 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 STAN (OECD), R&D Statistics (Eurostat), the EU Industrial R&D Investment Scoreboard (JRC-IPTS), and companies' financial reports for R&D data; and National Accounts, Trade, Price and GDP data (Eurostat), STAN (OECD), EU KLEMS (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 to correct for incoherencies and methodological differences, in order 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.

OECD and European Commission sources and companies' financial reports were used in order to assess impact of the financial crisis on the ICT sector performance and on ICT R&D investments.

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 worldwide and collected in the PATSTAT database of the EPO.[40] This global coverage makes possible a valid comparison of respective inventive prowess of the respective countries or world regions, which would otherwise be affected by a serious home 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.

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 Internationalisation Database* and looking at the global distribution of over 2 800 R&D sites of a group of 132 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.

37 See also the methodological annexes at the end of the report.
38 *Frascati Manual: Proposed standard Practice for Surveys on Research and Experimental Development*. Sixth edition; OECD, Paris, 2002.
39 The *EU Industrial R&D Investment Scoreboard* is available at: http://iri.jrc.ec.europa.eu/research/scoreboard_2009.htm
40 PATSTAT, the EPO Worldwide Patent Statistical Database contains 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.

2 The EU ICT sector: recent trends

Authors: Geomina Turlea, Anna Sabadash

This chapter presents a brief overview of the EU ICT business sector: its size, recent trends in value added (VA) and employment, and its structure in terms of manufacturing and services sub-sectors. It also provides a comparison of the structure and weight of the ICT sector in the EU economy compared to other large economies in the world. The last section of the chapter provides a more detailed analysis at the level of EU Member States.[41]

Definition of the ICT sector[42]

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 (including both post and telecom services, due to data availability, particularly for international comparisons)
- 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 this chapter only refer to those ICT industries included in the NACE classes listed above (30, 32, 33, 642 -or 64- and 72). Therefore, they do not cover ICT-related activities embedded in other sectors of the economy, such as those in IT departments of firms which do not belong to the ICT sector (e.g., the automotive or aeronautics industries). This definition covers the ICT business sector.

41 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.

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

2.1 Size of EU ICT sector: overview of employment and value added in the EU ICT sector

In 2008, the EU ICT sector produced value added to the value of € 574 billion and employed 8.3 million people.[43] This represented 4.7% of GDP in 2008, of which 1% is in manufacturing and 3.7% are in services. These shares are slightly lower than those of other innovative sectors of the EU economy: i.e., Machinery and Equipment (1.8%) and Automotive (1.5%) in manufacturing, and Financial Intermediation (5.8%) in service activities.

The contribution of the ICT sector remained relatively constant at 4-5% of GDP from 1999 to 2008. During the same period, the annual growth rate of the EU ICT sector (5.6%) was much higher than the annual growth rate of EU GDP (2.2%). The apparent contradiction between the stable contribution of the ICT sector to GDP and its higher growth rate is explained by the dynamics of volumes and prices of ICT goods and services over the period. There was a combination of a stronger growth of the ICT sector, compared to GDP, measured in *volumes*, and of decreasing ICT sector *prices* while prices at the level of the economy kept on increasing over the period (see Section 2.1.2 for a more complete explanation).

The ICT sector as a whole also has a stable share in total employment (an average of about 3.6% since 1999) of which 0.9% was in manufacturing and 2.7% in services in 2008. As was the case for value added, these shares were slightly smaller than those of other innovative manufacturing sectors (Machinery and Equipment: 1.7%, Automotive: 1.5%) but on a par with the Financial Intermediation service sector (2.7%).

Labour productivity in the ICT sector (value added/employment) was higher than the average for the economy, with a higher rate of growth.

2.1.1 ICT sector employment

Employment in the ICT sector was 12% higher in 2008 than in 1999: a total of 0.8 million ICT jobs were created over a period of 9 years. During this period, ICT sector employment dynamics showed three general tendencies (see also Figure 2-1):

- First, an increasing growth of employment led by ICT services, namely by the Computer Services and Software subsector.

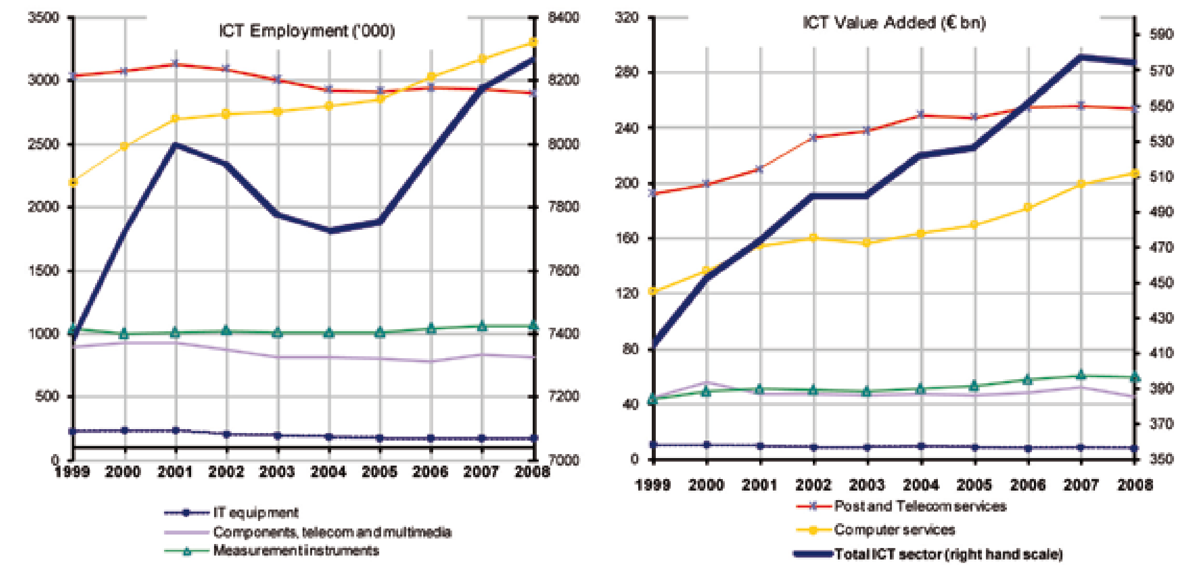
- Second, a cyclical iteration of relative expansion and contraction of employment in the sector. There was a major fall in employment after 2001 due to the dot.com crisis, which continued until 2004. This was followed by a rise and according to available data, ICT employment continued to grow during the 5 year period from 2004, although there was a relative slowdown in 2008.

- Third, a distinct divergence in the development of ICT manufacturing and ICT services. While employment in ICT services continued to grow steadily throughout the whole period under consideration, it shrank slightly in ICT manufacturing. The distribution of jobs within the ICT sector indicates an unambiguous and increasing dominance of ICT services: its share increased from 63% in 1999 to 71% in 2008.

In recent years, ICT employment has continued to grow, following the trend established in 2004, although at a slower rate in 2008 (0.4% in 2005, 2.7% in 2006, 2.6% in 2007 and 1.1% in 2008).

43 Data used in the current edition of this report are not fully comparable with the ones used in the previous editions, due to the methodological changes caused by the substantial revision of statistical classification of economic activities in the EU. Data used in the current edition come from the National Accounts, while the previous one is based on the Structural Business Statistics (SBS) data. Note that National Accounts data might overestimate Computer Services and Software employment with respect to SBS data. Additionally, this edition presents data from both Post and telecom services (NACE 64), while the previous edition presented Telecom services data only (NACE 642).

Figure 2-1: Employment and value added in the EU ICT sector, 1999-2008 (1 000 people and billions of €)



Source: Eurostat National Accounts Statistics.

Reallocation from manufacturing to services has intensified in recent years. Total employment in ICT services was almost 6.2 million jobs in 2008, which is 19% more than at the beginning of the analysed period. In 2008, ICT services generated over 100 000 jobs, as a result of jobs creation in Computer Services and Software (134 000 jobs or a 4% increase in 2008) and jobs destruction in Post and Telecom Services (34 000 jobs or 1% decrease). Computer Services and Software saw spectacular growth in employment in 2008. The number of people employed in the EU Computer Services and Software sub-sector subsector was over 51% higher in 2008 than it was in 1999. Computer Services and Software was thus confirmed as the leading ICT sub-sector employer in the EU. The share of Computer Services and Software in ICT services increased from 59% in 1999 to 65% in 2008, while its share in the ICT sector as a whole grew from 37% in 1999 to 46% in 2008. The Post and Telecommunications Services share did not change significantly after 1999 and fluctuated around 45% over the whole period. Though employment in this sub-sector decreased in 2008, its share in the ICT sector remained the second largest after Computer Services and Software.

ICT manufacturing accounted for slightly more that 2 million jobs in 2008, 98 000 less than in 1999. Employment in this sub-sector continued to stagnate throughout the whole 1999-2008 period: after a slight recovery in 2007, employment dropped 0.5% below its 2007 level. The main sub-sector contributing to falling employment in ICT manufacturing was the Components, Telecom and Multimedia sub-sector – with a 2% decline in employment in 2008. Two other sub-sectors, IT Equipment and Measurement Instruments, had weak employment growth (1.9% and 0.7% respectively), which occurred at a decreasing rate compared to 2007. Measurement Instruments remained the leader among the ICT manufacturing sub-sectors for the whole 1999-2008 period (its share in ICT manufacturing employment grew from 48% in 1999 to 52% in 2008) and it was the third largest ICT sub-sector in 2008 (accounting for 15% of employment in the ICT sector) after Computer Services and Software and Telecom Services. Components, Telecom and Multimedia accounted for 40% of ICT manufacturing employment in 2008 (slightly lower than in 1999) and remained the second most important manufacturing sub-sector despite its declining level of employment. IT Equipment continued to have the smallest share of employment, both among ICT manufacturing sub-sectors (9% in 2008) and in the ICT sector as a whole (2.5%), with decreasing shares throughout the whole period.

2.1.2 ICT sector value added, prices, and growth

The ICT sector is responsible for 5% of the average yearly growth of GDP between 1999 and 2008.[44] As already mentioned, the apparent contradiction between the stable -slightly declining- contribution of the ICT sector to GDP and its higher rate of growth can be explained by the different dynamics of volumes and prices of ICT goods and services (see Annex 2 for a discussion of *nominal* value added measured in current prices vs. *real* value added measured in volumes or constant prices). The real value added in the ICT sector grew faster than the real GDP, which means that the ICT sector made a positive contribution to GDP growth through the period of our analysis (see Figure 2-2 left). In turn, ICT prices declined relative to the growth of general price deflator (see Figure 2-2 right). The combination of these two factors explains the slight decline in the share of ICT value added in total GDP (from 4.8% in 1999 to 4.7% in 2008).

In ICT services, value added in nominal terms reached 80% of the total ICT sector value added in 2008, whilst it was less than 75% in 1999. In ICT manufacturing it declined in the same period from almost 26% in 1999 to 20% in 2008 (see Figure 2-1, right, for an evolution of nominal value added in ICT sub-sectors).

The growth in the nominal share of ICT services is almost exclusively due to Computer Services and Software: this sub-sector's share in total ICT increased from 29% in 1999 to 36% in 2008. The Post and Telecom Services share in total ICT, however, slightly declined in the same interval, from 46.5% in 1999 to little over 44% in 2008.

These dynamics can be further broken down into ICT sub-sectors by real (volumes) and nominal (prices) trends. This is done in Table 2-1 which shows an increase in real value added (volume growth) and a decline in prices in IT Equipment, in Components, Multimedia and Telecom Equipment, and in Post and Telecom; and shows growth in both volumes and prices in Computer Services and Software.

The decline in ICT manufacturing output prices is a well-known effect caused by a variety of factors including globalisation and commoditisation of semiconductors and their applications. The decline in prices is partly the result of strong innovation-based competition at the upper layers of the ICT value chain.

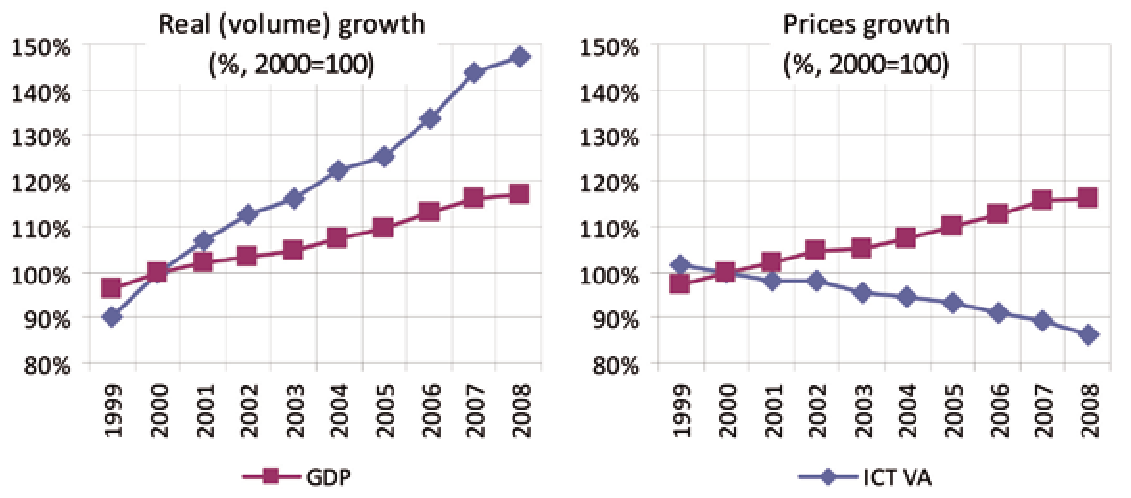
The very fast increase of the volume of ICT value added relative to the volume of GDP can certainly be explained by the fast diffusion of ICT goods, but it also results from sustained technological progress, which hints at the impact of the high R&D intensity in the ICT manufacturing sectors. According to EU KLEMS data, the real output of the EU ICT manufacturing sector[45] increased by 40% between 2000 and 2007 and its real value added by 43%.

In the Telecom Services sector, clearly an ongoing EU success story, liberalisation and restructuring have also led to a drop in prices and growth in real value added. These dynamics are led by better economy of scale and cost competition, and also by technological developments. The

44 This calculation only looks at the differential in the rate of growth between the ICT sector and the rest of the economy. It does not include the effect of ICT capital deepening or of the ICT-based innovation in other sectors. See a.o. J.Van Reenen et al. (2010), The Economic Impact of ICT, http://ec.europa.eu/information_society/eeurope/i2010/docs/eda/econ_impact_of_ict.pdf

45 For the EU25; proxied by the Electrical and optical Sector, of which ICT manufacturing is a part (http://www.euklems.net).

Figure 2-2: The dynamics of the real value added and prices in the ICT sector relative to the overall economy



Source: Authors calculations based on EUROSTAT data.

Table 2-1: Indicators of value added dynamics

Value added	2008 current prices, € billion	Share in GDP (2008, %)	Change in the share in GDP (2008/1999, pp)	Volume growth (2008/1999, %, annual rate of growth)	Price growth (2008/1999, %, annual rate of growth)
Total economy	12494	100%	0.00%	2.2%	2%
Total ICT	574.3	4.60%	-0.22%	5.6%	-0.67%
IT Equipment	8.1	0.06%	-0.06%	13.6%	-14.43%
Components, Multimedia and Telecom Equipment	46	0.37%	-0.16%	9.2%	-8.24%
Measurement Instruments	59.7	0.48%	-0.04%	3.3%	0.09%
Post and Telecom Services	253.5	2.03%	-0.21%	5.1%	-1.77%
Computer Services and Software	207	1.66%	0.24%	5.5%	0.95%

Source: Authors calculations based on EUROSTAT data.

process of consolidation of Telecom markets is still proceeding and, supported by technological trends, is expected to generate further economic growth and consumer benefits.

Computer Services and Software is the only ICT sub-sector that saw its real value added grow simultaneously with its prices, which directly reflects the growing demand for its services and the expansion phase which this sector is currently experiencing.

2.1.3 ICT sector labour productivity

In 2008, the ICT sector had a higher nominal labour productivity (nominal value added/total employment) than the average of the economy by 27% (70 k€/employed person in the ICT sector compared with 55.2 k€/employed person on average in the economy). Furthermore, if the value added is measured in constant prices, the yearly rate of growth of labour productivity (real value added/total employment) is almost four

Table 2-2: Indicators of labour productivity dynamics

Labour productivity (value added/employment)	2008 current prices, k€/employee	Volume growth (2008/1999, %, annual rate of growth)
Total economy	55.2	1.2%
Total ICT	70	4.3%
IT Equipment	45.5	16.7%
Components, Multimedia and Telecom Equipment	56.1	10.3%
Measurement Instruments	56	3.0%
Telecom Services	87.5	5.5%
Computer Services and Software	62.5	0.4%

Source: Authors calculations based on EUROSTAT data.

times higher in the ICT sector (4.3%) than in the rest of the economy (1.2%).

Of all the ICT sub-sectors, Computer Services and Software had the most modest increase in labour productivity in constant prices over the period considered, even lower than the total economy. This means that, when compared with other ICT sub-sectors, the expansion of the value added in Computer Services and Software was mostly matched by growth of employment. The dynamics of this sector reflect two further important features. Firstly, Computer Services and Software has played an increasingly important role in the economy, notably as an employer. Secondly, after the current expansion, a period of more intensive growth is expected, with a trend towards increasing labour productivity rather than increasing employment.

ICT manufacturing sub-sectors have had much higher growth in productivity than ICT service sub-sectors, when the value added is measured in constant prices. This means that ICT manufacturing has made a much higher contribution to total economy labour productivity growth (both measured in constant prices) than the ICT service sub-sectors. This is probably the effect not only of outsourcing lower value added manufacturing activities towards lower cost countries, but also of the EU industry's increasing specialisation in high value added niches. The EU components manufacturing industry, for instance, is specializing in the high value added niches of semiconductors and microsystems designed for specific microelectronics functions (power management, interface, security and digital processing expertise, enabling end-product market, RFID) and leveraging advanced semiconductor technologies for systems solutions, like MEMS, SoC (System on Chip), and SiP (System in Package).

The important role of the ICT manufacturing sectors in supporting growth, however, makes it even more crucial that the EU's ability to develop such high value-added ICT manufacturing activities is further enhanced. These activities should then be maintaining at the technological frontier.

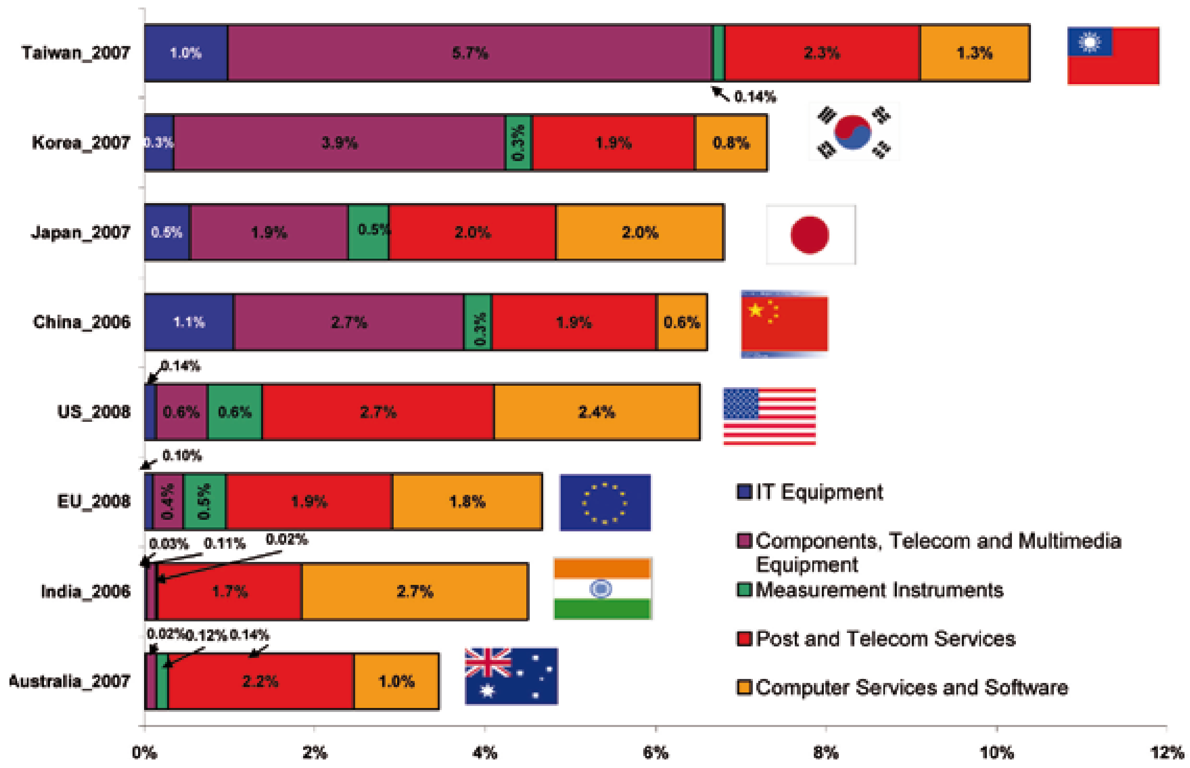
2.2 Structure and size of the EU ICT sector in a global perspective

Figure 2-3 shows the relative economic weight of the ICT sector and its manufacturing and services sub-sectors (in VA/GDP) in the EU and a selection of world countries and regions.

A first observation is that with ICT VA/GDP at 4.7%, the relative economic weight of the ICT sector was significantly smaller in the EU in 2008 than in the US (6.4%), China (6.6%[46]), Japan (6.9%), Korea (7.2%) and Taiwan (10.5%).

46 In 2006, most recent year available.

Figure 2-3: Economic weight of the ICT sub-sectors, % of sub-sector's value added in GDP, 2008, or latest data available



Source: JRC-IPTS based on data from EUROSTAT, OECD, EU KLEMS, IPTS (2010,a,b) and IPTS.[47]

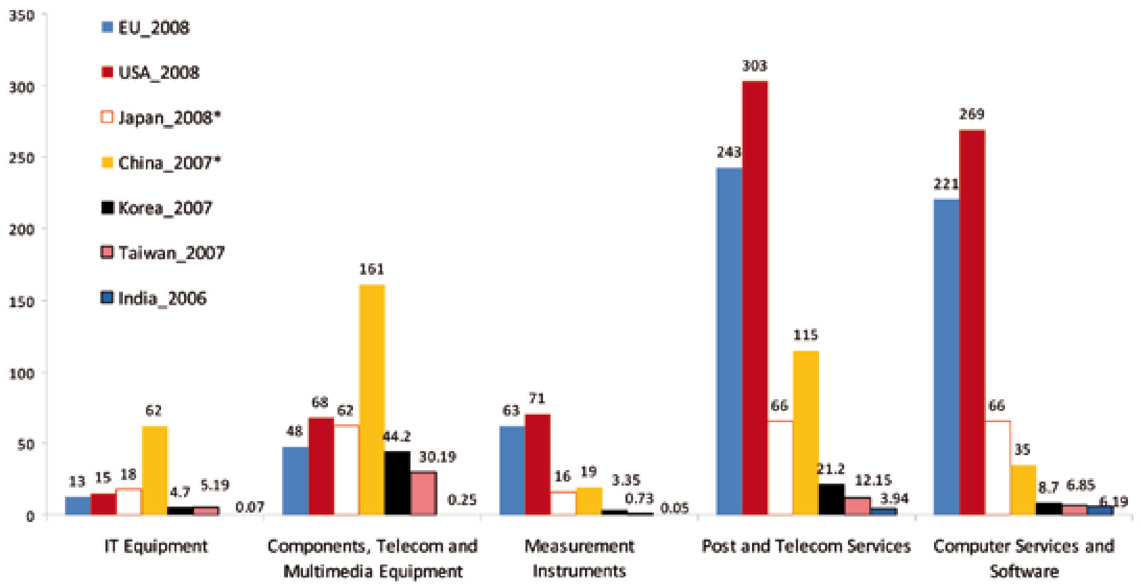
A second observation is that the structure of the ICT sector in the EU is fairly similar to that of the US, but very different to that of Japan, Korea and Taiwan.' The Asian countries have a comparatively much bigger ICT manufacturing sector. Japan's share of ICT manufacturing relative to GDP is three times bigger than the EU's and more than twice as big as the US's. And China, Korea and Taiwan all have a share in GDP of ICT manufacturing higher that Japan's.

Japan cannot, however, be labelled as primarily an ICT-manufacturing economy as its share of Telecom and Computer services in GDP is 4%, i.e., between those of the US (5.1%) and the EU (3.7%). A clearer case of national specialisation is Taiwan, with a share in GDP of its Components, Telecom and Multimedia Equipment sub-sector of 5.7%, i.e., higher than the share in GDP of the entire EU ICT sector.

In ICT services, the share of Telecom Services in GDP is fairly similar for the countries in this sample, while the share of Computer Services and Software shows a rather important dispersion: from 0.6% of GDP in China, to 2.7% in India. The fact that the highest share of Computer Services and Software in GDP is in India challenges the commonly-held belief that the development of services is associated with the size of internal demand: many ICT Services have become tradable, and indeed, the companies providing these have aspirations towards the global market.

47 Dr Shin-Horng Chen, Dr Pei-Chang Wen and Dr Meng-Chun Liu (2011), Trends in Public and Private Investments in ICT R&D in Taiwan. JRC Technical Note – JRC63993, Institute for Prospective Technological Studies, Joint Research Centre, Euopean Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/documents/ICT2_CR_Taiwan_1Novformattedjpsjan13.pdf; Malik P. and Vigneswara Ilavarasan, P. (2011), Trends in Public and Private Investments in ICT R&D in India, JRC Technical Note – JRC 64578. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/documents/ICT2RandDIndiafinal18012011.pdf; Ling Wang, Shiguo Liu (2011 forthcoming), Trends in Public and Private Investments in ICT R&D in China. Institute for Prospective Technological Studies, Joint Research Centre, European Commission.

Figure 2-4: Value added in the ICT subsectors, billions of €, PPP nominal exchange rates



Source: JRC-IPTS based on data from EUROSTAT, OECD, EU KLEMS, IPTS and IPTS.[48]

Figure 2-4 provides an image of ICT world markets and of the position of the EU versus its current and emerging competitors. The figure presents comparative statistics (in PPP exchange rates[49]) on size of the value added created in the ICT sectors for the Triad countries, for the most important ICT manufacturing Asian countries (Korea, China, Taiwan), and for India in 2008 - or the latest year available.[50]

A first observation is that India makes a very small contribution to the world ICT market compared with the rest of the countries in the sample. Korea, China and Taiwan play important roles on the manufacturing markets, while the Triad countries, and especially the US and the EU, produce comparatively much more value added in telecom and computer services than China, Korea, Taiwan and India together.

The specialisation of Asian countries in cheaper hardware production plays an important role in the diffusion of ICT technologies; it feeds the worldwide demand for ICT goods, including the growing demand in the EU and the US, and creates conditions for the consequent development in the more advanced economies of ICT services and sectors which embed ICT in their final products.

48 Dr Shin-Horng Chen, Dr Pei-Chang Wen and Dr Meng-Chun Liu (2011), Trends in Public and Private Investments in ICT R&D in Taiwan. JRC Technical Note – JRC63993, Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/documents/ICT2_CR_Taiwan_1Novformattedjpsjan13.pdf; Malik, P. and Vigneswara Ilavarasan, P. (2011), Trends in Public and Private Investments in ICT R&D in India, JRC Technical Note – JRC 64578. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/documents/ICT2RandDIndiafinal18012011.pdf; Ling Wang, Shiguo Liu (2011 forthcoming), Trends in Public and Private Investments in ICT R&D in China. Institute for Prospective Technological Studies, Joint Research Centre, European Commission.

49 PPP: Purchasing Power Parity or PPP adjustment of exchange rates 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.

50 Due to the very limited data availability, we could only include India for the year 2006.

2.3 The ICT sector in the EU Member States

2.3.1 Size and structure of the ICT sector by Member State

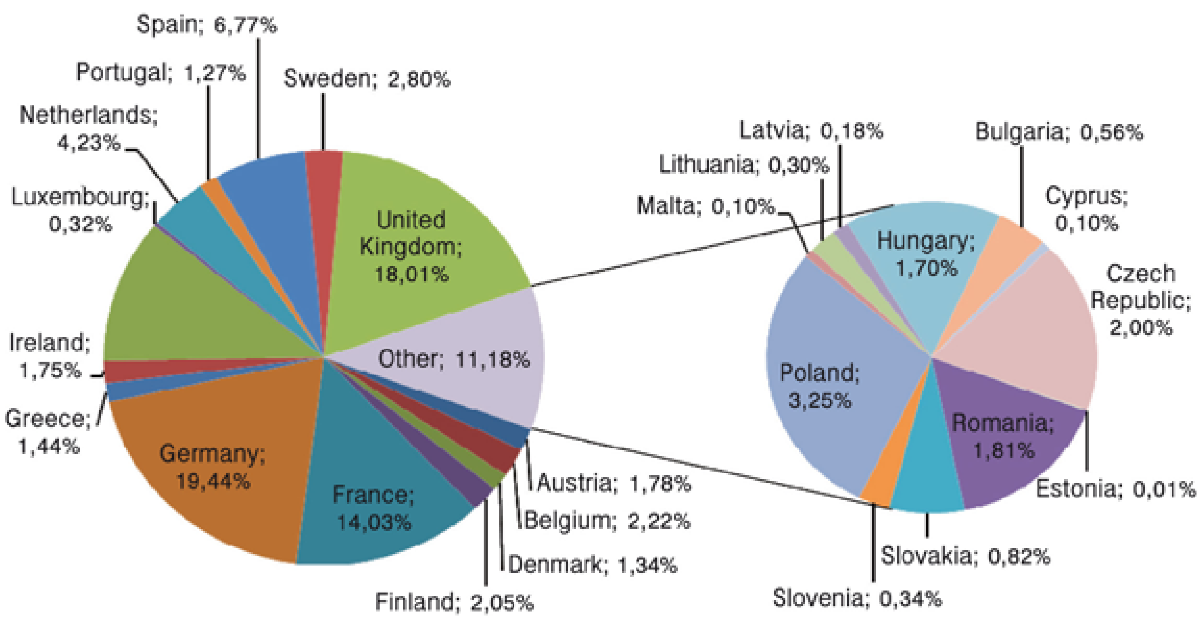
This section compares the EU Member States by their contribution to the EU total figure of ICT value added. It looks at both the size of the ICT sector in the 27 EU Member States and the 'weight' of the ICT sector in the national economies.

Figure 2-5 plots the distribution of EU ICT value added by Member State, in PPP.[51] Four countries - Germany, the UK, France and Italy - cover two thirds of EU total ICT production. European countries traditionally known for their ICT specialisation, such as Finland, Ireland, Hungary, Malta and Sweden, produce less than 7% of the total European ICT value added. The share of the EU12 countries[52] in total EU ICT value added (11.2%) is almost on a par with the share of their GDP in EU GDP (12.1%), which suggests that, at the level of the ICT sector as a whole, the level of specialisation of these countries is similar to those of the EU15 countries.

Figure 2-6 ranks the EU Member States according to the share of the ICT sector in their GDP. Of all the EU countries, the share of the ICT sector in the economy is largest in Finland and lowest in Cyprus. Four of the countries that joined the EU in 2004 are more specialised in ICT that the EU average: Hungary, Malta, Czech Republic and Slovakia.

Figure 2-6 also shows that the ICT sector in Finland, Ireland, Malta and Hungary is heavily dependent upon the manufacturing sub-sectors, while in Sweden, Germany and Italy the ICT sector structure is closer to the EU average. At

Figure 2-5: ICT value added produced by EU countries, % in EU ICT value added, PPP, 2008

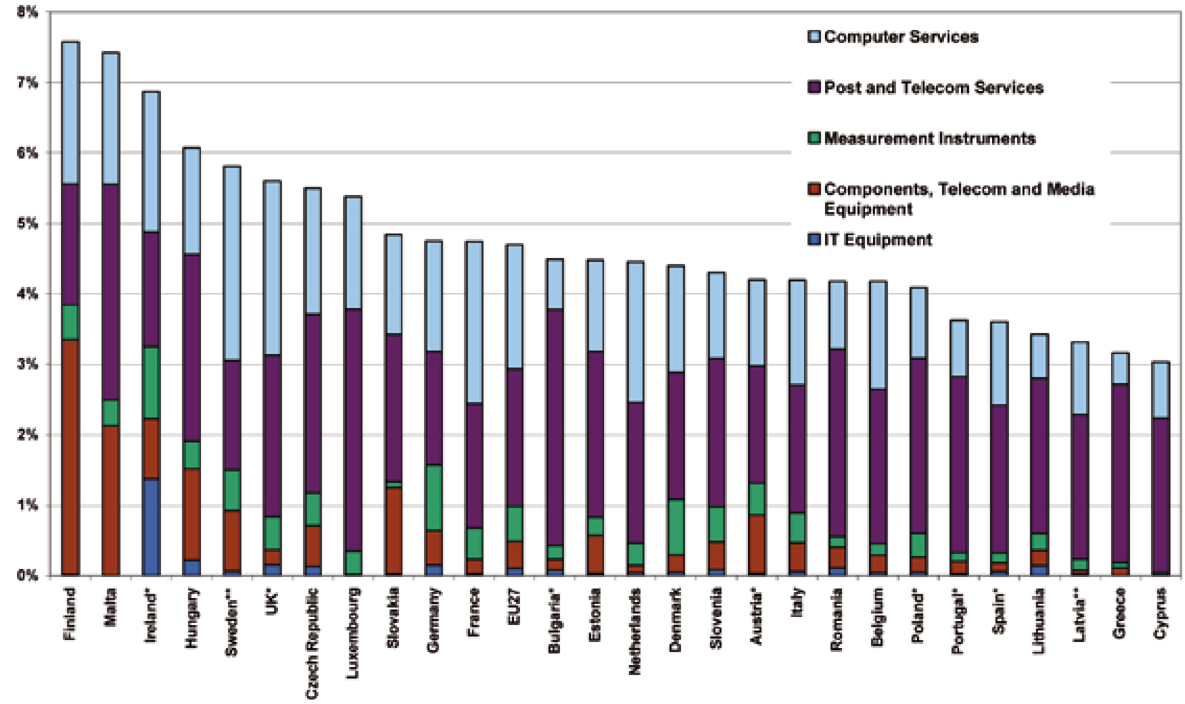


**- include estimations with lower confidence level.*
Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics.

51 Data expressed in PPP terms (for comparability) may lead to different results from those obtained using nominal values.

52 'EU 12' countries are the group of 12 Member States that most recently joined the EU.

Figure 2-6: Weight of the ICT sector in the economy of EU countries ICT value added / GDP, current prices, 2008



**- include estimations with lower confidence level.*
Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics.

the other extreme, in the UK and France, the ICT sector structure is more oriented towards the service sectors. This is also the case for most of the EU12 countries, where the dynamics of the relative prices of telecommunications services plays an important role.

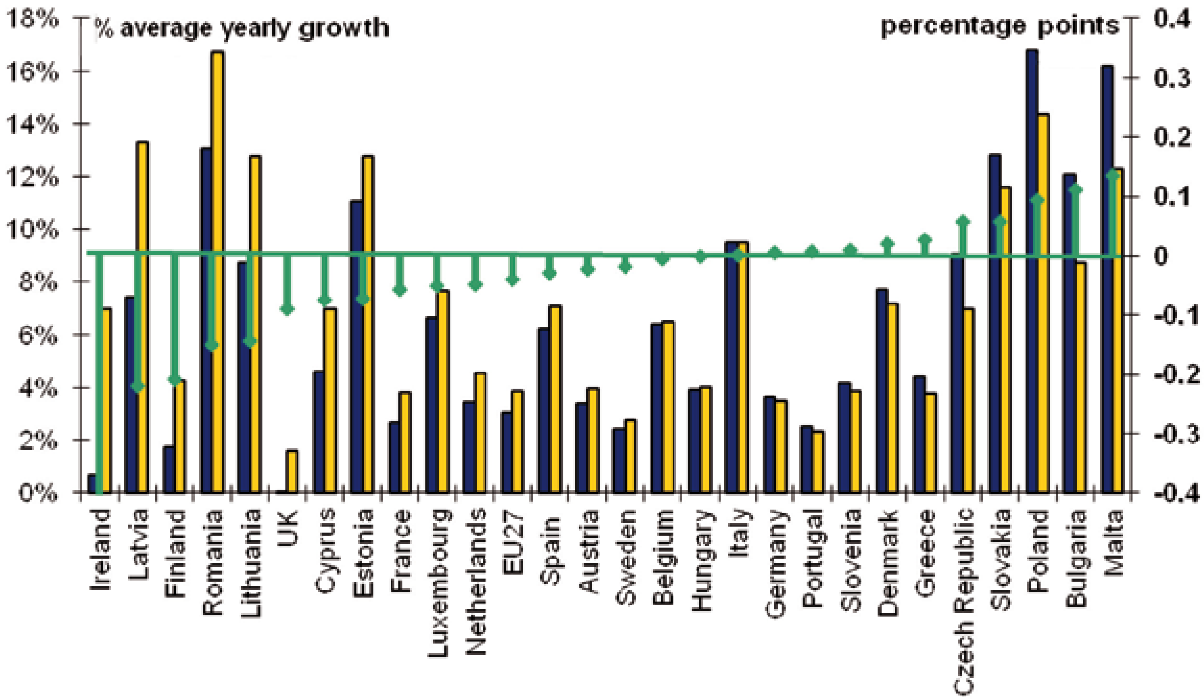
2.3.2 Trends and structural changes in the Member States' ICT sectors

During the 2000-2008 period, various EU Member States changed their relative positions with respect to their shares in the overall EU ICT production since they joined the EU. Greece, Spain and Portugal increased their shares between 2000 and 2008, mostly because they rapidly caught up in ICT services. But the most important structural trend is the steadily increasing share of the newer Member States, before and after the year of their accession, from approximately 8% in 2000 to over 10% in 2004 and to over 11% in 2008.

The share of the ICT sector in the national GDP of the EU Member States also changed during the period under scrutiny. 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 as well. Figure 2-7 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 2000 to 2008, two of the three countries most specialised in ICT - Ireland and Finland (as seen in Figure 2-6) - saw significant decreases in the shares of the ICT sector in their economies (as measured by ICT value added/ GDP, in percentage points). In Ireland, Finland and also in 13 other EU Member States, this decrease stemmed from 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 of the ICT nominal

Figure 2-7: 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, 2000-2008



*Note: data unavailable for Malta in 2000; *- include estimations with lower confidence level.*
Source: JRC-IPTS based on data from Eurostat, OECD, EU KLEMS and national statistics.

value added that were more rapid than of the total GDP, with Germany and Denmark as the only important exceptions.

In general, the share of ICT manufacturing sectors in GDP (when expressed in current prices) has declined since 2000, while the share of ICT services has grown in most of EU countries.[53] There are exceptions, because a lot of manufacturing was relocated from western EU countries to several eastern countries, and these countries saw a steady increase of their manufacturing base. However, EU12 countries have not achieved relative specialisation in manufacturing yet, and the share of ICT manufacturing value added produced in these countries is lower than the share of their GDP in total EU GDP, (see Figure 2-8). Moreover, while before and after their accession, these countries developed their hardware production and relative position within the EU space, they also increased their levels of ICT adoption and use, and hence the availability of services.

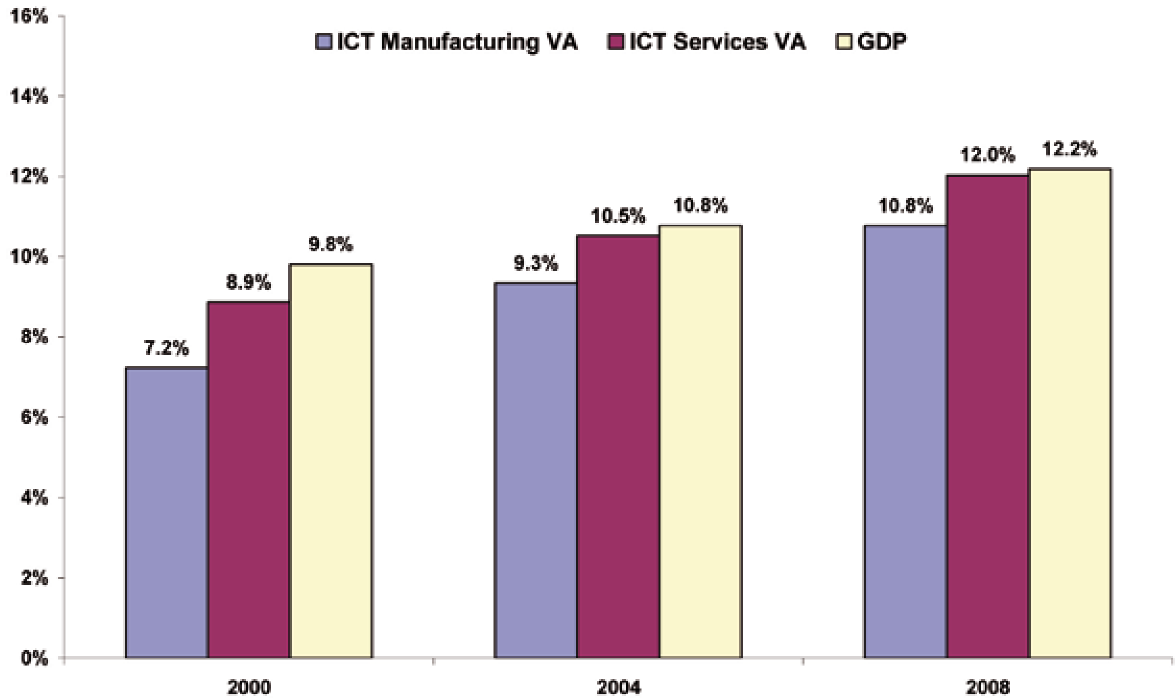
2.4 Summary of main observations

In 2008, the EU ICT business sector contributed 4.6% of EU GDP, and with over 8 million jobs representing 3.7% of total employment in the EU. Labour productivity is therefore significantly higher in the ICT sector than in the rest of the EU economy.

The share of ICT services in the EU ICT sector continued to increase, reaching 80% of value added (VA) and 71% of employment in 2008, driven by the Computer Services & Software ICT sub-sector that alone represents 46% of ICT employment.

53 Price dynamics play an important role in these developments, as pointed out in Section 2.1.2. However, in this section and for simplicity's sake, we limit the analysis to data expressed in current (PPP) prices.

Figure 2-8: Evolution of ICT VA and GDP shares of the EU12 countries in total EU (%, PPP)



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

Value added and employment in ICT manufacturing and Telecom Services sub-sectors stagnated, or declined, in recent years (at least until 2008, the latest year for which data is available). This observation must however be interpreted with caution, since it does not reflect a declining volume of activities, but is most probably the result of declining prices due to technological innovation in ICT manufactured products, and of increased price competition following liberalisation of telecoms. In fact, the ICT sectors continue to make sustained positive contributions to GDP and productivity growth.

Compared to other major economies of the world, the EU's ICT sector has the lowest weight in the economy: 4.7% of EU GDP in 2008, versus 6.4% in the US, 6.6% in China (in 2006, latest year available), 6.9% in Japan, 7.2% in Korea and more than 10% in Taiwan. Asian countries are also much more specialised in ICT manufacturing than the EU or the US.

Within the EU, the four largest economies (Germany, France, the UK and Italy) produce 2/3 of the EU ICT sector value added, and Germany alone produces 20% of it. However, Finland, Ireland, Hungary and Sweden, countries with important shares of ICT VA in their GDP, produce together less than 7% of the EU ICT sector VA (i.e., the same share as Spain alone). The share of EU ICT VA produced by the 12 Eastern countries that most recently joined the EU is regularly increasing, and reached 11% in 2008.

The share of ICT manufacturing relative to services is higher in Finland, Ireland, Hungary and Malta compared to the EU average. Germany, Sweden and Italy are closer to the EU average, while France, the UK and Spain produce relatively more ICT services compared with ICT manufacturing than the EU average. Although in the last decade ICT manufacturing activities have been relocated from Western to Eastern Europe, as a whole, 'EU12' countries are not more specialised in ICT manufacturing than the rest of the EU.

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3 The impact of the economic crisis on the ICT sector

Author: Wojciech Szewczyk

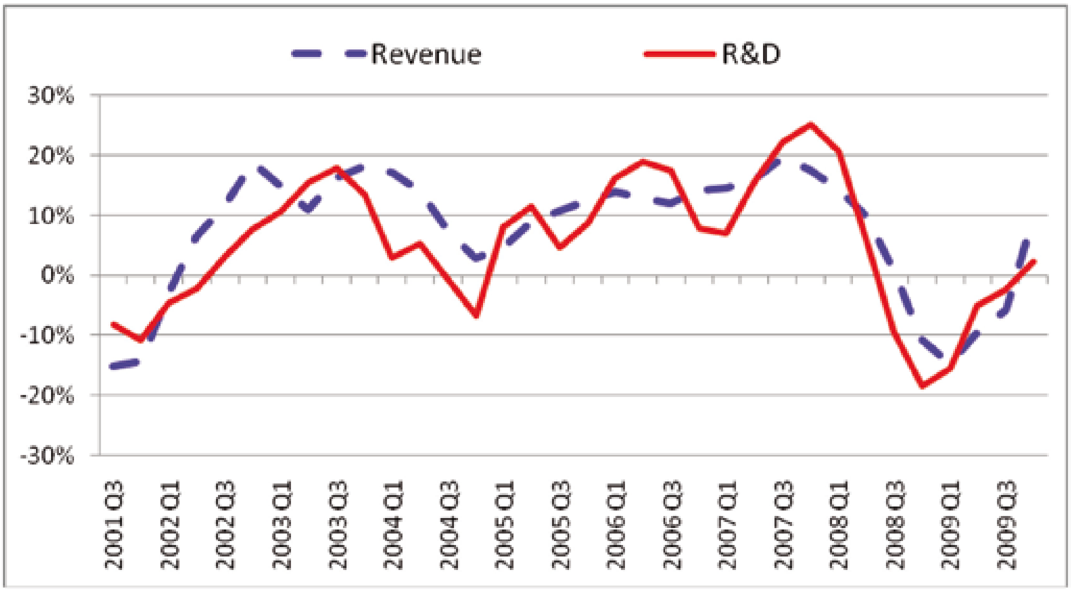
The 2008-2009 financial crisis slowed down the world economy profoundly. The ICT sector and ICT R&D activities were no exception to the overall reduced economic activity.

This section attempts to portray the impact of the crisis on ICT sector performance, including ICT R&D expenditure. It briefly presents selected statistics, including analysis of aggregated global ICT sector dynamics, description of underlying dynamics with respect to geographical distribution of semiconductor production, and trends by ICT sub-sectors. It also looks at recent revenue and R&D expenditure trends for a selection of EU and US companies.[54]

3.1 ICT sector revenue and R&D expenditure growth

Information collected by the OECD (2010) shown in Figure 3-1 depicts the trend in total revenue and R&D spending for the top 200[55] ICT firms over the almost ten year period between Q3/2001 and Q1/2010.

Figure 3-1: Change in R&D expenditure and total revenue for the top 200 ICT firms worldwide; 2-quarter moving average

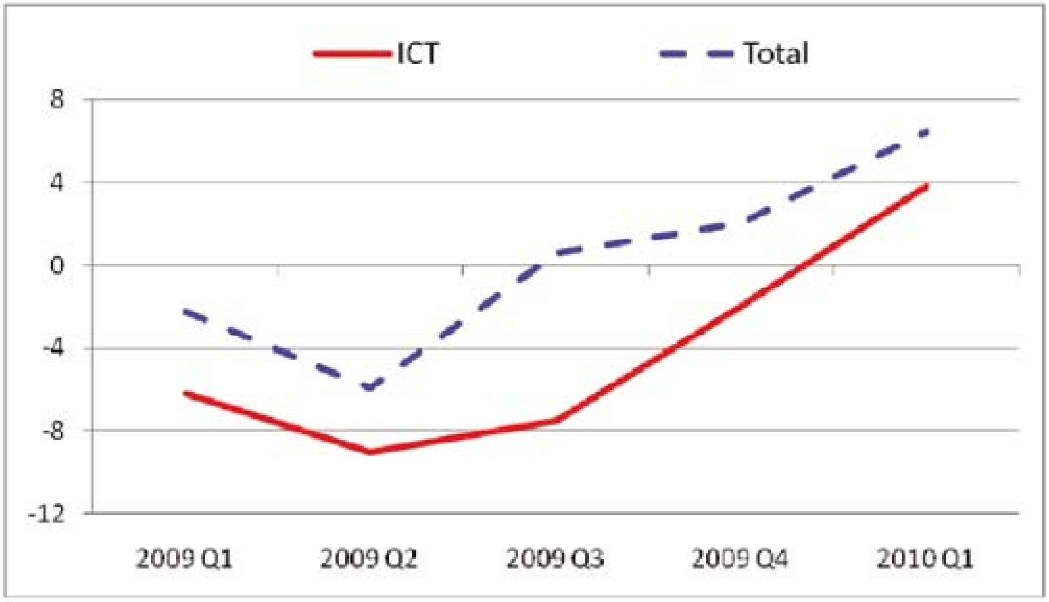


Source: OECD IT Outlook (OECD, 2010).

54 Analyses presented in this section are based on data obtained from OECD and companies' financial reports. This section also benefits from analysis presented in the Digital Agenda Scoreboard, Commission Staff Working Paper Pillar 5: Research and Innovation (2011), European Commission, available at: http://ec.europa.eu/information_society/digital-agenda/scoreboard/index_en.htm

55 The top 200 firms are selected with respect to their revenue. See OECD (2010) for details.

Figure 3-2: Change in growth rates for R&D expenditure in ICT firms and all firms from all sectors, percent.



Source: OECD (OECD, 2010), sample of about 2 000 firms listed at the US Stock Exchange Commission.

As Figure 3-1 shows, growth in R&D expenditure since the previous dot-com crisis in 2000 for the top 200 ICT firms worldwide follows, in an oscillating manner, the pattern of total revenue growth. The greatest decline was recorded during the last quarter of 2008 (R&D expenditure approaching -20%) and the first quarter of 2009 (-15% revenue). The ICT industry, however, returned to positive growth in the first quarter of 2010, with R&D initially recovering even faster than revenue.

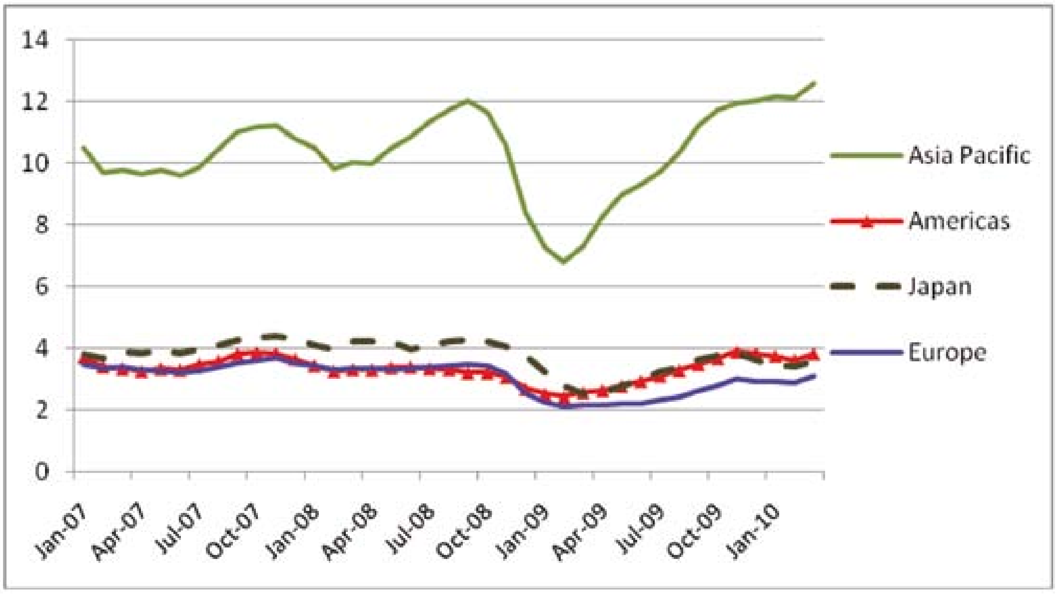
It is informative to picture the ICT sector's R&D dynamics in relation to what happened in other sectors. Figure 3-2 portrays the growth in R&D expenditure in a sample of ICT[56] firms relative to the growth of firms across all economic sectors worldwide from early 2009 to early 2010 (OECD, 2010). Figure 3-2 shows that not only was the slowdown in R&D expenditure for ICT firms deeper than across all sectors but also the recovery from the second quarter of 2009 was slower than the growth in R&D expenditure across all sectors.

56 The ICT sector here is proxied by a group of technology firms specialising in ICT. The group consists of firms dealing with communications equipment, computer hardware, computer networks, computer peripherals, computer services, computer storage devices, electronic instruments and controls, office equipment, scientific and technical instruments, semiconductors, software and programming.

3.2 Semiconductor market

The evolution of semiconductor supply between 2007 and 2010 for four broad geographical regions is shown in Figure 3-3. The impact of the crisis is clearly reflected in the decline in values of semiconductors traded across the world economy. The Asia-Pacific region, the largest supplier of semiconductors, almost halved its output over the six month period between 09/2008 and 02/2009. The respective changes for other regions, although related to smaller volumes produced, were still very substantial: almost 40% reduction in Europe and 35% decline in Japan, and about 20% in the Americas (relatively, the smallest decrease). The subsequent recovery had different dynamics across the regions. The Asia-Pacific region had rebounded to the pre-crisis levels by the end of 2009 and then continued to grow. The Americas surpassed production levels from the pre-crisis period in the last quarter of 2009. Japan and Europe did not reach their pre-

Figure 3-3: Semiconductors supply by region, 2007-2010, billions of US dollars, current prices



Source: OECD (OECD, 2010) based on World Semiconductor Trade Statistics.

crisis levels of semiconductor production, and their output in March 2010 was still lower by about 11% (Europe) and 15% (Japan) compared to the first quarter of 2007.

3.3 Impact on ICT sub-sectors

The study now turns to a more detailed analysis of performance and R&D expenditure data for the largest EU and US ICT companies classified into six ICT sub-sectors: Internet, Computer Hardware, Software, Semiconductors, Computer Services and Telecom Equipment. This more detailed analysis indicates[57] the behaviour of the sub-sectors that make up the broader ICT industry.

Figure 3-4 presents the performance of the ICT sub-sectors[58] between 2007 and 2010 and consists of two charts: one shows the firms' revenue and the other the firms' R&D expenditure. The data presented is based on a sample of 39 EU and US ICT firms selected for their high revenue and R&D spending; the data is normalised to equal 100 in 2007.[59] 2007 was chosen as the base year in order to provide a pre-crisis benchmark.

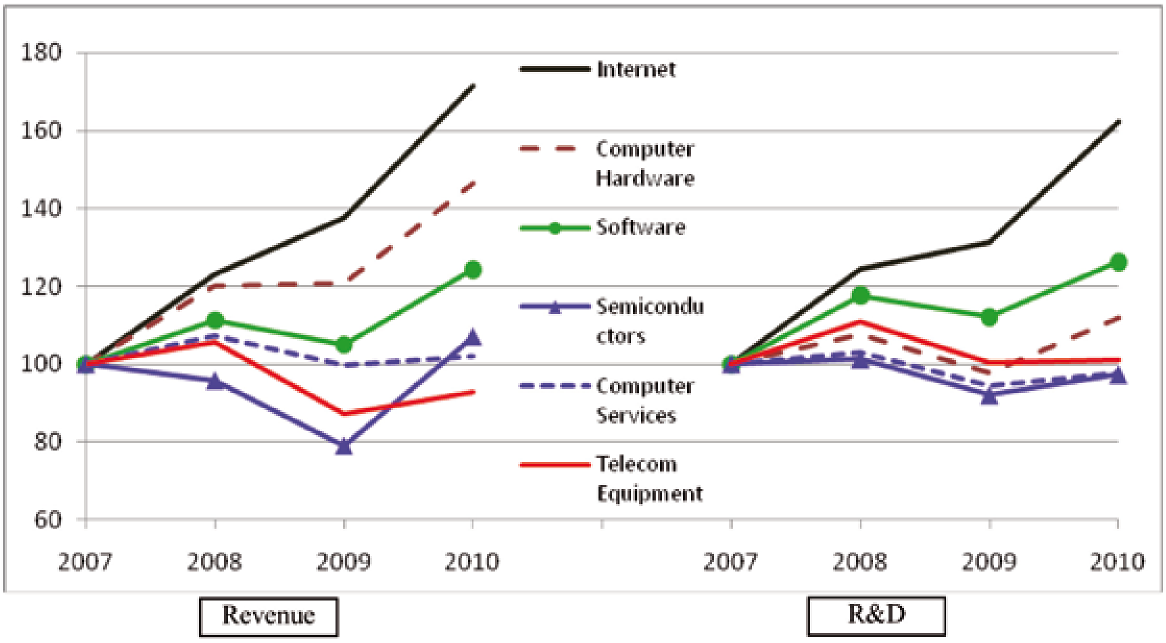
The left chart of Figure 3-4 shows how the ICT sector revenue trend previously presented in Figure 3-1 changes for the constituent industries. The graph clearly shows that the Internet sub-sector experienced the greatest growth between 2007 and 2010 with almost no signs of slowdown at the peak of the crisis in 2008. By 2010, this sub-sector had achieved 70% growth in revenues relative to 2007 levels. Computer Hardware and Software exhibited a less rapid trend between 2008 and 2009, but then grew rapidly in 2010,

57 The sample of firms used for the sub-industry analysis is not identical to the sample of firms used for the ICT sector performance analysis presented in the first part of this section, hence this sub-sector analysis is not an exact breakdown of the ICT sector behaviour. However, the trends identified are accurate representation of the industry dynamics.

58 The sub-groups comprise the following companies: **Computer Hardware**: HP, Apple, EMC; **Computer Services**: IBM, CSC, Accenture, Cap Gemini, Atos Origin; **Internet**: Amazon.com, Google, eBay, Yahoo; **Semiconductors**: ASML, Applied Materials, Intel, Broadcom, AMD, Texas Instruments, Freescale Semiconductor, Infineon, STMicroelectronics, ARM, NXP; **Software**: Oracle, Microsoft, SAP, Symantec, Dassault Systèmes; **Telecom Equipment**: RIM, Motorola, Sony Ericsson, Nokia, Qualcomm, Cisco, Ericsson, Juniper Networks, Alcatel Lucent.

59 Data is normalised to allow for comparisons abstracting from differences in revenues and in expenditures levels.

Figure 3-4: Growth rates for ICT sub-sector revenue (left) and R&D expenditure (right), 2007-2010, index=100 in 2007



Source: compiled from companies' financial reports.

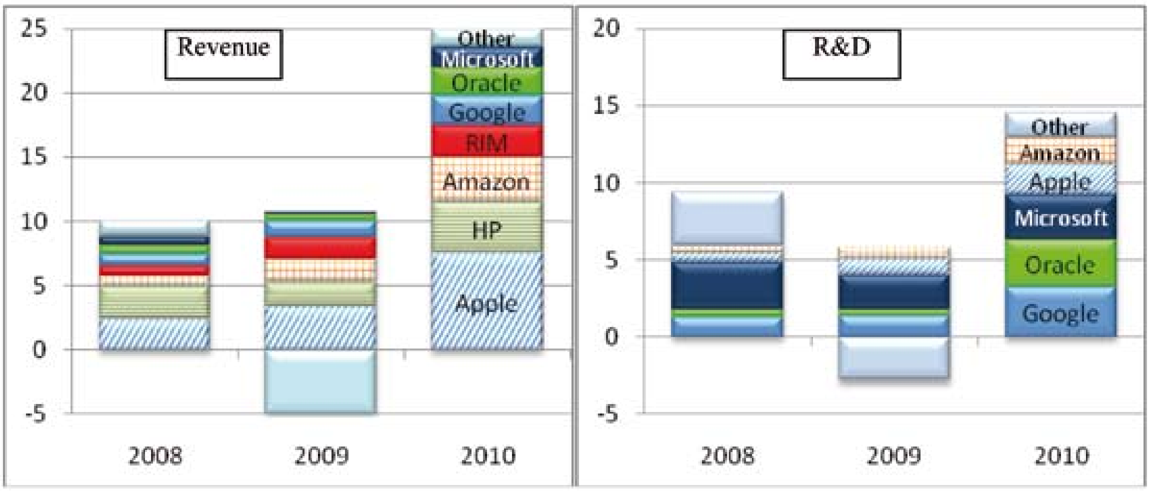
by almost 50% and 25% respectively, relative to 2007. Telecom Equipment and Computer Services displayed a decline in 2009 (13% and 0.5% respectively, relative to 2007) followed by modest positive growth in 2010. Semiconductors followed a declining trend until 2009 (21% drop relative to 2007) and then rebounded in 2010, reaching values above the 2007 levels (7% above the 2007 level), in line with similar observations made in Figure 3-3.

The corresponding trends for R&D expenditure are depicted on the right of Figure 3-4. Here, again, the most rapidly growing sub-sector is Internet: though the impact of the crisis was visible in 2009, positive growth rates began to accelerate in 2010. This sub-sector achieved over 60% growth in R&D expenditures in 2010 relative to 2007, almost as high as the 70% growth rate in its revenues. For the rest of the sub-sectors, the effect of the crisis in 2009 was more pronounced and resulted in a decline in R&D expenditure in 2009, though the Software sub-sector was able to maintain expenditures above the 2007 levels and the Telecom Equipment sub-sector's expenditures were equal to 2007 levels. R&D expenditures for Computer Hardware, Computer Services and Semiconductors declined below the 2007 levels in 2009. In 2010, Software, Computer Hardware and Telecom Equipment recorded growth rates high enough to recover to, or above, the pre-2007 levels (26%, 12% and 1% above the 2007 values, respectively). Though Computer Services and Semiconductors registered positive growth rates in 2010, they remained below the pre-crisis R&D expenditure values (2% and 3% below the 2007 levels, respectively).

3.4 Impact on performance of individual multinational companies

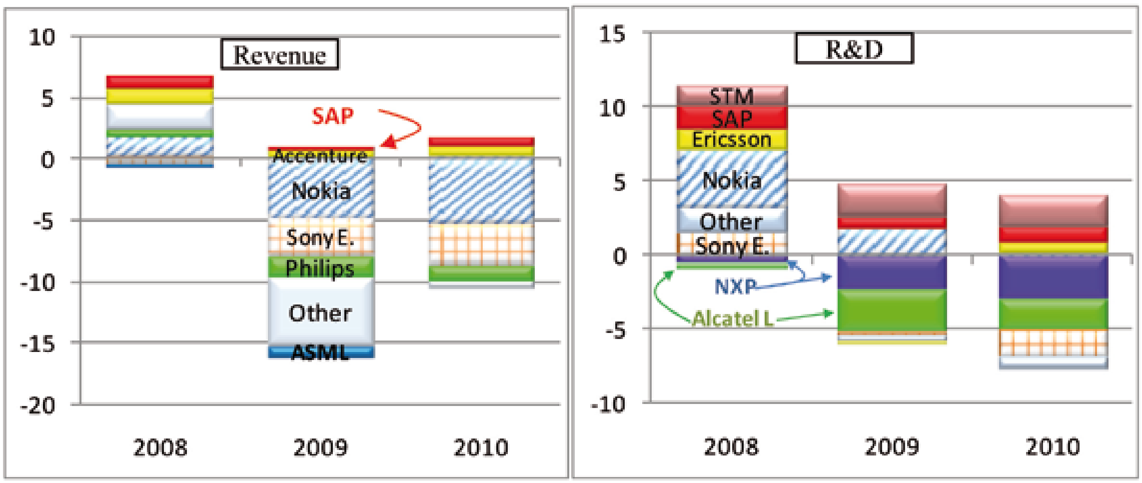
In times of global multinational companies, the behaviour of a sector or industry can often be linked to the decisions of a few larger companies, which make up the bulk of the sector or industry. This section looks at the contributions to ICT sector performance made by the largest ICT companies for the US (Figure 3-5) and the EU (Figure 3-6). The analysis looks at the revenue (on the left) and R&D expenditure (on the right) for the biggest ICT companies.

Figure 3-5: Contributions to growth in revenue (left) and R&D expenditure (right) of the top 25 US firms relative to 2007, percent



Source: compiled from companies' financial reports.

Figure 3-6: Contributions to growth in revenue (left) and R&D expenditure (right) for the top 20 EU firms relative to 2007, percent



Source: compiled from companies' financial reports.

Figure 3-5 (left) depicts revenue growth rates for the top 25 US companies relative to 2007. It shows that out of 25% growth for all 25 firms between 2007 and 2010, almost 10% was contributed by Apple and RIM (important smart phone and tablet producers). Another 7% was contributed by growth in global Internet platform products (Amazon and Google). The IT hardware manufacturer, Hewlett-Packard (HP), added 4% growth by itself. None of the major companies showed negative growth between 2007 and 2010. Motorola and Freescale Semiconductor were the main contributors to the decline in growth in 2009.

R&D expenditure growth between 2007 and 2010 (Figure 3-5, right) was 15%, to which Google, Oracle and Microsoft together contribute 9.2%. If figures for Apple and Amazon are also included, this contribution increases to 12.8%. Growth in R&D expenditure reached its lowest point in 2009 at 3.1%, down from 9.3% in 2008.

Figure 3-6 depicts similar statistics for the top 20 EU companies. Consolidated revenue growth (left) for the top EU ICT firms relative to 2007 was 6.3% in 2008 and declined sharply by 14% in 2009. The rate of decline levelled out in 2010 to 8.8%. The 14% negative growth in 2009 was largely due to changes in the revenues of four firms: Nokia (-4.7%), Sony Ericsson (-3%), Philips (-1.7%) and ASML (-1.1%). A small positive growth contribution was made by Accenture[60] (0.7%) and SAP (0.3%). In 2010, Nokia and Sony Ericsson accounted for most (8.5%) of the decline in consolidated revenue.

The growth in R&D expenditure for the top 20 EU ICT companies, relative to 2007 (Figure 3-6, right), ranged from 10% growth in 2008, through a modest 0.9% decline in 2009, to a 3.6% drop in 2010. In 2009, the decline in R&D expenditure of NXP and Alcatel Lucent affected the consolidated R&D growth by -2.4% and -2.7% respectively. This negative impact was balanced by R&D expenditure increases by STM (2.1%) and Nokia (1.9%). In 2010, overall growth declined due to a drop, greater than in previous years, in R&D expenditure at Sony Ericsson (-1.9%), and reduced R&D expenditure growth at Nokia (to 0.2%).

3.5 Conclusion

In conclusion, the negative effect of the crisis on the aggregated ICT sector appeared to have waned by the end of 2010. The recovery dynamics, however, have differed across the ICT sub-sectors. Some of the sub-sectors have experienced only a minor reduction in growth rates (Internet, Software), whereas others (Computer Services, Telcom Equipment) are struggling to recover pre-crisis levels of growth. These global market trends appear to translate through performance of specific companies to the regional performance. For example, the rapid development of the Internet platform industry is underpinned by Amazon and Google which are based in the US, and the EU does not host Internet firms with comparable performance. Similarly, the recent growth in demand for smart phones and tablets is satisfied mostly by the North America-based Apple and RIM, whereas the European firms from this sub-sector, such as Nokia, report relatively lower performance in both revenue and R&D expenditures. Finally, as the post-crisis picture of the economy in general and the ICT sector in particular is only just beginning to emerge (particularly given the delayed availability of official statistics), it may take more time before the complete impact of the crisis on the ICT sector is revealed and fully understood.

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Available at: http://ec.europa.eu/information_society/digital-agenda/scoreboard/index_en.htm

60 Accenture's change of place of incorporation from Bermuda to Ireland was announced by the Board of Directors on 26 May, 2009: http://newsroom.accenture.com/article_display.cfm?article_id=4830

4 The top world R&D-investing companies from the ICT sector – a company-level analysis

Authors: Daniel Nepelski, Juraj Stancik

4.1 Methodological introduction

The analysis presented in this chapter is based on company data from the *2009 EU industrial R&D Scoreboard*[61] (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 2008. The *Scoreboard* covers about 80% of all company R&D investments worldwide. From the *Scoreboard*, we have extracted the sub-set of ICT sector companies, which we refer to in this chapter as *ICT Scoreboard*. This dataset serves for the following analysis that aims to benchmark R&D investments of EU ICT companies against those of non-EU companies.[62]

This chapter summarises the main observations of a separate full length PREDICT Series report[63] and highlights its most relevant findings. Interested readers are referred to the full length report for more material and analyses.

It is also an update and an extension of a chapter of the 2010 PREDICT report (Turlea et al., 2010). Compared to the 2010 edition, there are a number of methodological modifications. First, the current chapter is mainly based on data from 2008, instead of 2007 as was the case in the 2010 PREDICT report, and analyses R&D investments for the time series between 2005 and 2008. Second, it expands the analysis to all ICT sub-sectors listed in the *Scoreboard*. Lastly, due to the emerging role of the Asian economies on the ICT landscape, Asian companies are clustered into one regional group. As a result, companies from five world regions are analysed: EU, US, Japan, Asia (excluding Japan) and the Rest of the World (RoW).[64] The RoW region includes, among others, countries such as Australia, Brazil, Canada and Switzerland.

In the *Scoreboard*, the groups of 1 000 EU and 1 000 non-EU top R&D spending companies include companies with different volumes of R&D investment. In 2008, the R&D investment threshold for the EU group (of 1 000 companies) was about € 4.3 million, while for the non-EU group (also of 1 000 companies) it was about € 31.5 million. In order to compare EU and non-EU companies on a similar basis, it is advisable[65] to use the same R&D investment

61 European Commission (2009).

62 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., 2008. Therefore, the set of top investors varies from one year to the next and those companies that invested most in, say 2008, are not necessarily the same as the ones that invested most in 2005. Additionally, there may also be some other companies that are not included in the *Scoreboard* because of their varying financial reporting practices when R&D is reported as a different expenditure category.

63 Nepelski, D. and Stancik, J. (2011). The Top World R&D-investing Companies from the ICT Sector: A Company-level Analysis. JRC Scientific and Technical Report EUR 24841 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

64 See Annex 4 for the full list of countries.

65 The elimination of companies below a particular threshold guarantees consistent treatment for each region. Otherwise, the EU region would be favoured by having 650 extra companies. And although these extra companies are characterized by very small R&D investment (almost two thirds of the EU 1 000 group represent only 5% of total R&D investment by this group), their inclusion in our analysis would have resulted in biased conclusions. For example, if there were many big firms among those excluded, we would underestimate the EU R&D intensity compared to other regions; or by including all of these companies, we would overestimate EU R&D investments by 5%. Moreover, by having many low R&D investing firms in our sample, we would end up with an inconsistent panel – given their small R&D investments and the fact that as the number of companies grows rapidly with decreasing R&D investments, it is likely that the sample of those 650 firms would be totally different for each year of our analysis.

Table 4-1: Distribution of ICT Scoreboard companies by sectors and regions of registered headquarters (2008)

ICT NACE class		EU	US	Japan	Asia	RoW	Total	
30	IT Equipment	3	25	7	12	3	**50**	**12%**
32.1	IT Components	19	89	35	29	10	**182**	**43%**
32.2	Telecom Equipment	10	32	1	3	7	**53**	**12%**
32.3	Multimedia Equipment	2	2	4	3	1	**12**	**3%**
64.2	Telecom Services	10	2	2	4	3	**21**	**5%**
72	Computer Services & Software	21	72	3	8	6	**110**	**26%**
Total ICT sector		**65**	**222**	**52**	**59**	**30**	**428**	
		15%	**52%**	**12%**	**14%**	**7%**		

Source: Authors' elaboration.

threshold for both groups, and therefore to consider only EU companies with R&D investments above the non-EU threshold of € 31.5 million. This comprises a group of 350 EU companies, representing approximately 95% of total R&D investment by the EU 1 000 group. Hence, there are 1 350 (ICT and non ICT) companies in total in the group of *Scoreboard* companies analysed in this chapter.

In order to create the dataset of ICT top R&D investing companies (henceforth *ICT Scoreboard*) from the *Scoreboard,* only the companies belonging to the following NACE Rev.1.1 classes have been extracted from the *Scoreboard*: 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).[66] Extracting the relevant ICT companies generates the *ICT Scoreboard*, a sub-set of 428 ICT companies out of the 1 350 ICT and non-ICT companies mentioned above.

The population of these 428 *ICT Scoreboard* companies is distributed as indicated in Table 4-1.

Regarding the geographical origin of the *ICT Scoreboard* companies, it can be seen that more than half (52%) of the companies have headquarters in the US, while 15% are from the EU and 14% are from Asia, excluding Japan which accounts for 12% of companies in the sample. The remaining 7% are located in countries included in the RoW group. Concerning the type of business activity of the firms in the *ICT Scoreboard* dataset, it can also be noted that more than two thirds of the companies are in the IT Components (43%) and the Computer Services and Software sub-sectors (26%).

It must be noted that the (company level) data presented in this chapter is not directly compatible with (BERD) data. 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 (ICB[67] and NACE class), regardless of whether some of the R&D performed concerns

66 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 also assign the companies to NACE sectors. Companies classified by the *Scoreboard* in other sectors appear to conduct large R&D investments in EMI. This poses an analytical problem in comparing with BERD data, which in turn includes this EMI sector.
Second, the EMI sector shows some specificity. It is a fragmented sector with many SMEs (Lindmark et al. 2008), and, in terms of classification, EMI is no longer included within the new OECD definition of the ICT-sector (ISIC Rev.4) (See: http://www.oecd.org/dataoecd/49/17/38217340.pdf), even though it is today a clearly important part of the ICT sector as recognised in other parts of this report.

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

products or services related to other sectors than the one the company is attributed to. Also, '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 to a sector 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).[68]

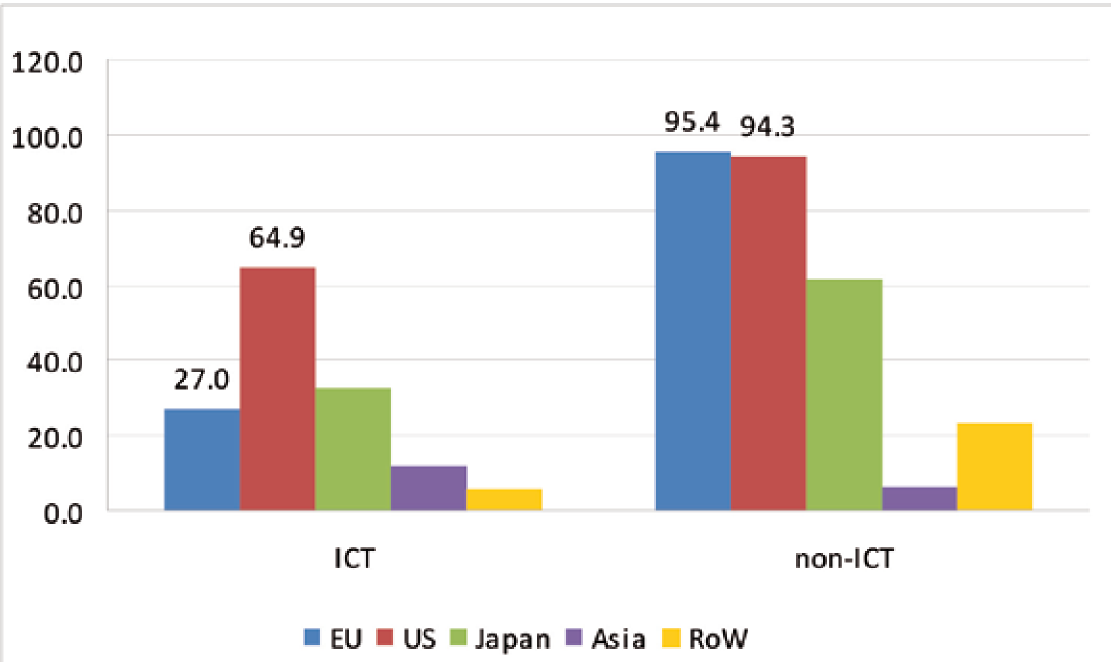
4.2 Global perspective

This section aims to assess the size of R&D investments by ICT companies in the global context. According to *Scoreboard* data, the ICT sector is clearly a key R&D investing sector in the world economy. In 2008, to put the ICT figures in perspective, the 1 350 top global R&D investing companies spent € 423 billion on R&D, out of which € 142 billion (or 34%) were invested by the 428 ICT sector companies.

4.2.1 R&D investments by ICT and non-ICT companies across world regions

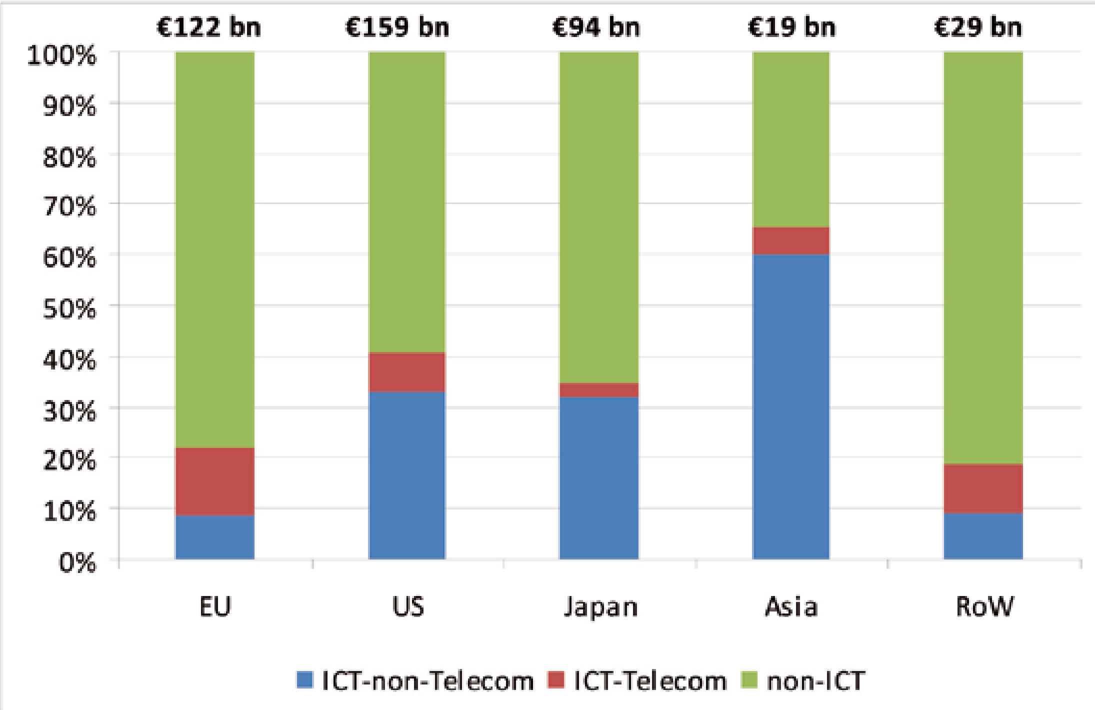
Figure 4-1 compares the R&D investments by ICT and non-ICT sector companies for 2008, showing the size of those investments for EU, US, Japan, Asian and RoW companies.

Figure 4-1: R&D investments in the ICT sector and non-ICT sectors by EU, US, Japanese, Asian and RoW Scoreboard companies, in billions of € (2008)



68 For a fuller methodological description, see Annex 3. For a discussion on the issue of BERD versus company R&D data, see e.g., Azagra Caro and Grablowitz (2008), European Commission (2009) or Lindmark *et al.* (2008) and Annex 3.

Figure 4-2: R&D investment in the ICT-sector and non-ICT sectors by EU, US, Japanese, Asian and RoW companies, as a % of total R&D investment (2008)



Note: Bold numbers above bars represent total R&D investments.

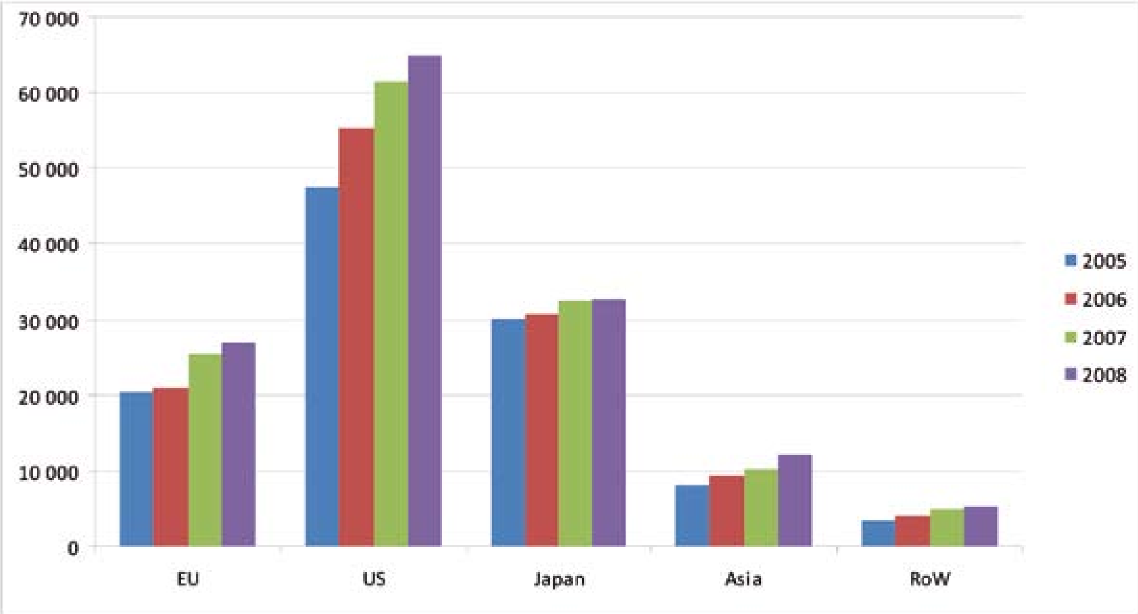
In 2008, the total R&D investments of EU *ICT Scoreboard* companies amounted to € 27 billion, as compared to € 95.4 billion for EU non-*ICT Scoreboard* companies. Comparatively, US ICT companies spent € 64.9 billion on R&D, while US non-ICT companies invested € 94.3 billion that same year. EU ICT firms, as a whole, invested far less in R&D than their US counterparts while EU non-ICT firms, as a whole, invested more than their US counterparts. In 2008, there was an R&D investment differential between EU and US ICT companies of nearly € 38 billion.

Figure 4-1 also shows that the investments of EU non-ICT companies are higher than for any other world region, including the US. EU non-ICT companies, as a whole, invested about € 1 billion more than their US counterparts in 2008. As a result, the R&D investment gap between EU and US ICT companies (€ 38 billion) is slightly larger than the total R&D investment gap (€ 37 billion) between all EU and US *Scoreboard* companies (both ICT and non-ICT). As explained in Section 4.5, this gap is not necessarily due to lower R&D investment by EU companies taken individually, but rather due to the different size and composition of the sectors and industries in the two regions.

Figure 4-2 compares the shares of ICT and of non-ICT R&D investments by the *Scoreboard* companies, from different world regions: the EU, US, Japan, Asia and RoW, for 2008. It also distinguishes between Telecom and non-Telecom R&D investment shares.

Figure 4-2 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 companies from other regions. This share is only 22% for EU companies. Except for firms located in the RoW, ICT-related R&D company investments play more important roles in the US, Japan and particularly in Asia than in the EU. In all three regions, ICT sector company R&D investments account for at least one third of total R&D investments. The case of Asia is particularly interesting, as ICT companies

Figure 4-3: *R&D investments in the ICT-sector by EU, US, Japanese, Asian and RoW ICT Scoreboard companies, in millions of € (2005-2008)*



Note: Nominal terms, not adjusted for inflation.

from this region contribute over 65% of total company R&D investments. Despite the overall comparatively smaller value, this shows a strong specialization among Asian companies.

Comparatively also, ICT R&D investments by EU companies seem very much concentrated in the telecom-related sub-sectors, i.e., Telecom Equipment and Telecom Services taken together, and especially Telecom Equipment.[69] Almost 60% of total EU ICT company R&D investments, that is € 16.5 billion out of € 27.6 billion, are invested by Telecom Services and Telecom Equipment companies. The corresponding rates in other regions are much lower. Hence, while the proportion of ICT R&D as part of total R&D is lower for EU companies than for rest of the world, the Telecom part within EU ICT company investment is higher.

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

Figure 4-3 shows the evolution of R&D investment by ICT companies with headquarters in the different geographical regions between 2005 and 2008.

According to Figure 4-3, R&D investments by EU ICT firms increased year by year (Compound Annual Growth Rate from 2005 to 2008 – CAGR 10%). This increase in R&D spending accelerated in 2007, when it reached a 22% growth rate. It then decelerated in 2008 to 6%. The increases shown by US companies were at a comparable level to EU companies (CAGR 11%). Companies from the other regions also consistently increased ICT R&D investments during the same period. Here, however, some differences can be observed. For example, whereas the R&D growth of Japanese companies appeared to be relatively modest (CAGR 3%), companies headquartered in Asia and the RoW increased their R&D

69 Figure 4-2 contrasts an *'ICT-Telecom'* group aggregating the data of companies from NACE 32.2 (Telecom Equipment) and NACE 64.2 (Telecom Services) and an *'ICT-non-Telecom'* group aggregating the data of companies from NACE 30 (IT Equipment), 32.1 (IT Components), 32.3 (Multimedia Equipment) and 72 (Computer Services and Software). This aggregation helps us to appreciate the specific importance of Telecom activity (Manufacturing and Services) in Europe.

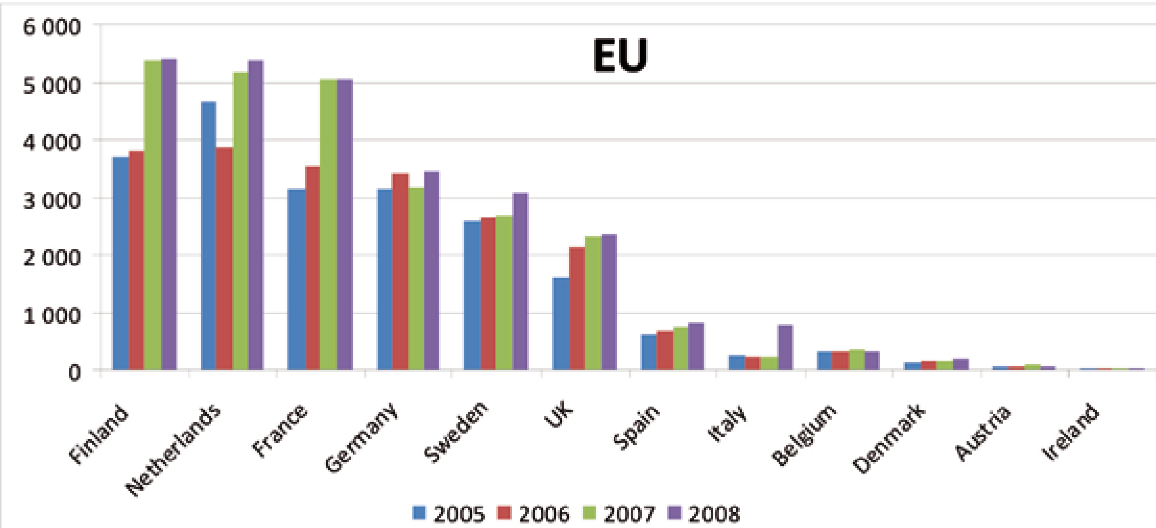
investments relatively rapidly (CAGR 14% and 17% respectively). It must be noted that these high growth rates apply to relatively small absolute values of R&D investments. More detail on ICT R&D in some emerging economies is given in Chapter 6 dedicated to the Internationalisation of ICT R&D.

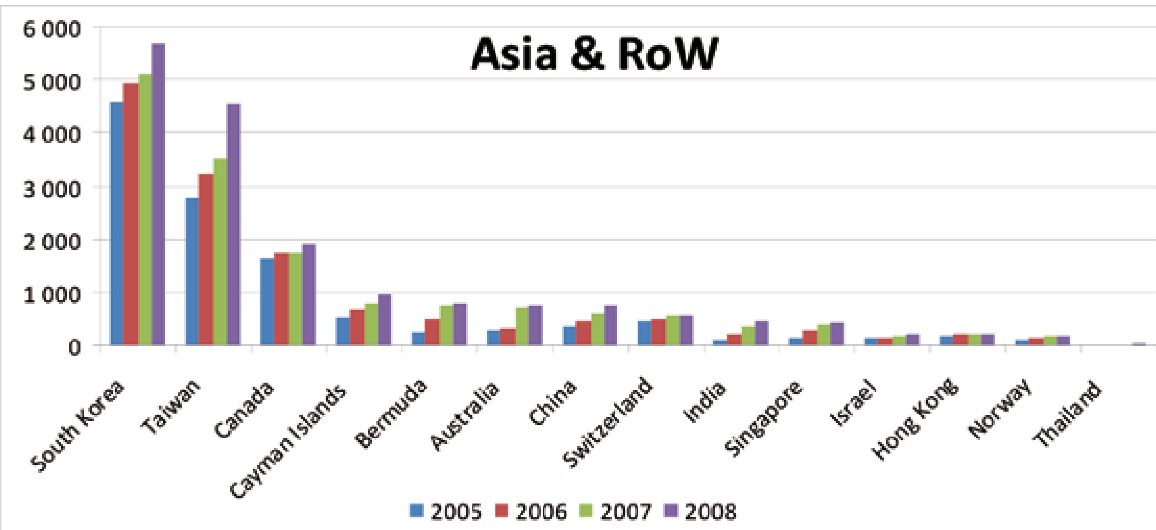
4.3 Country-level perspective

Figure 4-4 offers a breakdown of ICT company R&D investment per country of registered headquarters in the EU, Asia and the RoW (excluding US and Japan, already presented above) for the period 2005-2008.

Breaking down R&D figures of the EU, Asia and RoW to country level shows that the major R&D investing ICT companies outside the US and Japan are registered in Finland, the Netherlands, France, Germany, Sweden and the UK within the EU; and in South Korea, Taiwan and Canada, respectively for Asia and the RoW. This confirms that global ICT R&D activity is mainly financed by companies whose

Figure 4-4: R&D investments by ICT Scoreboard firms per country of registered headquarters in the EU and the Asia & RoW, in millions of € (2005-2008)





Note: Nominal terms, not adjusted for inflation.

headquarters are concentrated in a small number of developed economies, while companies of emerging economies, such as China and India, still have comparatively lower levels of ICT R&D investments.

Concerning the absolute growth of company R&D spending between 2005 and 2008, French companies stand out with an increase of R&D investment of € 1.8 billion, followed by Finnish companies (€ 1.7 billion). This level of growth is also observed for Taiwanese companies, which increased their R&D spending by € 1.8 billion in the same period. In relative terms, Indian and Singaporean companies increased their R&D investments four- and threefold respectively. However, it must be noted that company R&D investments in these countries are still very low in absolute terms.

As a word of caution, it should be mentioned that the picture presented by the above figures at the country level is strongly influenced by both industry dynamics and by changes in the way R&D is accounted for in company accounting systems. The former is illustrated by the impact of mergers and acquisitions on the assignment of company R&D spending to a certain country. For example, within the EU, the rapid growth of France-based companies in 2007 is partly due to the Alcatel merger with Lucent, which resulted in the ICT R&D of Lucent, previously a US firm, being attributed in the *Scoreboard* to France, where the headquarters of the new firm is. Similarly, Finland's R&D growth in 2007 is largely a result of the creation of Nokia Siemens Networks: in the *Scoreboard*, Siemens' Telecom Equipment R&D spending was attributed to Finland and to the Telecom Equipment sub-sector, instead of being attributed to Germany (and to Electrical Components & Equipment) as before. Another example is Dutch NXP, a spin-off of Philips Electronics, which only started to report R&D in 2007. This led to a decline in R&D figures in the Netherlands for 2006, compensated in 2007 by a sudden rebound.

4.4 Company-level perspective

The top 30 R&D investing ICT companies of the 2008 *ICT Scoreboard* are listed in Table 4-2. Of these, seven are EU-based (shown in red): Nokia, Alcatel-Lucent, Ericsson, SAP, Philips Electronics, STMicroelectronics and BT. Most of the remaining companies have their headquarters in the US (13, close to half of the top 30) and Japan (8). The remaining two companies are from South Korea. Of the seven EU firms, three are in the Telecom Equipment sub-sector and the four remaining respectively in Telecom Services, Computer Services and Software, Multimedia Equipment, and IT Components.

These top 30 ICT R&D investors report diverse rates of R&D growth. For example, between 2005 and 2008, the unquestioned leader in increasing R&D investments was Google. The CAGR (Compound Annual Growth Rate) of Google's R&D investments was close to 70%. Google is followed by Qualcomm and Alcatel-Lucent from Telecom Equipment industry with CAGR of 31% and 21% respectively. Alcatel-Lucent has also the highest growth in R&D investments among the EU companies listed in Table 4-2. However, the high 2005-2008 CAGR of Alcatel-Lucent is essentially the result of the 2007 merger of Alcatel and Lucent, as indicated in Section 4.3 above. Other top growing EU companies are BT, SAP and Nokia with a CAGR of around 14-15%.

The double-digit R&D growth rates are mainly found in the Services and the Telecom Equipment sectors, with a few notable exceptions (ST Microelectronics, EMC and Advanced Micro Devices). This table also illustrates indirectly the very high level of concentration of R&D investments, declining by a factor range of 6 within the first 30 top ranking ICT companies, from € 6 482 million (Microsoft) to € 1 157 million (BT).

Table 4-2: Top 30 R&D-investing ICT sector companies (2008)

#	Company	NACE sub-sector	4 digit ICB sub-sector	Country	R&D 2008 (€ m)	R&D growth 2005-2008 (€ m)	CAGR* 2005-2008 (%)
1	Microsoft	Computer Services and Software	Software	USA	6482	1745	11.0%
2	Nokia	Telecom Equipment	Telecommunications equipment	Finland	5321	1692	13.6%
3	Matsushita Electric (now Panasonic)	Multimedia Equipment	Leisure goods	Japan	4401	-484	-3.4%
4	IBM	Computer Services and Software	Computer services	USA	4327	458	3.8%
5	Sony	Multimedia Equipment	Leisure goods	Japan	4132	147	1.2%
6	Intel	IT Components	Semiconductors	USA	4117	415	3.6%
7	Cisco Systems	Telecom Equipment	Telecommunications equipment	USA	3707	1317	15.8%
8	Samsung Electronics	IT Components	Electronic equipment	South Korea	3469	669	7.4%
9	Hitachi	IT Equipment	Computer hardware	Japan	3398	314	3.3%
10	Alcatel-Lucent	Telecom Equipment	Telecommunications equipment	France	3167	1375	20.9%
11	Ericsson	Telecom Equipment	Telecommunications equipment	Sweden	2975	644	8.5%
12	Canon	IT Components	Electronic equipment	Japan	2969	695	9.3%
13	Motorola	Telecom Equipment	Telecommunications equipment	USA	2956	309	3.7%
14	NEC	IT Equipment	Computer hardware	Japan	2795	610	8.6%
15	Hewlett-Packard	IT Equipment	Computer hardware	USA	2549	38	0.5%
16	NTT	Telecom Services	Fixed line telecommunications	Japan	2151	-373	-5.2%
17	Fujitsu	Computer Services and Software	Computer services	Japan	2053	147	2.5%
18	Google	Computer Services and Software	Internet	USA	2010	1578	67.0%
19	Oracle	Computer Services and Software	Software	USA	1991	644	13.9%
20	Qualcomm	Telecom Equipment	Telecommunications equipment	USA	1641	914	31.2%
21	SAP	Computer Services and Software	Software	Germany	1627	538	14.3%
22	Philips Electronics	Multimedia Equipment	Leisure goods	Netherlands	1613	-1013	-15.0%
23	Sharp	IT Components	Electronic equipment	Japan	1557	381	9.8%
24	STMicroelectronics	IT Components	Semiconductors	Netherlands	1545	427	11.4%
25	EMC	IT Equipment	Computer hardware	USA	1473	630	20.4%
26	Texas Instruments	IT Components	Semiconductors	USA	1396	-54	-1.3%
27	Sun Microsystems	IT Equipment	Computer hardware	USA	1394	109	2.8%
28	Advanced Micro Devices	IT Components	Semiconductors	USA	1330	506	17.3%
29	LG	IT Components	Electronic equipment	South Korea	1304	81	2.2%
30	BT	Telecom Services	Fixed line telecommunications	UK	1157	405	15.5%

Notes: Nominal terms, not adjusted for inflation. Companies headquartered in the EU are shown in red.

** CAGR = Compound Annual Growth Rate.*

4.5 Sub-sector analysis perspective

Whereas the previous sections aimed to assess the overall importance of ICT R&D investments at the global level and at individual company level, this section takes a closer look at ICT *sub-sectors*.

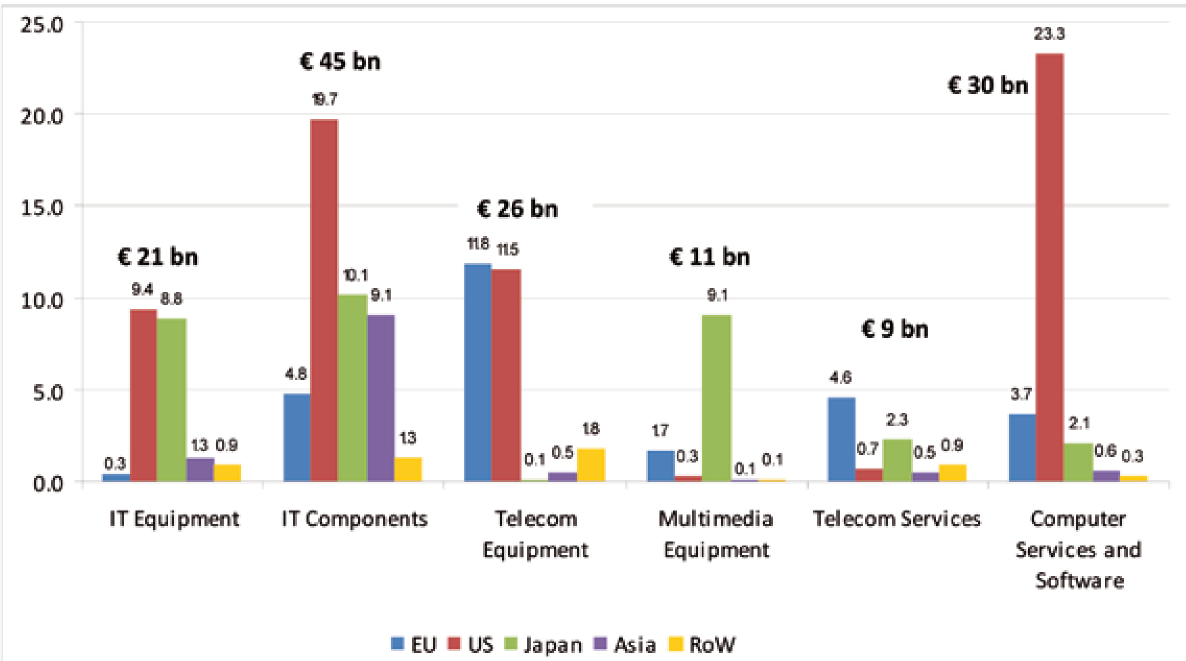
Figure 4-5 shows the size of R&D investments in the ICT sub-sectors by EU, US, Japanese, Asian and RoW *ICT Scoreboard* companies for the year 2008.

According to Figure 4-5, overall, the most important sub-sector in terms of R&D investment is **IT Components**. In 2008, it accounted for € 45 billion, which represents over one third of the global ICT R&D investments in the *Scoreboard*. Another characteristic of the IT components industry is that it is also the only sub-sector where companies from all regions display large R&D investments. US, Japanese and Asian companies clearly dominate in the IT Components sub-sector. In 2008, EU IT Components companies spend around € 5 billion in ICT R&D versus almost € 20 billion for US companies. Regarding EU companies, ST Microelectronics shows the highest investments and is the only EU company from this sub-sector listed in the *ICT Scoreboard* top 30, as shown in Table 4-2.

Second in size come R&D investments in **Computer Services and Software**. In 2008, *Scoreboard* companies classified in this sub-sector spent over € 30 billion. Most of the dynamics of the sector have developed in the Software and Internet segments. Here, US firms strongly dominate, while firms from other regions are far behind. Regarding EU companies, SAP shows the highest investments and is the only EU company from this sub-sector listed in the top 30.

The third largest R&D investing sub-sector, slightly below Computer Services and Software, is **Telecom Equipment**. In 2008, it accounted for nearly € 26 billion in R&D spending. Most of this was spent by EU (Nokia, Alcatel-Lucent, Ericsson – ranked respectively second, tenth and eleventh

Figure 4-5: R&D investments in the ICT sub-sectors by EU, US, Japanese, Asian and RoW ICT Scoreboard companies, in billions of € (2008)



Note: *Bold numbers above bars represent total sectoral R&D investments.*

in the *ICT Scoreboard* top 30 R&D investors) and US companies.

IT Equipment ranks next, displaying relatively high total R&D investment of over € 21 billion in 2008. In this sector, it is Japanese companies that are challenging the US for the global R&D investment leadership position. There are no EU companies from this sub-sector listed in the *ICT Scoreboard* top 30.

The only sub-sectors where US companies have a weak R&D presence are **Multimedia Equipment** and **Telecom Services**. Both these sub-sectors show lower levels of total R&D investment with respectively € 11 billion and € 9 billion of total R&D investment in 2008.

R&D in **Multimedia Equipment** is led by Japanese company investments. Regarding EU companies, Philips shows the highest investments and is the only EU company classified in this sub-sector which is listed in the top 30.

Telecom Services, the sub-sector with the smallest total R&D investment, is, with Telecom Equipment, the second sector where EU R&D investment levels are the highest among the analysed regions. Regarding EU companies, BT shows the highest investments and is the only EU company from this sub-sector which is listed in the top 30.

Figure 4-6 shows R&D intensities (R&D investment/net sales) for ICT sub-sectors from the EU, US, Japanese, Asian and RoW as determined by the *ICT Scoreboard* for 2008.[70]

Although different patterns can be observed across sub-sectors and across the regions, an essential observation is that, in most sub-sectors, the EU and the US show very similar R&D intensity levels. This similarity would seem to indicate that the *ICT Scoreboard* R&D gap observed between the US and the EU (as described in Section 4.2) is not due to the lower R&D intensities (i.e., R&D to sales ratio) of the EU sub-sectors. This gap may instead be due to the differing size and composition of the ICT industries in the two regions.

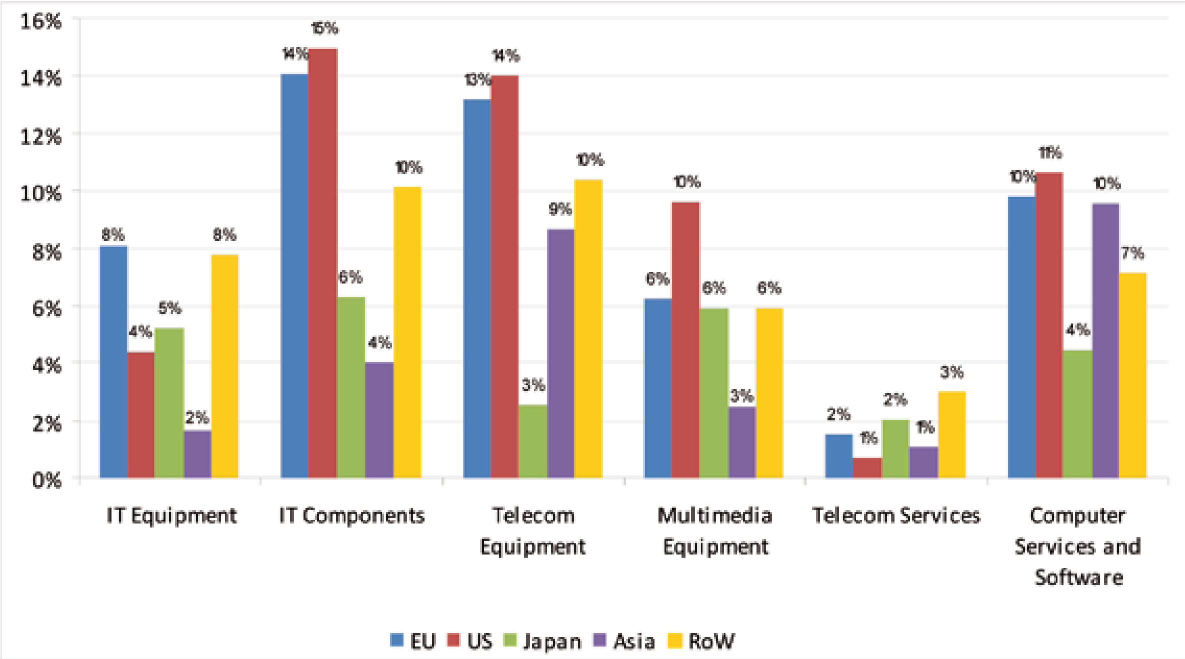
The other regions differ quite a lot from this EU/US pattern. On the one hand, in IT Components and Telecom Equipment, EU and US R&D intensities are well above those of Japan. On the other hand, Japan shows close or higher R&D intensities in IT Equipment and Telecom Services. These results must be interpreted with caution. For example, the Japanese figures appear to vary less across the sub-sectors. This may be due to their relatively high level of diversification across the ICT subsectors, which would tend to make their R&D intensities converge across sub-sectors. Except for the Computer Services and Software firms, Asia shows lower R&D intensities than the EU and the US. In conclusion, it appears that EU and US ICT sub-sectors have, on average, higher R&D intensities than sub-sectors from Asia, Japan and the RoW.

ICT sub-sector interdependencies: analysing R&D investments with a new 'ICT ecosystem' approach

In the case of the Telecom industry, an historically rooted division of labour of products and of revenues between two interdependent sub-sectors (Telecom Services and Telecom Equipment) had traditionally explained an important part of what can be interpreted as an under-investment in R&D on behalf of Telecom Services. Currently, there is a surge of new interdependencies – and competition – between the Telecom Services and Equipment industries and neighbouring industries such as the Software industry and the Internet and Content

70 Here, the R&D intensities of sub-sectors have been calculated on the basis of the following ratio: total R&D investments of the companies of the *ICT Scoreboard* and pertaining to a given sub-sector, divided by their total net sales. It is hence a different approach to the one based on aggregated data from national statistics that establishes a ratio: this is also called R&D intensity but it is based on BERD and Value added (VA) data for each sub-sector.

Figure 4-6: *R&D intensities (R&D investment / net sales) in EU, US, Japanese, Asian and RoW ICT Scoreboard companies (2008)*



industries. In such a complex environment, the analytical approach by sub-sectors may not suffice to capture the dynamic of the ICT sector, as the level of interrelation and exchanges between formerly separated actors increases. An additional approach, that of the 'ICT ecosystem', could help us to better track the way players are climbing up (or down) the value chain, integrating applications and services they did not provide before. This approach would aim to capture more accurately the drastic changes that are taking place in the ICT sector, and especially the entry of new players from ICT and non-ICT sectors (such as, Apple, Google, Yahoo, etc.), and to a lesser extent from the Media and Content industries. This new approach can complement the company level data analysis presented in this chapter and will be the object of future analyses.

A more detailed analysis describing the level of ICT company R&D investments and their evolution over the period between 2005 and 2008 for all these sub-sectors can be found in a separate report of the PREDICT series.[71]

4.6 Summary of main findings and conclusions

The findings in this chapter essentially corroborate those of the previous edition of the PREDICT report (Turlea et al., 2010), with some differences and additions. First of all, EU ICT sector companies make very substantial R&D investments. At an aggregate level, however, they invest less in R&D than companies from the US or Japan, and they represent a smaller share of total R&D in the EU than ICT R&D represents elsewhere (except RoW). In comparison with

71 Nepelski, D. and Stancik, J. (2011). The Top World R&D-investing Companies from the ICT Sector: A Company-level Analysis. JRC Scientific and Technical Report EUR 24841 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

the US, there is a gap in the EU ICT sector R&D investments (for the *ICT Scoreboard* companies) and the detailed analysis suggests that, in absolute terms, US companies further increased their R&D investment lead (in volume), although EU companies show a very positive trend with similar relative growth rates.

However, as shown in Figure 4-6, this is not necessarily because individual US companies are more R&D intensive than EU ones. Instead, R&D intensity (i.e., R&D investment to sales ratio) varies more according to sectors than to regions. 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 428 top global R&D investing ICT companies are from the US.

The preceding analysis of the 2009 *ICT Scoreboard* data allow us to make a number of detailed conclusions with respect to the developments of company R&D investments over the last few years. The main conclusions and findings can be summarised as follows:

Regarding the levels and trends in ICT R&D investments across the major world regions:

- Shares of ICT R&D in total R&D investments: Asia (excluding Japan) shows very high concentration of R&D in ICT: around 65% of all company R&D efforts are devoted to ICT. For US and Japanese companies the shares of ICT R&D in total R&D investments are around 40% and 35% respectively. For EU companies, this share is around 20%, suggesting the presence of a smaller number of large companies in the ICT sector. Other observations rather confirm this hypothesis.

- Growth of R&D investments: Concerning the growth of R&D investments from 2005 to 2008, Asian and RoW companies report the highest relative increase of their R&D investments (14% and 17% respectively) but from rather low values. EU and US firms show similar growth rate (10% and 11% respectively). The R&D growth rate of Japanese companies was the lowest (3%).

- Sub-sector specialisation: worldwide, the most important sub-sector in terms of R&D investment is IT Components. It accounts for over one third of the global R&D investments in the ICT sector. IT Components is followed by Computer Services and Software and by Telecom Equipment. EU companies R&D investments are concentrated in the Telecom Equipment and Telecom Services sub-sectors, whereas US, and to some extent, Japanese companies show strong presence in the IT Components, Computer Services, and Telecom Equipment.

- National behaviours: Concerning EU and Asian companies, ICT R&D investments are made by companies headquartered in a small number of developed countries. For example, in the ICT R&D *Scoreboard* 2008, there were only 6 EU and 2 Asian countries (excluding Japan) with R&D investments exceeding € 1 billion (e.g., Finland, Netherlands, France, Germany, Sweden, UK, South Korea, and Taiwan).

Concerning particular ICT sub-sectors, the following can be noted:[72]

- Worldwide, the most important sub-sector in terms of R&D investment is IT Components. It accounts for over one third of global R&D investments in the ICT sector. IT Components

72 For more details on analysis by sub-sectors, please refer to the long version of this chapter, published as an independent report: Nepelski, D. and Stancik, J. (2011). The Top World R&D-investing Companies from the ICT Sector: A Company-level Analysis. JRC Scientific and Technical Report EUR 24841 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

is followed by Computer Services and Software and Telecom Equipment.

- The above three sectors show a strong presence of US firms with high R&D investments and growth. The top EU R&D spending companies are mainly in Telecom Equipment, IT Components and Telecom Services. Japanese companies, on the other hand, hold very strong R&D positions in IT and Multimedia Equipment and in IT Components. The latter shows a very strong presence of Asian companies, predominantly from South Korea and Taiwan.

- Telecom Equipment has long been regarded a stronghold of the EU ICT industry, which includes world leaders such as Nokia, Ericsson and Alcatel-Lucent. In absolute volumes, EU companies still hold the first position in R&D investments in this sector but US companies come close (Cisco Systems, Motorola, Qualcomm).

- Multimedia Equipment is the only sub-sector that experienced a decline in R&D investments in the analysed period. R&D in this sub-sector is dominated by Japanese companies.

- The Software and Internet segments of Computer Services and Software are the most dynamic in terms of R&D investment, displaying high R&D intensities as well as high growth rates. However, EU companies' absolute R&D investments 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, whereas the EU Internet industry does not. Interestingly, indications of the presence of rapidly growing companies like these can also be seen in India.

R&D and sales growth rates analysis offers additional insights:

- Based on our observations, high/low R&D and sales growth rates seem to go together. One usually cannot expect to observe high sales growth without corresponding R&D growth. The only general exception to this is Telecom Services with several companies with high R&D growth and zero or negative sales growth (or vice versa).

- The three sub-sectors with higher average R&D & Sales growth rates were Telecom Equipment, Computer Services and Software and partially also Telecom Services. IT Equipment and Multimedia Equipment were below.

- US companies (and also some Asian ones) dominate the top sales growth analysis in all analyzed sub-sectors. Usually more than half of the top 20 companies in sales growth come from the US. The biggest company in each of the sub-sectors, except for Multimedia Equipment, also comes from either the US or Asia.

ICT sub-sector interdependencies: analysing R&D investments with a new 'ICT ecosystem' approach

In the complex Telecom industry environment, the analytical approach by sub-sectors may not suffice to capture the dynamic of the ICT sector, as the level of interrelation and exchanges between formerly separated actors increases. An additional approach, that of the 'ICT ecosystem', could help us to better track the way players are climbing up (or down) the value chain, integrating applications and services they did not provide before. This new approach can complement the company level data analysis presented in this chapter and will be the object of future analyses.

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5 Performance of ICT R&D – ICT patenting

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5.1 Introduction

This chapter extends the analysis of ICT R&D by presenting patent statistics as a measure of *output* of the R&D process. The chapter builds on previous analyses described in the 2009 edition of the PREDICT Report (Turlea et al., 2009) (Part 2 – *Thematic Analysis: Output of ICT R&D in the European Union*) and its 2010 edition (Turlea et al., 2010) (Chapter 7 – *ICT Patents in the European Union*). New developments in the current edition include wider coverage of patent databases and refined, more detailed analysis of patent statistics.[73]

Examples of measures which proxy invention or new knowledge created include the Community Innovation Survey (CIS), and Patent and Trademark statistics. The CIS provides representative data on innovation activities across the EU[74] for product and process innovations for goods and services at the NACE 2-digit level. Patent statistics, in turn, are particularly informative about inventions specific to ICT. The OECD finds that countries with strong specialisation in ICT are turning to patents as a prime method of securing rights on new knowledge.[75] Various studies[76] have already addressed the numerous advantages coming from the exploitation of patent data as a measure of inventive output. Patent data provide increasingly detailed and wide information on what the results of research and development efforts and of inventive activity in general are expected to be. Moreover, the type of information they provide is seen as 'objective', as it offers quantitative results and can be effectively combined with other indicators for cross-validation. Patent data are built from the administrative data compiled by patent offices for their internal purposes of managing the patenting process. Thus, they can provide wide coverage at relatively low cost and, importantly, for long time series.

However, the use of patent data as a proxy of inventive output also has several shortcomings. On the one hand, not all the inventions (and related innovations) are patented, and on the other hand, not all patented inventions turn into innovations. In fact, some innovations cannot be screened by means of patent data (production process innovation, for example), and firms often opt for different strategies to protect and exploit their inventions (keeping them secret is the most obvious way). Furthermore, the value of patents can be very different, as strategic or defensive patenting is a widely applied strategy to slow down competition in specific markets or as patent portfolios can be accumulated to be used as bargaining power. Differences in patenting fees and rules also affect the propensity for patenting innovations in different countries.[77]

For these reasons, different patent-based indicators are used in order to exploit the available data on patents in the most effective way. This chapter analyses priority patent application statistics as a proxy to measure inventive activity related to ICT R&D in the EU, the US and other regions of the world.

These observations are developed in two sections. Section 5.2 mainly compares the EU (as a whole) with the US, Japan, and Asia. Section

73 This chapter summarises the main observations of a separate full length report 'The Performance of ICT R&D' Institute for Prospective Technological Studies, JRC Scientific and Technical Report (forthcoming), and highlights its most relevant findings. Interested readers are referred to the full length report for more material and analyses. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

74 The latest CIS (2008) was carried out in 27 Member States, candidate countries and Norway.

75 (OECD, 2010a). See also Rassenfosse and Potterie (2009) and Picci (2008) for further empirical analysis.

76 Among many others, Griliches (1990), Smith (2005), Guellec and van Pottelsberg (2007), Picci (2009).

77 See Rassenfosse and Potterie (2009) and Rassenfosse and Pottelsberghe (2010).

5.3 analyses the ICT inventive output of the EU Member States. This analysis is preceded by a brief overview of the methodology used to develop the patent data analysis.

Methodology overview

The European Patent Office (EPO) develops and updates the EPO Worldwide Patent Statistical Database (known as the PATSTAT database), providing worldwide coverage of patent applications submitted to around 90 patent offices in the world.[78] The present analysis is based on indicators built by extracting and elaborating patent application data from the April 2010 release of the PATSTAT database. The analysis takes into account priority patent applications filed at 59 patent offices worldwide: the EPO itself and 58 national patent offices including those of the 27 EU Member States, the US Patent and Trademark Office (USPTO), the Japan Patent Office (JPO) as well as the OECD countries' patent offices and other patent offices with the highest number of patent applications, including China and India.[79] The time period taken into account covers from 1 January 1990 to 31 December 2007.[80] Patent applications data from the PATSTAT database provide information on the country of residence of the inventors and of the applicants who have legal title to the patent, therefore patents are usually attributed to countries using either the 'inventor criterion' or the 'applicant criterion'.[81]

Working on priority applications[82] is a methodological choice that needs to be clearly assessed. It allows us to take into account, process and analyse a much broader dataset than any other methodology used before in the domain of patent analysis (e.g., PCT or triadic patent-based indicators). Today, this methodology is supported by a growing body of scientific literature[83] and generates an increasing number of relevant results.[84]

Compared to the patent analysis presented in the two previous editions of the PREDICT report, the present analysis has implemented several methodological improvements. Annex 5 provides an overview of these methodological improvements.

78 PATSTAT updates are released twice per year by the EPO. PASTAT 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: 12 December 2010).

79 The selected patent offices cover 99.7% of the total number of priority patent applications worldwide in 2007. The complete list includes: EPO, EU27 Member States, USPTO, JPO, Arab Emirates, Australia, Brazil, Canada, Chile, China, Columbia, Croatia, Hong Kong, Iceland, India, Indonesia, Israel, Korea, Malaysia, Mexico, New Zealand, Norway, Pakistan, Philippines, Puerto Rico, Russia, Singapore, South Africa, Switzerland, Taiwan, Thailand, Turkey, Vietnam.

80 The accuracy of data for more recent years could suffer from delays in the collection process and updating procedure of the PATSTAT database (even if the updating of data appears to have remarkably improved in the latest releases of the database).

81 Please refer to Annex 5 for more detailed information about priority applications and about the 'inventor criterion' and 'applicant criterion'.

82 A patent application for a given invention first filed at any of the patent offices worldwide by an applicant seeking patent protection is assigned a priority date (in case of first filing in the world) and is known as the 'priority application'. Counting priority applications only, rather than all patent applications, avoids multiple counting of the same inventions and is a better proxy measure of inventive activity. Please refer to Annex 5 for more detailed information about priority applications.

83 See for example: Picci L. (2010), Picci (2009), Turlea et al (2010). Important source of information were also the presentations held by participants of the workshop "The Output of R&D activities: Harnessing the Power of Patents Data" held at the Institute for Prospective Technological Studies (JRC, European Commission) in Seville (May 2009, May 2010), and the OECD-EPO conference on patent statistics in Vienna (October 2009).

84 Among the different methodologies proposed by literature in order to build indicators based on patent applications, the consideration of families of 'triadic patents' is widely adopted, in particular, among others, by Eurostat and OECD. In this approach 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, which are therefore suitable to be considered of high value. On the other hand, the cost of triple filing is expected to prevent smaller firms from accessing it. Moreover, concern about the possibility of strategic patenting has been raised by literature, in consideration of the fact that patenting activity performed at international level could hide strategic marketing purpose of slowing competition by means of the fear of litigation costs, rather than being oriented at protecting the results of inventive activity.

5.2 Patenting activity across the world

This section provides a global perspective of inventive activity, by giving a comparative overview of the innovative prowess of the EU, the US, Japan, Asia and the rest of the world (RoW) as proxied by patent application statistics. The analysis is based on priority patent applications and reflects the patenting activity of inventors based in different regions. It provides figures regarding: (1) total patent applications (ICT and non ICT), and (2) patent applications in technological categories related to ICT.

5.2.1 Total and ICT patent applications across the world

The analysis of the total number of priority applications filed by inventors located in the five analysed world regions (EU, the US, Japan, Asia (excluding Japan), and rest of the world (RoW)), between 1990 and 2007, in all technology classes (ICT and non ICT), indicates that:

- the output of inventors based in Japan in terms of total patent applications is more than three times bigger than that of EU inventors or of US inventors.
- the output of inventors based in Asia has rapidly increased since 1997. In 2000, it overtook the EU level, and by 2007, it had almost reached that of Japan.
- EU inventors have filed more patent applications every year than US inventors since the mid 90s.

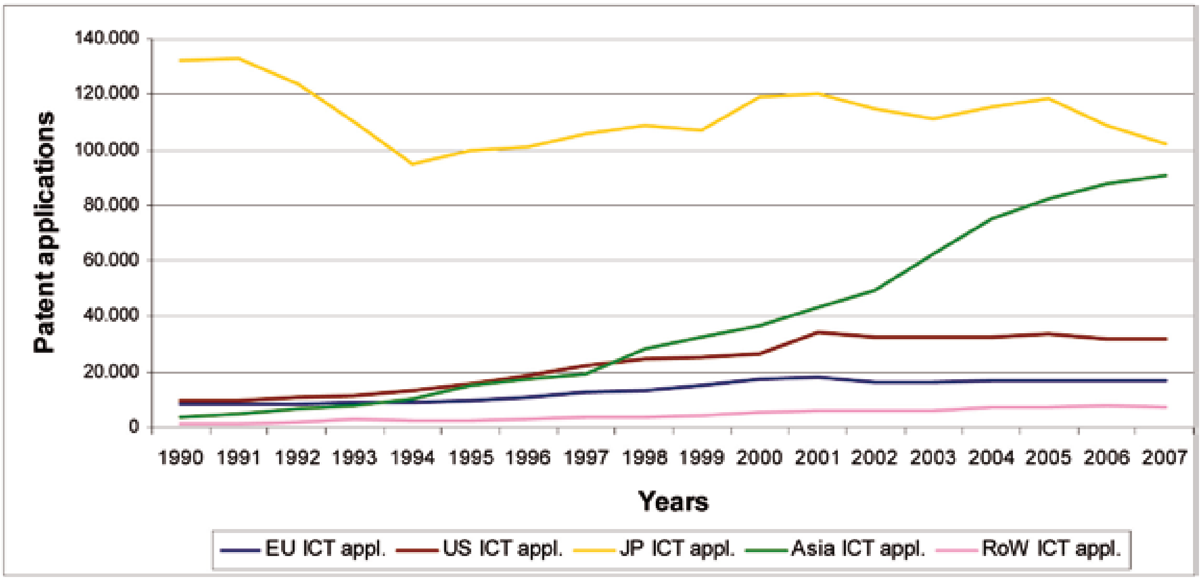
The trend for EU-based inventors is fairly stable, reaching about 100 000 patent applications with a compound annual growth rate (CAGR) from 1990 to 2007 of 3%. A similar trend applies to the US, showing a CAGR of 2% over the same period. The trend for Japan-based inventors is also relatively stable (CAGR at about -0.3%).

Figure 5-1 shows the numbers of ICT priority applications by inventors based in the EU, US, Japan, Asia (excluding Japan), and rest of the world (RoW), between 1990 and 2007

When considering ICT applications, the main observations are:

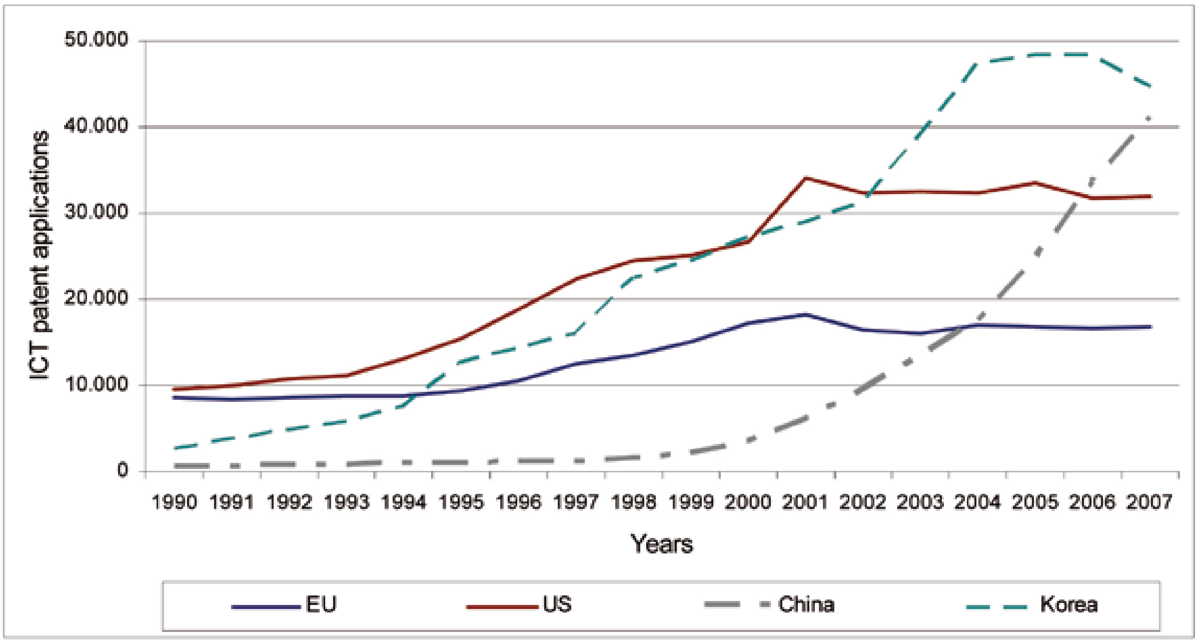
- The number of ICT applications by Japan-based inventors (yellow line) is consistently

Figure 5-1: ICT priority patent applications by EU, US, JP, Asian, and RoW inventors



Source: JRC-IPTS calculations based on PATSTAT data (April 2010 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices, the USPTO, the JPO, and 29 further Patent Offices. Inventor criterion.

Figure 5-2: ICT priority patent applications by EU, US, China and South Korea inventors



Source: JRC-IPTS calculations based on PATSTAT data (April 2010 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices, the USPTO, the JPO, and 29 further Patent Offices. Inventor criterion.

higher over the period than that of inventors based in the other regions.

- The number of ICT applications by Asia-based inventors (green line) overtook the number of applications by EU-based inventors in the early 90s, and the number of applications by US-based inventors in the late 90s.
- More ICT applications have been filed every year by US-based inventors (red line) than by EU-based inventors (blue line), contrary to what was observed previously when considering patent applications in both ICT and non-ICT technology classes.

Asian ICT patenting output shows an impressive CAGR of more than 22% over the considered period. The number of Asian ICT patent applications started from less than 3 500 in 1990 and grew to about 94 000 in 2007. This important growth is further analysed below.

The output of Japanese ICT patenting activity shows certain signs of instability in the early 1990s, with a CAGR between 1990 and 2007 of about -1.5%.

The EU CAGR between 1990 and 2007 was close to 4%, whereas for the US it was higher than 7%.

It should be noted that US-based inventors made twice as many ICT patent applications as EU-based researchers.

Furthermore, the US share of ICT applications over the total number of applications (ICT and non ICT) largely exceeds the EU share: 48% in 2007 for the US against 17% for the EU (not shown on the figure).

The impressive growth observed for Asia raises the question of which Asian countries contribute most to this growth. Figure 5-2 shows that the ICT patent applications filed by China- and South Korea-based inventors in 2007 made up 91% of the total Asian ICT application output, explaining Asia's strong performance.

Figure 5-5 shows the output of ICT inventive activity in China and Korea as compared with the EU, the US and Japan.

Japan's outstanding performance in patenting

Japan is a world leader in patenting. In 2009, the JPO is reported to have issued almost 348 600 patents, the majority with domestic origins.[85] As a result of this patenting prowess, Japanese patent applications represented almost 50% of the global total from 2000 to 2004, according to the Derwent World Patents Index. Japanese patenting predominance lies in three major industry sectors: Chemicals & Materials, Electrical & Electronic, and Engineering.[86] The effects of this important patenting activity are also reflected abroad, as the same source reports that, in the first semester of 2005, approximately 16 000 patents granted in the US followed a priority application filed in Japan.

Patent data available in the PATSTAT database confirms these trends, and shows that in 2007 the JPO received about 339 000 applications against the almost 305 000 received by the USPTO (irrespective of the country provenance of inventors and applications). With regard to priority patent applications, those filed at the JPO in 2007 were more than 298 000, those filed at USPTO were 85 000, and those at the EPO almost 19 000.

The literature (Motohashi, 2003; Motohashi, 2006; Kiyokawa, 2006; Goto, 2001) explains this high performance by taking into consideration several factors, e.g., firms' strategic behaviour, the gradual expansion of technology fields covered by patent protection (especially with regard to ICT and pharmaceutical patents), and also the fast increase in R&D expenditure in the 1990s and the changes in the regulatory framework towards stronger support for intellectual property. This last aspect can be identified in several revisions of the Japanese Patent Law since its enforcement in 1953 (the Strategic Framework for Intellectual Property policy was published in June 2003), which support pro-patent poiicies on innovation by firms (Motohashi, 2003).

In 2007, South Korea accounted for more than 47% of all Asian ICT patent applications, and China about 44%. The overall CAGR of South Korea in the period 1990-2007 was 19%, while that of China was 21%. China's inventive output has increased impressively since 2000: by the mid-2000s, it had overtaken both EU and US output.

There are two distinct phases in the growth of the contribution made by Asian countries: an earlier phase up until 2000 clearly dominated by the rise of South Korea, and a second one from 2000 on marked by the impressive emergence of China in ICT patenting activity.

The analysis of the shares of ICT applications in the total number of priority patent applications (ICT and non ICT) by region, over the period 1990-2007, indicates that the EU share has remained stable (17% in 2007, versus18% in 2000 and 2001) while the US share increased much faster. In 2007, the EU share was the lowest of the five regions' shares and the US share was the highest (it reached 48% in 2007).

Japan stabilised its ICT share of patenting activity after seeing it shrink in the early 90s: it has been around 35% from 2000 on. Asia reached a share of 39% in 1998, which then reduced but went back up to 38% in 2004. The RoW showed a slow but steady increase from the lowest level of 8% in the 90s to 19% in 2006, when it overtook the EU share.[87]

5.2.2 Total and ICT patenting activity per capita across the world

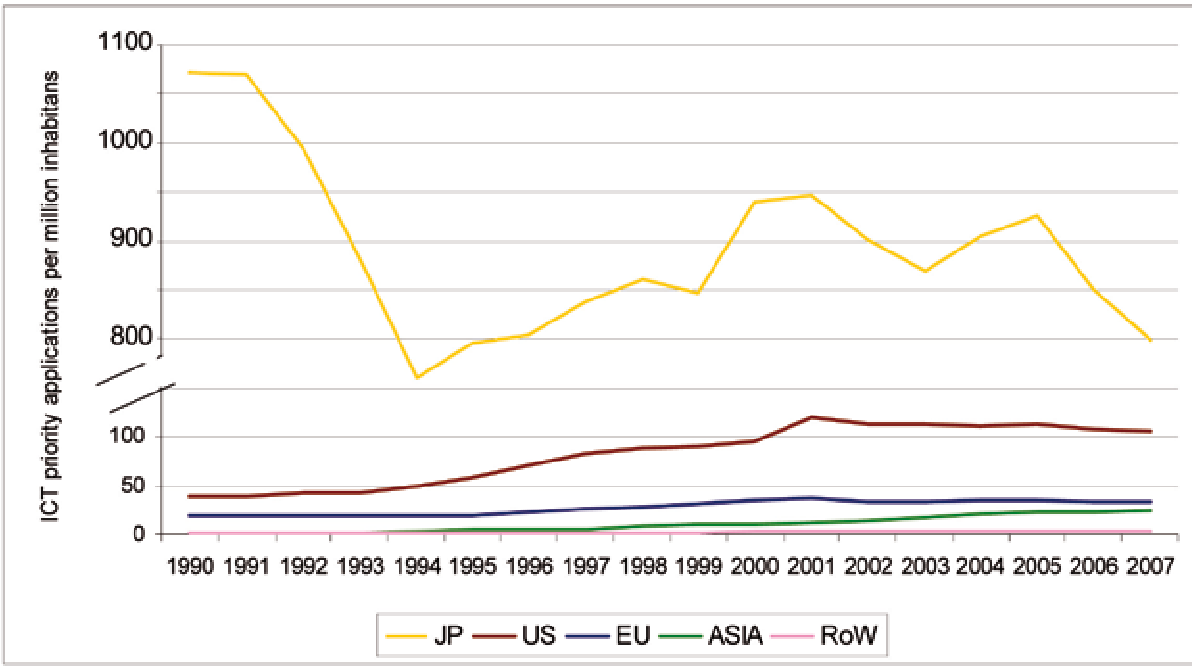
Weighting the output of inventive activity by the size of population makes Japan stand

85 http://www.japan-patents.com/japan_patent_application.html

86 Jeremy Rosie, Thomson Scientific, October 2005, available online at: http://science.thomsonreuters.com/news/2005-10/8292452/

87 In the RoW group, the top 5 ICT patenting countries were responsible for about 93% of ICT patent application s by inventor in 2007. They were, in order of decreasing contribution, Russia, Canada, Australia, Brazil and Switzerland.

Figure 5-3: ICT priority patent applications per million inhabitants, by region



Source: JRC-IPTS calculations based on PATSTAT data (April 2010 release) and on IMF data on population. Priority patent applications to the EPO, the 27 Member States' National Patent Offices, the USPTO, the JPO, and 29 further Patent Offices. Inventor criterion.

out even more than it does in previous figures. Japan has a smaller population than the US and the EU (around 128 million inhabitants in 2007, against 300 million in the US and 493 million in the EU), and it reached a maximum of more than 2 800 total patent applications (ICT and non ICT) per million inhabitants in 2001. This figure started to decrease slowly afterwards. The EU reached 200 total applications per million inhabitants in 2004; this figure then remained stable. In 2007, the US reached about 220 total applications per million inhabitants and Asia 70. The figures for Asia are obviously affected by the size of the population of this region (more than 3 900 million inhabitants in 2007).

Figure 5-3 allows comparison among the analysed regions by taking into account the total number of ICT applications per million inhabitants. Please note that the figures present a discontinuity on the vertical axis.

The picture is clearly dominated by Japan: EU ICT applications per million inhabitants in 2007 were about 4% that of Japan, while US reached 13%. Both the EU and the US show a continuing increase until 2001, i.e., just after the burst of the Internet bubble (38 and 120 ICT applications respectively per million inhabitants in 2001). Then they both stabilised at relatively lower values (about 35 for the EU and 110 for the US in 2007). Asia, however, continued to increase slowly, and has reached about 34 ICT applications per million inhabitants in 2007.

5.3 Patenting activity by EU Member States

This section provides a comparative view of the ICT innovative output of the different EU Member States, from 1990 to 2007, proxied by patent application activity.

Table 5-1: ICT priority patent applications by EU Member State, 1990 and 2007

ICT patent Applications		ICT patent Applications		CAGR, ICT Patent Applications		ICT Patent Applications /milllion inhab.		ICT Patent Applications/GDP (billion euro)	
2007		2000		2000-2007		2007		2007	
DE	7971	DE	8098	EE	35.7%	FI	136	FI	4.03
FR	3030	FR	2888	PT	26.1%	DE	97	DE	3.28
UK	1809	UK	1821	BG	22.4%	SE	62	SE	1.69
FI	723	IT	942	GR	13.6%	AT	52	FR	1.60
SE	571	FI	833	CZ	10.7%	FR	49	AT	1.58
NL	497	SE	721	AT	9.0%	IE	36	BG	1.35
AT	430	NL	458	LT	7.8%	NL	30	SI	1.06
IT	350	PL	305	SI	7.6%	UK	30	CZ	0.91
ES	318	ES	273	CY	6.5%	DK	29	EE	0.89
BE	236	AT	235	BE	5.3%	BE	22	UK	0.88
DK	156	BE	165	SK	4.8%	SI	18	NL	0.87
IE	155	IE	139	DK	4.0%	LU	17	IE	0.82
CZ	116	DK	118	ES	2.2%	CZ	11	HU	0.77
HU	78	HU	91	IE	1.6%	EE	11	BE	0.71
GR	72	CZ	57	LU	1.2%	HU	8	DK	0.69
PT	54	RO	43	NL	1.2%	ES	7	SK	0.59
BG	42	GR	29	FR	0.7%	GR	6	MT	0.36
SI	37	SK	23	UK	-0.1%	SK	6	LT	0.32
RO	36	SI	22	DE	-0.2%	IT	6	GR	0.32
SK	32	LV	11	FI	-2.0%	BG	6	PT	0.32
PL	23	PT	11	HU	-2.1%	PT	5	ES	0.30
EE	14	BG	10	MT	-2.6%	MT	5	RO	0.29
LT	9	LU	7	RO	-2.7%	CY	3	IT	0.23
LU	8	LT	5	SE	-3.3%	LT	3	LU	0.22
LV	5	MT	2	LV	-11.9%	LV	2	LV	0.21
CY	3	CY	2	IT	-13.2%	RO	2	CY	0.16
MT	2	EE	2	PL	-31.0%	PL	1	PL	0.07
EU	**16776**	**EU**	**17312**	**EU**	**-0.4%**	**EU**	**34**	**EU**	**1.35**

5.3.1 Overview of the Member States' ICT patenting activity

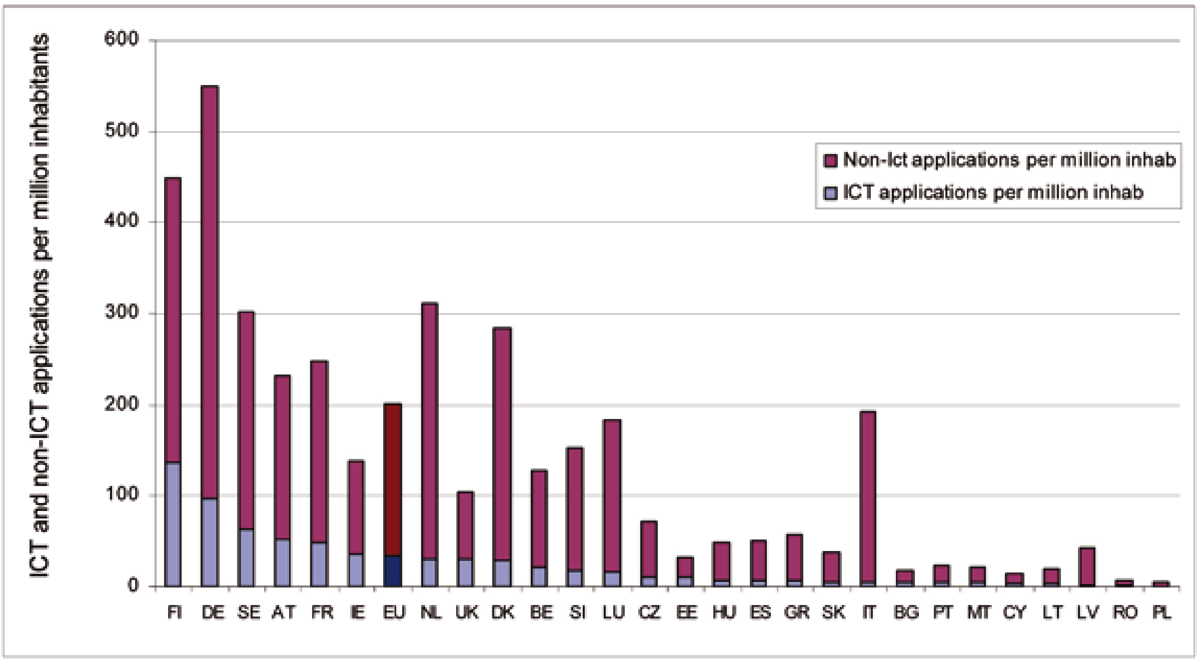
Analysis of ICT patent applications filed in 2007 to **the 59 patents offices covered by this analysis**[88] is shown in Table 5-1.

This analysis confirms that, in absolute terms, the leading EU countries in ICT patenting are the three largest EU economies: Germany, France and the UK. The number of applications in ICT by Germany-based inventors (8 000 applications in 2007) is more than 2.5 times that of France-based inventors (3 000 applications) and 4.4 times that of the UK (1 800 applications).

Finland, with 720 ICT applications in 2007, is next, followed by Sweden, the Netherlands, Austria, Italy, Spain and Belgium, with between 200 and 600 applications each.

88 See methodology overview in Section 5.1.

Figure 5-4: Number of ICT and non-ICT patent applications per million inhabitants, by EU Member State, 2007



Source: JRC-IPTS calculations based on PATSTAT data (April 2010 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices, the USPTO, the JPO, and 29 further Patent Offices. Inventor criterion.

Inventors based in the ten best performing countries filed 95% of all EU ICT patent applications (and almost the same share of total patent applications – ICT and non-ICT-). Inventors based in Germany alone contributed almost half the EU total and ICT inventive activity.

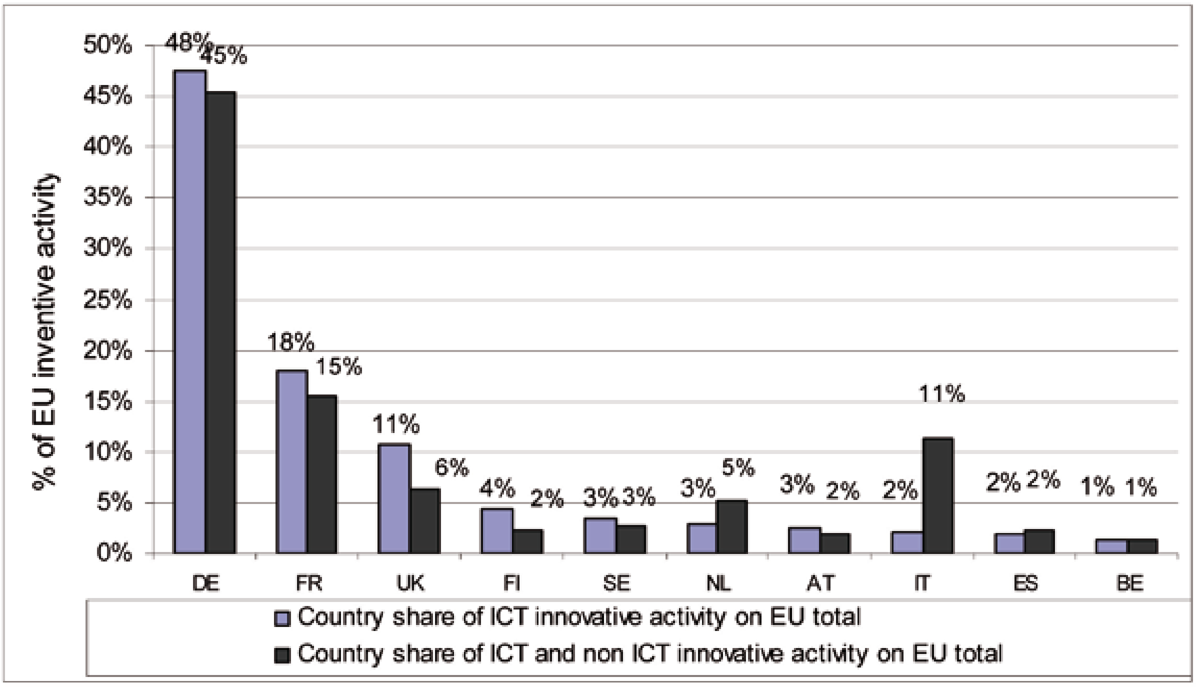
When considering the ratio of ICT patent applications on gross domestic product (GDP) at national level,[89] Table 5-1 (last column) shows that Finland (with a ratio of 4 ICT applications per billion euro of GDP) is first, followed by Germany (with 3.3), Sweden (1.7), France and Austria (1.6). The European average is 1.35 ICT applications per billion euro of GDP. Bulgaria, Slovenia, the Czech Republic and Estonia then follow (below the European average), followed by the UK, 10th in the list.

Table 5-1 (in its 3rd column) also presents the compound annual growth rate (CAGR) of the number of ICT priority patent applications between 2000 and 2007 per EU Member State. For Estonia, Portugal, Bulgaria and Greece, the number of applications increased during the period at compound annual rates higher than 10%, all of them recovering from very low values over the previous decade. The Czech Republic, Austria, Slovenia achieved annual growth rates higher than 5%. These countries are characterised by the fact that they all started from low figures and rapidly increased their outputs in terms of ICT priority patent applications. For the Czech Republic, for example, the number of ICT patent applications grew from 57 in 2000 to 116 in 2007.

France with an annual growth of 0.7% stands immediately above the UK, Germany and Finland, which occupy positions between 17th and 20th, with null or slightly negative growth. The stable performance of this group of countries can be explained in part by the fact that they already had a high number of ICT patent applications in the 90s. These countries remained the most patenting countries in ICT in the 2000-2007 period. The

89 Eurostat data on gross domestic product at market prices; in millions of euro from 01.01.1999 and millions of ECU up to 31.12.1998.

Figure 5-5: Contribution (%) to total ICT and non ICT EU priority patent applications by the ten most ICT-patenting EU Member States– inventor criterion



Source: JRC-IPTS calculations based on PATSTAT data (April 2010 release). Priority patent applications to the EPO, the 27 Member States' National Patent Offices and the USPTO, the JPO, and 29 further Patent Offices. Inventor criterion.

European average annual growth is also slightly negative over the period (-0.4%).

5.3.2 ICT and total patenting activity per capita in the EU Member States

In order to better understand the prowess of individual Member States in the production of ICT inventions, it is relevant to weight the number of ICT patent applications by country size measure, either by GDP or population.

When weighting the number of ICT applications by country population, Finland leads, with almost 140 ICT patent applications per million inhabitants, as can also be seen in Table 5-1 (4th column). Germany comes next with about 100 ICT applications per million inhabitants, and Sweden and Austria follow with numbers above 50 ICT applications per million inhabitants. Then, above the European average of 34 ICT applications per million inhabitants come France and Ireland. They are followed by the Netherlands, the UK, Denmark and Belgium, which are immediately below the EU average.

Figure 5-4 shows the ratio of ICT and non-ICT applications per million inhabitants for the 27 EU countries in terms of ICT priority patent applications in 2007. Countries are ranked by number of ICT applications per million inhabitants.

Figure 5-4 allows us to compare ICT inventive effort to non-ICT inventive activity in 2007. While Finland leads in term of ICT-related applications per million inhabitants, Germany is first for the total number of applications (ICT and non-ICT). Among the countries with good overall patenting performance but lower intensity in ICT patenting activity are the Netherlands and Denmark, with a total number of applications per million inhabitants comparable to that of Sweden. Luxembourg and Italy come next in terms of general applications per million inhabitants, while they are ranked 12th and 19th respectively as regards ICT priority applications over population.

5.3.3 Contribution of Member States to EU patenting activity

As already pointed out, the contribution to total and ICT inventive activity in terms of patent applications is concentrated in a small number of EU Member States. In 2007, the ten 'most patenting' countries contributed up to 95% of total EU patent applications. These countries are, in decreasing order of contribution to the EU total number of ICT priority patent applications, Germany, France, UK, Finland, Sweden, the Netherlands, Austria, Italy, Spain, and Belgium (see Figure 5-5 and Table 5-1, first column). When total patent applications are considered, the picture is similar, with 10 countries contributing 95% of the EU output (with Denmark substituting Belgium and Italy ranked 3rd, before the UK). Figure 5-5 shows that in general those countries responsible for high shares of ICT patenting activity in Europe also contribute more to total patenting activity.

5.4 Summary of main findings and conclusions

Based on the data and the analysis presented in this chapter, the following observations can be made:

- While the annual number of ICT priority patents application by inventors based in the EU steadily increased in the period from the early 90s until 2001, it has remained stable since the burst of the dot.com bubble.
- A similar pattern can be observed for ICT applications by inventors based in the US, but US absolute values are about twice as high as the EU ones. For example in 2007, EU-based inventors applied for about 17 000 ICT patents while US-based researchers applied for 32 000 ICT patents
- For reasons ranging from sector specialisation to regulatory frameworks and policy support, the annual numbers of ICT priority patent applications by inventors based in Japan have traditionally been the highest of all geographic areas, with figures five times higher than those of the EU.
- Since the early 90s, the annual number of ICT priority patent applications by inventors based in Asia (excluding Japan) has strongly increased, reaching close to 91 000 in 2007 (from 3 600 in 1990). Most of this spectacular growth can be attributed to two countries; first to South Korea where annual figures reached almost 50 000 in 2004 and then stayed at this level; and second to China where a spectacular increase started in 2000, and where annual figures exceeded 40 000 in 2007, significantly above the annual figures for both the EU and the US.
- When the number of ICT priority patent applications is weighted by number of inhabitants, Japan reinforces its leading position (with about 800 applications per million inhabitants in 2007). Next comes the US, with around 100 applications, followed by the EU by with 34 applications, and Asia with 24 applications per million inhabitants.
- Within the EU, the most patenting countries in ICT are Germany, France and the UK. Together, they accounted in 2007 for 80% of all ICT priority patent applications by EU-based inventors, with Germany-based inventors alone generating half the total ICT applications for the EU.
- When the annual number of ICT priority patent applications is weighted by number of inhabitants, Finland, Germany and Sweden were the top three performers in the EU with respectively 136, 97 and 62 applications per million inhabitants in 2007, followed by Austria, France and Ireland with respectively 52, 49, and 36 applications per million inhabitants, above the EU average of 34 applications per million inhabitants.
- Among the western EU Member States, the ICT patenting performance of Portugal, Italy, Greece and Spain remains low, with less than 10 applications per million inhabitants in 2007, although absolute values for Portugal, Greece and Spain have risen since 2000.

- Among the eastern EU Member States, performance is mixed, with figures rising (compared to 2000) particularly in Estonia, Bulgaria, the Czech Republic, Lithuania, and Slovenia, and decreasing in Hungary, Romania, Latvia and particularly Poland.

Though it should be remembered that patent applications are only a *proxy* for inventive activities, the power of patent-based indicators is confirmed by their wide coverage and availability, the increasing accuracy of large amounts of data over a period of 18 years, and the possibility of considering a number of countries.

In-depth analysis of country specificities and dynamics can be carried out, to investigate countries behaviour and to provide better explanations of resulting trends. Useful comparisons can be also carried out at country level, by exploiting the detailed information that patent data provide.

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6 Internationalisation of ICT R&D

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6.1 Introduction

This chapter analyses the internationalisation of ICT R&D.[90] It focuses mainly on the way in which innovation in the ICT industry is taking place across five major world regions - the EU, the US, Asia, Japan and the rest of the world (RoW) - and where the EU stands in this regard. The reasons for taking up the subject of internationalisation of ICT R&D activities are manifold. This analysis, however, is driven by the following two main concerns:

First, following the internationalisation of their production activities, large multinational ICT companies are increasingly internationalising their R&D activities (Kuemmerle, 1997). While most of the 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 F., 2006; OECD, 2008; UNESCO, 2010). The increasing role of developing countries, particularly 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 could have a negative impact on domestic R&D expenditures and employment and on the domestic knowledge base.

The second 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 could harm the competitiveness of these industries and undermine the current state and future 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). 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 could positively affect the overall knowledge creation balance, the inventive capacities of individual countries and the growth perspectives of EU companies. Hence, this motivates the interest in whether EU countries are attractive companies, on the one hand, and, on the other hand, whether EU companies are actively searching for new sources of knowledge abroad.

Lastly, although the internationalisation of R&D has received a lot of attention, the process has not been captured by official data yet, which creates a challenge for informed policy

90 This chapter summarises the main observations of a separate full length report 'The Internationalisation of ICT R&D' Institute for Prospective Technological Studies, JRC Scientific and Technical Report (forthcoming), and highlights its most relevant findings. Interested readers are referred to the full length report for more material and analyses. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

making. Moreover, R&D internationalisation challenges the available tools for measuring inventive performance. As observed in European Commission (2009), BERD data and company data are used to track inventive activity. However, as this 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. Recent attempts to capture this phenomenon do not offer a complete assessment of its nature, dynamics and implications (see, for example, OECD, 2008; UNESCO, 2010; Eurostat, 2010).[91] This, of course, puts the decision-making process at risk by giving a partial view of the reality. A better grasp of the internationalisation process and the corresponding data could help to disentangle these dynamics.

The remaining part of the chapter is organised as follows: Section 6.2 presents the methodological framework used to study the internationalisation of R&D; Section 6.3 analyses the internationalisation of R&D input, such as R&D centre locations and semiconductor design expenditures, and Section 6.4 describes the level of internationalisation of the output of research activities based on patent statistics. Together these sections offer unconventional complementary views at statistical, company and country levels. Section 6.5 provides in addition a perspective on ICT R&D in two emerging Asian economies: China and India.

6.2 The methodology used to study R&D internationalisation

In spite of the abundance of anecdotal evidence regarding R&D internationalisation, very little systematic analysis has been carried out and very low levels of international inventive collaboration have been observed so far. These rather puzzling results can be explained by the complexity of the inventive process and the different motivations behind decisions to do R&D abroad. For example, as explained earlier, not all R&D activities are taken abroad 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. Moreover, 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). As a result, the tangible outputs of international inventive collaboration remain few or at least, extremely difficult to observe and measure.

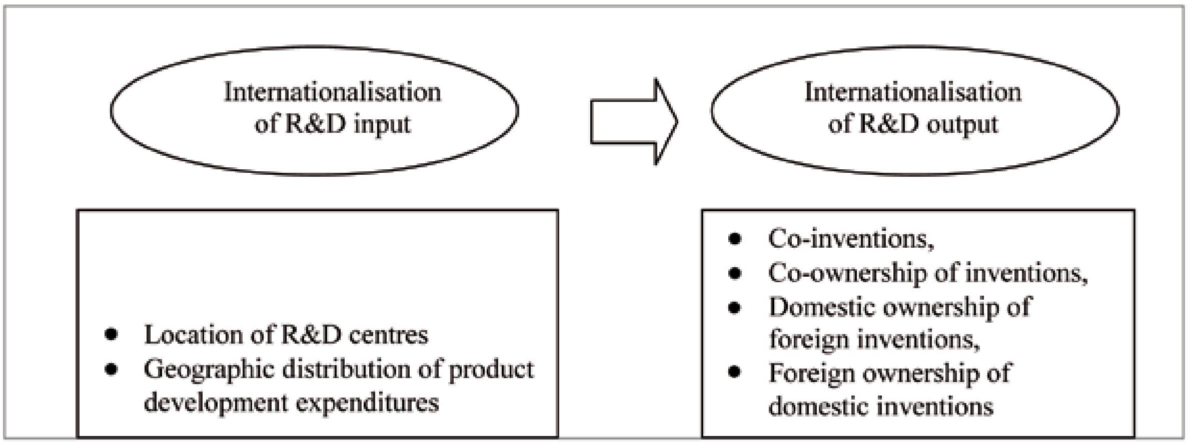
To address the complexities related to R&D internationalisation outlined above, it is necessary to follow the developments of the global knowledge creation network, paying particular attention to the complexity of the knowledge creation process and its stages. To this end, the following analysis uses the methodology of analysing R&D internationalisation as presented in Figure 6-1.

To put it simply, and as presented in Figure 6-1, the process of R&D can be divided into two stages. The first stage concerns the input-side of the R&D process and the second one the output side of R&D activity. This division reflects some of the complexity of the R&D process and, hence, allows for a more accurate assessment of the internationalisation of R&D activities. Thus, following this division, the level of internationalisation of each R&D stage will be analysed separately.

In this chapter, the main measures used to assess the internationalisation of the R&D input-side include data on the

91 For example, the recent Eurostat (2010) attempt is a presentation of the first-ever data collection in the EU on 'national public funding to transnationally coordinated research', defined as the total budget funded by the government, as measured by GBAORD. Moreover, this concerns only public expenditures and does not cover companies' activities.

Figure 6-1: Methodology to study the internationalisation of R&D



location of R&D centres (Section 6.3.1) and the geographic allocation of semiconductor design expenditures (Section 6.3.2) by ICT companies. Concerning the R&D output side, ICT patent data are used (Section 6.4).

In the absence of official statistics on R&D internationalisation, this analysis makes use of proprietary and unique data with a view to building a comprehensive source of information on ICT companies' R&D internationalisation levels. Hence, for example, in Section 6.3.2 information on semiconductor design expenditures, an R&D activity at the beginning of the ICT value chain (Tuomi, 2009), is used.

Despite delivering valuable insights into the internationalisation of ICT R&D, this poses some limitations. First of all, only a subset of activities of a small group of companies are analysed and not of the entire ICT industry.[92] Moreover, the information on R&D activities relate only a part of the R&D process and does not provide complete insights into the type, size, quality or scientific complexity of activities performed by the companies included in these datasets. In a similar way, patents are used as a proxy of R&D output, which also poses some limitations to the interpretation of the results. Therefore, the evidence presented here should be interpreted with caution.

6.3 Internationalisation of ICT R&D input

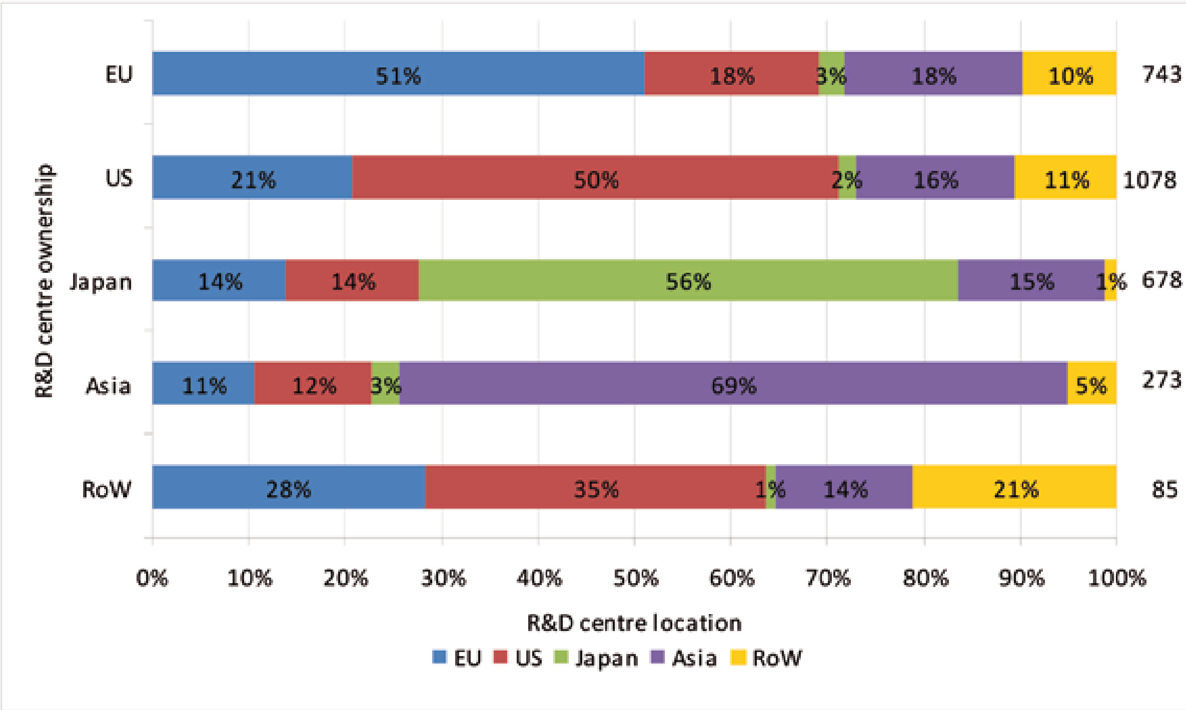
The following analysis investigates the patterns of internationalisation of ICT R&D input based on the location of ICT R&D centres of major ICT companies (Section 6.3.1) and the allocation of semiconductor design expenditures across the world (Section 6.3.2). The analysis is based on information extracted from the *2010 JRC-IPTS ICT R&D Internationalisation Database* (see Annex 6).

6.3.1 Location of ICT R&D centres

The analysis of the internationalisation of ICT R&D input starts with a first look at the location of ICT R&D centres, i.e., business units devoted to research and development activities, across the five major world regions, i.e., the EU, the US, Japan, Asia and the RoW. It also looks at where the headquarters of companies owning these centres are located.

92 Covering the entire ICT industry is of course an unrealistic objective. At the moment, JRC-IPTS is working with a reasonably representative sample of companies (see Annex 6), and in the longer term aims to cover exhaustively the top ICT R&D spenders worldwide.

Figure 6-2: Location of ICT R&D centres by region of ownership, 2009, in %



Source: JRC-IPTS ICT R&D Internationalisation Database, 2010.

Where do ICT companies locate their R&D centres?

Figure 6-2 shows where companies from different regions tend to locate their R&D centres.

Out of 743 R&D centres owned by EU companies, Figure 6-2 indicates that in 2009, 51% were located in one of the EU Member States. The other most frequent location choice for R&D activities among the EU firms was the US (18%) and Asia (18%). Only 3% of R&D centres owned by EU companies were located in Japan.

R&D centres owned by US companies: 50% of the 1,078 R&D centres owned by US companies were located in the US. The other most frequent locations for R&D activities among US firms were the EU (21%) and Asia (16%). Only 2% of US-owned R&D centres were located in Japan.

R&D centres owned by Japanese companies: 56% of the 678 Japan-owned R&D centres were located in the Japan. 15% of Japan-owned research centres were based in other Asian countries. The remaining centres were located in either EU or US, each hosting 14% of R&D centres belonging to Japanese companies.

R&D centres owned by Asian companies: 69% of the 273 R&D centres owned by Asian companies were located in Asia. The other most frequent location for R&D activities among Asian firms were the US (12%) and the EU (11%). Only 3% of R&D centres owned by Asian companies were located in Japan and 5% in the RoW.

The data presented above shows that the pattern of locating R&D activity in the same region as a company's headquarter is very common among all firms, as usually described in literature. However, there are also some considerable differences between the regions. For example, whereas companies from the EU and the US have around 50% of their R&D centres located in other regions, their Asian counterparts maintain about 70% of their R&D centres in Asia and only 30% outside of Asia.

The data also confirms the existence of strong linkages between the EU and the US. Out of all foreign locations, US ICT firms seem to consider the EU countries as most attractive for locating R&D centres outside of the US. 21% of all US-owned research sites are located in the EU (16% in Asia, 11% in RoW and only 2% in Japan). Very similarly, EU ICT firms seem to consider the US as most attractive for locating R&D centres outside of the EU. 18% of all EU-owned research centres are located in the US (18% also in Asia, 10% in RoW and only 3% in Japan).

In addition, the analysis clearly shows the high attractiveness of the Asian countries as a destination for R&D expenditures, particularly with US and EU companies. For example, hosting 18% of EU-owned and 16% of US-owned R&D centres, Asian countries are already one of the most attractive foreign locations for EU and US companies for establishing R&D outside of the US.

6.3.2 Internationalisation of semiconductor design expenditures

This section analyses the allocation of semiconductor design expenditures across the five major world regions considered in the previous section, i.e., the EU, the US, Japan, Asia and the RoW.[93] In particular, the following analysis of the internationalisation of ICT R&D input is focused on two questions: First, what does the regional allocation of semiconductor design expenditures look like? Second, where do companies from different regions of the world spend their money to conduct these activities? Thus, this analysis complements and extends the previous analysis of the internationalisation of R&D centre location.

93 The analysis is based on the data from the *JRC-IPTS ICT R&D Internationalisation Database* that includes information on semiconductor design expenditures for over 176 ICT companies broken down by country where investments are carried out. More information on the definition of semiconductor design expenditures and the methodology for collecting the data can be found in Annex 6.

Destination of semiconductor design expenditures

In order to cast more light on semiconductor design expenditure patterns across the geographic regions, Figure 6-3 presents the allocation of semiconductor design spending according to their source.

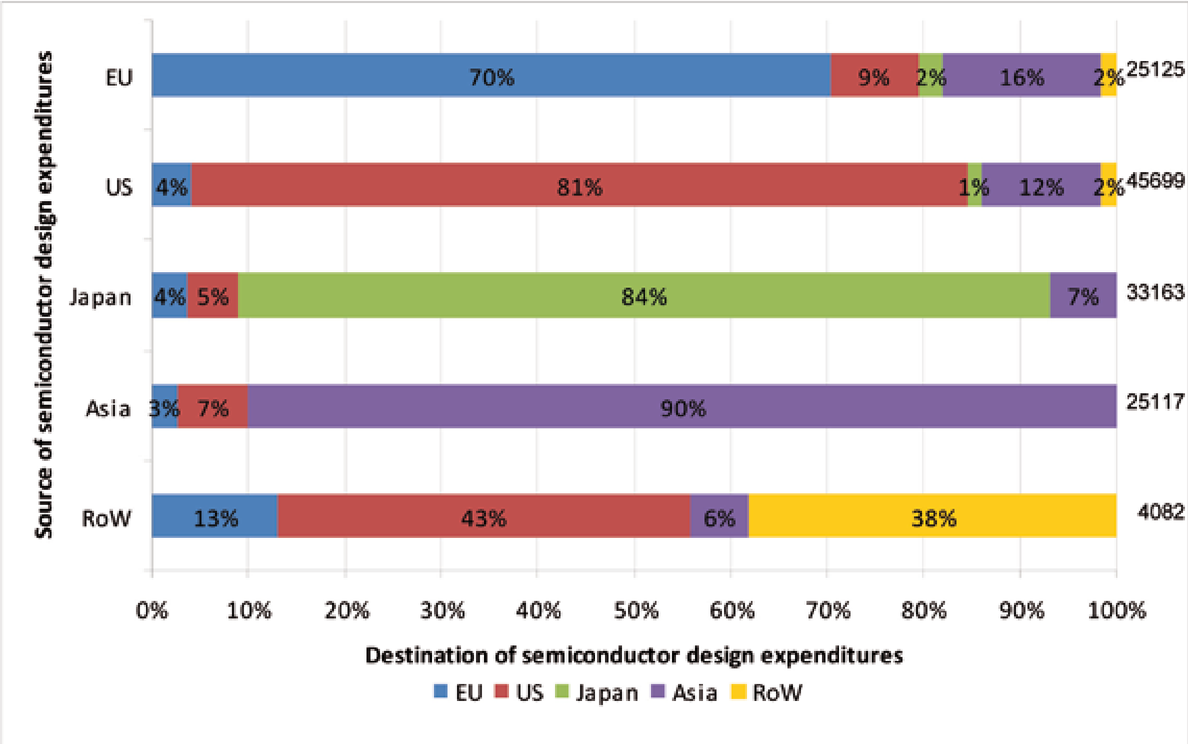
In 2008, EU companies spent 70% of the semiconductor design budget within the EU. Among foreign destinations, Asia emerges as the major recipient of the semiconductor design expenditures by EU companies. In 2008, EU companies spent 16% of their semiconductor design budget in Asia, while only 9% was spent in the US.

Despite some slight differences, US companies show similar allocation patterns of their semiconductor design expenditures to their EU counterparts. They invested the majority of these expenditures (81%) in the home country and see Asia as the most attractive foreign location for developing electronic products, as do EU companies. In 2008, 12% of the total budget of US companies was spent in Asia, as compared to 4% in the EU or only 1% in Japan.

Similarly to EU or US firms, Japanese companies spend the majority of their semiconductor design expenditures within their country. In 2008, 84% of their budget was spent within Japan. Regarding the amount spent in other regions, Japanese firms, like their counterparts from other regions, appear to favour Asia the most. In 2008, Asian countries received 7% of the semiconductor design budget of Japanese companies. In comparison, the US and the EU obtained 5% and 4%.

Additionally, the data points to the fact that Asian companies also concentrate their semiconductor design expenditures within their region. In 2008, they spent 90% of their budget within their home region. Among foreign destinations of their semiconductor design

Figure 6-3: Destination of semiconductor design expenditures by source, 2008, in % (absolute values on the right hand side in €m)



Source: JRC-IPTS ICT R&D Internationalisation Database, 2010. Conversion to $US Euro at the exchange rate from 31.12.2008.

expenditures, the US holds the first and the EU the second position. In 2008, these regions received respectively 7% and 3% of the budget of Asian companies.

The analysis of the data on the allocation of semiconductor design expenditures across the world regions reveals the following. First, as for other measures of inventive activity, irrespective of the region of origin, companies tend to invest the largest share of their semiconductor design budget within the geographical borders of their home country or region. Second, in relative terms, Asia is the largest recipient of semiconductor design expenditures made by ICT firms abroad, regardless of the region of origin, except for firms from the RoW.

6.4 Internationalisation of ICT R&D output: patent-based evidence

The previous section maps the allocation of ICT R&D input resources, such as R&D sites and semiconductor design expenditures. Following the methodology described briefly in Section 6.2, the current section attempts to measure and identify inventions, i.e., the output of R&D activity resulting from international collaboration. To this end, ICT patent data is used. A methodology for constructing measures of internationalisation based on information included in patent applications is described in Annex 7.

The remainder of the chapter is organised as follows: Section 6.4.1 compares the levels of international co-invention, co-ownership and cross-border ownership of inventions across the major world regions. Section 6.4.2 analyses in detail the patterns of internationalisation in the EU and the US.

6.4.1 Internationalisation of ICT inventive output in global perspective

This analysis starts with a general assessment of the internationalisation of ICT inventive activity for the period 1990 to 2007 in five world regions: EU, US, Japan, Asia (excluding Japan) and the rest of the world (RoW).[94] Figure 6-4 consists of four subfigures, each one presenting a distinct measure of international collaboration. All these four measures of internationalisation of ICT inventive activities are based on the concepts of internationalisation defined in Annex 7.

ICT Co-inventions

Figure 6-4a presents the levels of international co-invention. In this case, each line represents collaboration of inventors from one particular region with inventors from the remaining four regions, i.e., collaboration of EU and non-EU inventors, US and non-US inventors, etc. This figure shows that by far the highest co-inventive activity occurs between RoW and non-RoW inventors. The level of their co-invention gradually grows, reaching a peak of more than 3% in 2007 (i.e., more than 3% of the total number of RoW ICT inventions is co-invented with non-RoW inventors). Lower co-inventive activity is done by EU and non-EU inventors, as well as by US and non-US ones. Both these regions show very similar patterns, peaking at 2%. Japan and Asia are the only two regions with below 1% co-inventive activities but these levels are growing. In fact, Japan shows the highest increase among these regions (more than 600% over the analyzed period).

94 The RoW group includes altogether 78 countries that, in 2007, produced 7 423 ICT patent applications (as compared to 16 776 EU ICT patents). This group includes very heterogeneous countries and only a few of them play some role in terms of ICT patent numbers. Thus, in 2007, only 6 countries accounted for 95% of the total number of patents included in the RoW group. These countries are: Russia (3 641), Canada (1 909), Australia (467), Brazil (462), Switzerland (406) and Norway (143).

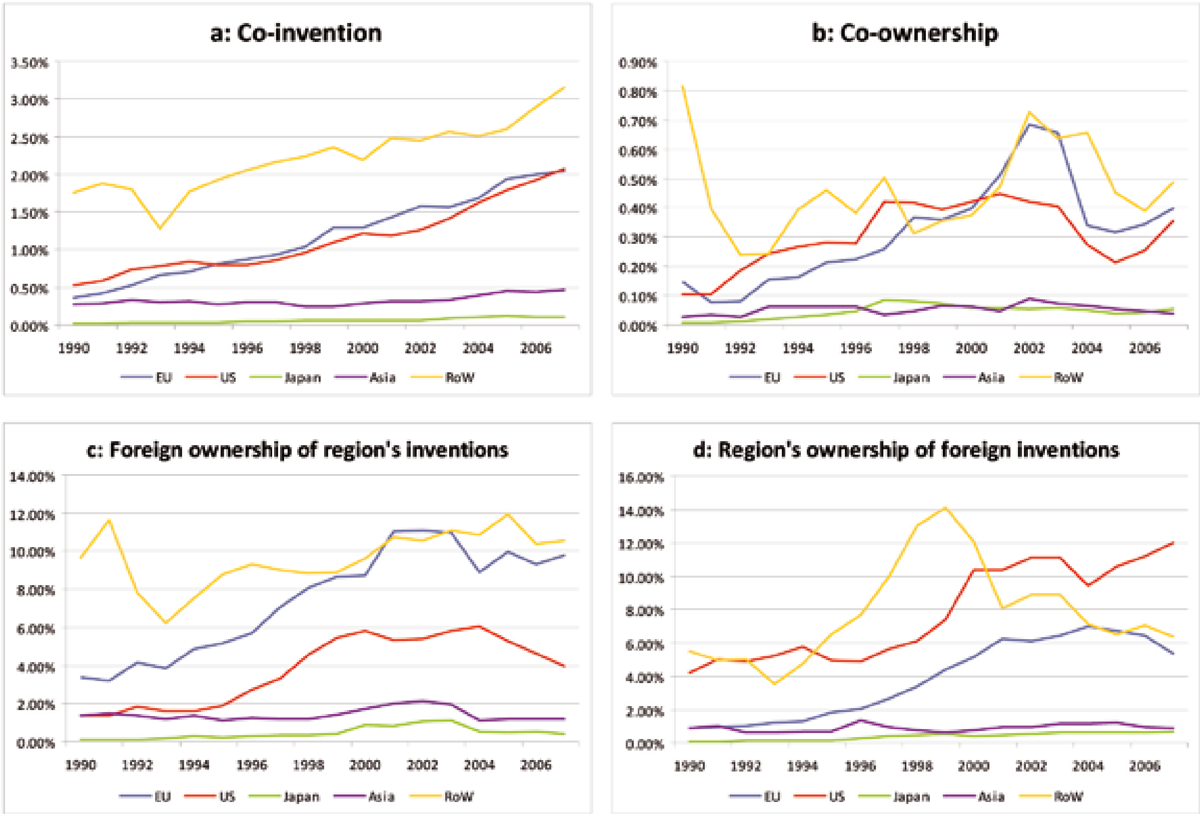
Co-ownership of ICT inventions

In a similar fashion, Figure 6-4b presents co-ownership of inventions by applicants. Each line represents a share of inventions co-owned by applicants from one particular region with applicants from the remaining four regions, i.e., co-ownership of EU and non-EU applicants, US and non-US applicants, etc. Comparing this kind of collaboration with co-invention (described above), one can see that although the ranking of regions stays the same (except the period 1998-2001 when EU and US co-ownership shares exceed the RoW), the levels are much lower. The applicants from the RoW again have the highest share of RoW inventions co-owned with applicants from non-RoW but this share is now below 1%, significantly lower than the share of co-inventive activities related to this region. Co-ownership for the EU and US regions is again very similar, as it is for Japan and Asia. In general, however, co-ownership shares presented in this subfigure appear to be much more volatile than co-inventive ones.

Foreign ownership of domestic ICT inventions

With respect to the levels of cross-border ownership of ICT inventions, Figure 6-4c presents the share of foreign ownership of region's ICT inventions in the total number of region's ICT inventions, i.e., non-EU ownership of EU ICT inventions, etc. Between 1990 and 2007, this share grows for every region except Asia. Similarly to the previous picture, peaks occur during the period 2000-2005. The RoW shows again the highest level of collaboration when the share of RoW inventions owned by non-RoW applicants in the total number of RoW ICT inventions oscillates between 10 and 12% during the last period. But EU collaboration is very close to these values – almost 10% of EU ICT inventions are owned by non-EU applicants. Then, there is a clear gap between these two regions and the rest. US collaboration is only at about 5%; Japan and Asia are again at the bottom of this ranking.

Figure 6-4: Shares of co-invention, co-ownership and cross-border ownership of inventions in the total number of ICT inventions for world regions (1990-2007)



Note: Priority patent applications filed at 58 national patent offices, including all EU and US patent offices, and the EPO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.
Source: JRC-IPTS calculations based on PATSTAT data.

Domestic ownership of foreign ICT inventions

Finally, Figure 6-4d presents the opposite relationship between inventors and applicants. It depicts the regions' ownership shares of foreign ICT inventions in the total number of foreign ICT inventions, i.e., EU ownership of non-EU ICT inventions, etc. Interestingly, the situation for the EU and the US is exactly opposite in this case. Now the US applicants own about 5-6% more non-US ICT inventions than EU applicants own non-EU ICT inventions. Furthermore, the RoW region is no longer in the leading position and dropped from 14% in 1999 to 6% in 2007, which is at about the same level as the EU. Japan and Asia are at the bottom of this ranking with below 1% shares.

An analysis of this data allows us to draw the following conclusions. First, there are significant differences among the levels of the four alternative metrics, with the two measures of cross-border ownership of inventions being well above the measures of inventor collaboration and co-ownership of inventions. Second, these data show that, in general, the degree of internationalisation in the production of technology has increased since the early 90s, but it is still rather low. Third, there is a clear gap between the two measures of cross-border ownership of inventions in the case of the EU and the US. As regards the EU, it 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 (Figure 6-4c) is higher than the share of non-EU ICT inventions owned by EU applicants (Figure 6-4d) indicates the relatively high importance of extra-EU applicants in 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.

Alternatively, as regards the gap in the case of the US, the share of US ICT inventions owned by non-US applicants (Figure 6-4c) is lower than the share of non-US ICT inventions owned by US applicants (Figure 6-4d). This highlights the important role of US firms in global inventive activity.

6.4.2 Internationalisation of the EU inventive output

ICT Co-inventions

Figure 6-5a presents the international distribution of EU ICT co-inventive activities. In this case, the level of co-inventive activity by EU and non-EU inventors, presented in the previous section as a blue line in Figure 6-4a, is further examined by analysing the contribution of each remaining region to this level. This figure shows that US inventors are the major partners for their EU colleagues. Despite the fact that the EU level of co-invention is gradually growing, the contribution of US inventors to it remains stable at around 65%. When interpreting this number, one has to keep in mind that it represents only the portion of small EU co-inventive activities. Thus, if the level of total co-invention between EU and non-EU inventors in 2007 is 2%, the corresponding level between EU and US inventors is 1.3%. To be more precise, 1.3% of the total number of EU ICT inventions is co-invented with US inventors. The remaining portion of EU collaboration is split mostly between the RoW and Asia (17% and 15% in 2007 respectively). Interestingly, while at the beginning of 90s Asia plays only a minor role (4%) compared to Japan (12%), the situation in 2007 is very different with a contribution from Japan of 4%.

Co-ownership of ICT inventions

Figure 6-5b presents the international distribution of co-ownership with EU applicants. Here, the share of EU inventions (from the total EU inventions) co-owned by EU and non-EU applicants, presented in the previous section as a blue line in Figure 6-4b, is further examined by analysing the contribution of each remaining region to this share. From the perspective of relatively even and stable results of previous paragraph, the situation in this case looks much more unstable. While the contribution by US applicants is about 25% at the beginning as well as at the end of our sample, it peaks at almost 80% in 2001. Again, one has to keep in mind that these numbers represent only contributions to the overall EU co-ownership level, i.e., the share of EU inventions co-owned by EU applicants with applicants from remaining four regions, which is 0.3% on average. On the other hand, in an exactly opposite pattern, the contribution of RoW applicants to EU co-ownership starts at 51% in 1990, drops down to 9% in 2001 and rises again to 45% in 2007. Similarly volatile, but lower in magnitude, are contributions by Japan and Asia.

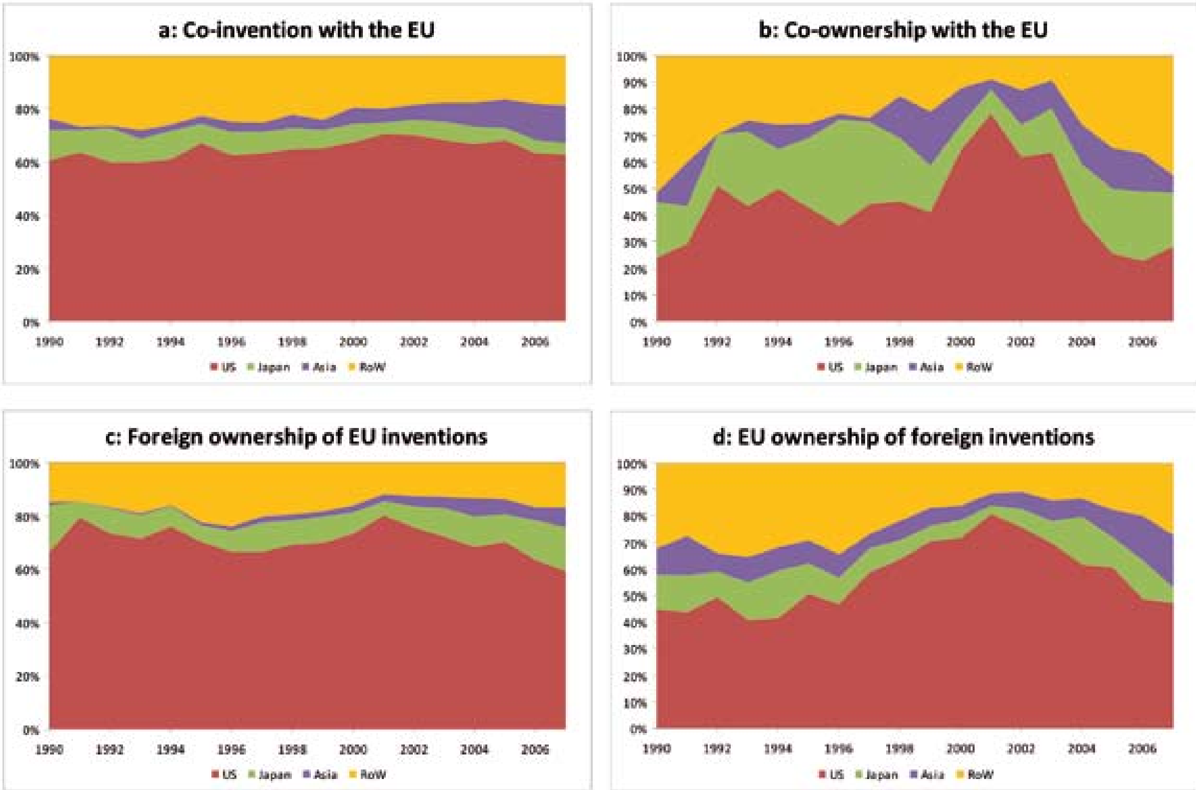
Foreign ownership of EU ICT inventions

Regarding the levels of cross-border ownership of ICT inventions, Figure 6-5c presents the international distribution of applicants owning EU ICT inventions. In other words, the level of foreign ownership of EU ICT inventions, presented in the previous section as a blue line in Figure 6-4c, is further examined by analysing the contribution of each remaining region to this level. The main foreign owner of EU ICT inventions are US applicants with about 70% average contribution, although their share has been decreasing over the last few years. This number represents only the portion of the level of foreign ownership of EU ICT inventions. Thus, if on average 7.4% of EU inventions are owned by foreign applicants, US applicants own on average about 5% of all EU inventions. On the other hand, the role of Asian applicants is growing even though their contribution is still below 10%. The remaining two regions (Japan and the RoW) also contribute about 16% in 2007.

EU ownership of foreign ICT inventions

Finally, Figure 6-5d presents the opposite relationship between inventors and applicants. It

Figure 6-5: Regional distribution of EU ICT collaboration (1990-2007)



Note: Priority patent applications filed at 58 national patent offices, including all EU and US patent offices, and the EPO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.
Source: JRC-IPTS calculations based on PATSTAT data.

depicts the international distribution of the share of EU ownership of foreign ICT inventions in the total number of foreign ICT inventions. This share is presented in the previous section as a blue line in Figure 6-4d. The overall pattern here is very similar to the one shown in Figure 6-5b. The contribution of the US to the inventions portfolio owned by EU applicants is again very important and varies between 41% (in 1994) and 81% (in 2001). In 2007 this contribution is about 50% which means that out of all ICT inventions held by EU applicants, 2.7% are US inventions. Naturally, the contribution of other regions grows/declines with decreasing/increasing role of the US. The second most owned foreign inventions are the ones from the RoW (about 27% in 2007). Thus, in 2007, about 27% of the total number of foreign innovations owned by EU applicants is invented by RoW innovators.

Based on the analysis presented above, we can conclude that the US region plays the most significant foreign role in EU ICT inventive activity. The US is then followed by the RoW. The increasing role of Asia and the decreasing role of Japan also stand out.

6.4.3 Internationalisation: the US inventive output

ICT Co-inventions

Figure 6-6a presents the international distribution of US ICT co-inventive activities. In this case, the level of co-inventive activity by US and non-US inventors, presented in the previous section as a red line in Figure 6-4a, is further examined by analysing the contribution of each remaining region to this level. This figure shows that although EU inventors are major partners for their US colleagues at the beginning of 90s, they have been overtaken by Asian inventors during the last few years. In 2007, Asian inventors' contribution to the US level of co-invention reaches 42%. When interpreting this number, one has to keep in mind that it represents only the portion of small US co-inventive activities. Thus, if the level of total co-invention between US and non-US inventors in 2007 is 2%, the corresponding level between US and Asian inventors is 0.84% (i.e., less than 1% of the total number of US ICT inventions is co-invented with Asian inventors). Nevertheless, it is necessary to add here that the position of EU inventors remains more or less the same during the analyzed period and Asian inventors gain mostly at the expense of Japanese ones.

Co-ownership of ICT inventions

Figure 6-6b presents the international distribution of co-ownership with US applicants. Here, the share of US inventions (from the total US inventions) co-owned by US and non-US applicants, presented in the previous section as a red line in Figure 6-4b, is further examined by analysing the contribution of each remaining region to this share. Figure 6-6b shows that the majority of co-owned US inventions are co-owned with Japanese inventors. During the 90s, the Japanese contribution to the US level of co-ownership is stable around 60-70% (these, as well as the following numbers, represent only contributions to the overall US co-ownership level, i.e., the share of US inventions co-owned by US applicants with applicants from remaining four regions, which is 0.3% on average). EU and Asian applicants then followed with 20% and 10% respectively. The situation, however, has changed since 2000 when the contribution of Japan drops down to almost 25%, while the EU reaches more than 50% (2003). Although this change is temporary and lasts only a few years, the regional co-ownership has never returned to its 90s level and is much more diversified now. In 2007, three regions have over 20% contributions each – Japan (48%), Asia (28%), EU (23%). Here, the only region with a decreasing trend is the RoW.

Foreign ownership of US ICT inventions

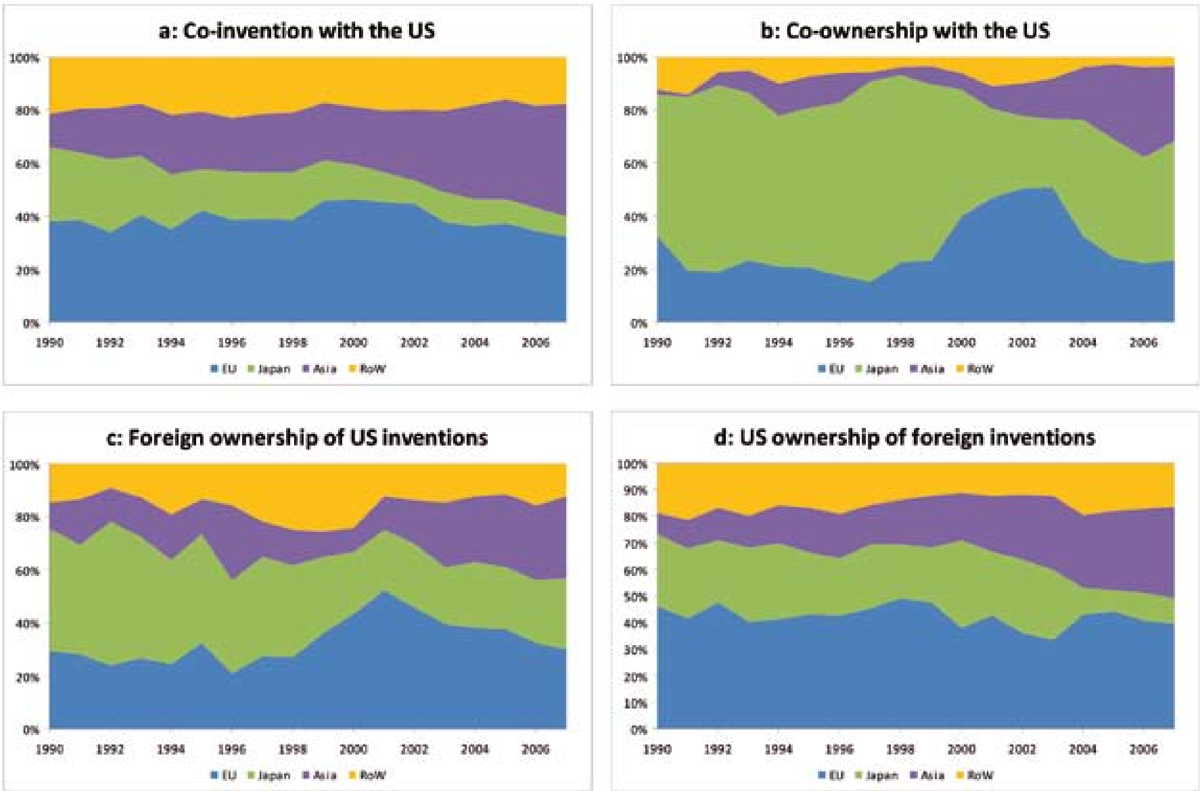
Regarding the levels of cross-border ownership of US ICT inventions, Figure 6-6c presents the international distribution of applicants owning US ICT inventions. In other words, the level of foreign ownership of US ICT inventions, presented in the previous section as a red line in Figure 6-4c, is further examined by analysing the contribution of each remaining region to this level. This figure shows an almost exact analogy with the previous paragraph – Japan plays a significant role in the 90s, which decreases from 2000, and the EU and Asia play an increasing role. The difference now is that the evolution over time is slightly more volatile. Moreover, contrary to co-ownership, by the end of the analyzed period, EU and Asian applicants already play the most important role, both with about 30% shares in US ICT inventions owned by foreign applicants. Thus, if in 2007 4% of US inventions are owned by foreign applicants, EU applicants own 30% of that and Japan follows with a 27% of the US applications owned by foreign applicants.

US ownership of foreign ICT inventions

Finally, Figure 6-6d presents the opposite relationship between inventors and applicants. It depicts the international distribution of the share of US ownership of foreign ICT inventions in the total number of foreign ICT inventions. This share is presented in the previous section as a red line in Figure 6-4d. There is an analogy here as well where the overall pattern is very similar to the one shown in Figure 6-6a. It is characterized by the important and stable role played by the EU (out of all foreign ICT inventions owned by US applicants, about 40% come from the EU), the increasing role of Asia and the decreasing role of Japan. Again, the RoW is even more important than Japan.

Based on this analysis, we can conclude that there is no single region that, overall, plays the most significant role in US ICT inventive activity. Most of it is split among three regions (EU, Japan and

Figure 6-6: Regional distribution of US ICT collaboration (1990-2007)



Note: Priority patent applications filed at 58 national patent offices, including all EU and US patent offices, and the EPO. Invention counts are based on the inventor or the applicant criterion, the priority date and fractional counts.
Source: JRC-IPTS calculations based on PATSTAT data.

Asia), each of them following a different pattern. While the EU holds more or less the same position over time, Asia has been slowly overtaking Japan.

6.5 Perspectives on ICT R&D in two emerging Asian economies

6.5.1 China[95,96]

China is becoming the manufacturing engine of the world and is now a major player in the global economy. China's GDP average annual growth rate has reached 9% for the period 1978-2008, much higher than in developed economies during the same period.[97]

The Chinese ICT industry

The ICT industry contributed 8.4% of GDP in 2006 and employed over 6 million people, with manufacturing making up the major share.

The Chinese ICT sector builds on the presence of foreign multinationals but also on the emergence of large national champions, which have already developed a global reach. The industry is highly concentrated as large companies have emerged which dominate the market. It is also concentrated geographically in only a few

95 Sections 6.5.1 and 6.5.2 are excerpts from a set of reports on the ICT industry and its R&D in emerging economies. Ling Wang, Shiguo Liu (2011 forthcoming); Malik P., Vigneswara Ilavarasan P. (2011); Shin-Horng Chen, (2011); Simon J-P (2011 forthcoming). All four sources are based on work commissioned by JRC-IPTS. The data provided here is based on specific research complemented by desk research, expert workshops and interviews.

96 Based on data from: Ling Wang, Shiguo Liu, 2010; Stephan Pascall, 2010.

97 World Bank, WDI Databases, 2009.

Table 6-1: The Chinese ICT Industry economic profile (2006)

GDP	€ 2.11 trillion
ICT VA	€ 172 billion
ICT VA/GDP	8.4%
ICT Manufacturing VA	€ 94 billion
ICT employment	6.26 million people

Source: Adapted from data in: Ling Wang, Shiguo Liu, 2011 (forthcoming).

Table 6-2: Chinese ICT R&D expenditures profile (2006[98])

Total GERD	€ 30 billion
Total GERD/GDP	1.4%
ICT Manufacturing BERD	€ 5.67 billion
ICT Manufacturing BERD / Total GERD	18.9%
ICT R&D employment	593 420 people

Source: Adapted from data in: Ling Wang, Shiguo Liu, 2011 (forthcoming).

regions of China. During the last two decades, large multinationals, in particular Taiwanese, have played an important role in the development of the ICT sector in China. Some large domestic companies have also emerged, supported by a strategy of building national champions, and have become global players, including Huawei Technologies, Lenovo, and ZTE.

ICT R&D in China

ICT R&D in China appears to be in its infancy. In spite of its important growth, the level of R&D and ICT R&D expenditures remains modest. Still, R&D expenditure (GERD) for China has been growing even faster than GDP, resulting in a rapidly increasing R&D intensity growing from 0.9% in 2000, to 1.23% in 2004, 1.3% in 2005 and 1.42% in 2006, amounting to some € 30 billion (2006).[99] An estimated 20% of Total GERD was dedicated to ICT R&D.

ICT R&D expenditures and ICT R&D employment followed a similar growth trend, reaching close to € 6 billion R&D expenditures in Manufacturing, with Services representing only a very low share, and some 150 000 R&D employees in 2006, also mainly in manufacturing.

ICT R&D expenditure in China is more focused on the development and applications side (observers estimate less than 20% of ICT R&D expenditure is dedicated to basic research). Nevertheless, China also achieved some significant breakthroughs in core technologies such as system-on-chip technology, multi-application processor, digital TV, etc.

FDI-led ICT R&D

Since 2003, China has become the world's largest recipient of FDI (ICT and non-ICT), overtaking the US. Supported by these foreign investments, by 2004, China had become the third most important offshore R&D location after the United States and the United Kingdom, followed by India (sixth) and Singapore (ninth).[100] For some observers, China is expected to become an even more attractive location for future R&D investments than the United States. FDI in China

98 Latest official statistics available.

99 In comparison, EU27 GERD was above € 200 billion and US GERD above € 300 billion. EU27 ICT expenditures alone were similar to the total Chinese GERD.

100 UNCTAD, 2005.

Table 6-3: The Indian ICT Industry economic profile (2004)

GDP	€ 555.4 billion.
ICT VA	€ 19 billion
ICT VA/GDP	3.42%
ICT Manufacturing VA	€ 1 billion
ICT Services VA	€ 18 billion
ICT Employment in CSS sub sector	830 000 people
ICT employment in CSS sub sector (2007)	1 630 000 people

Source: Adapted from data in: Malik P., Vigneswara Ilavarasan P., (2011). Employment data from NASSCOM, quoted by Mita Bhattacharya, Graham Vickery, (2010).

is mainly located in the Eastern coastal areas, such as Guangdong, Zhejiang and the Fujian Provinces.

Chinese ICT R&D off-shoring

China is also becoming an important source of outward foreign direct investment (OFDI). China's OFDI flow and stock now stands as the 4th and 6th largest, respectively, among *developing* countries, but its OFDI stock accounts for only 0.6% of *global* OFDI (OECD, 2006). Compared to the large FDI inflow in China, China's OFDI is on a smaller scale and is still in the early stages.

Conclusion

Chinese indigenous ICT innovation capability has been increasing in recent years. But when compared with developed countries, the R&D capability of the Chinese ICT industry is still weak, and is largely dependent on foreign multinational companies. Truly global ICT R&D initiated and managed by Chinese companies is still a long way off, considering that the absolute level of R&D expenditure is still modest.

6.5.2 India[101]

Since the introduction of market-based economic reforms in 1991, India has become one of the fastest growing major economies in the world. GDP growth rate has been impressive for last two decades with 9.1% in 2007-08 and it is forecasted to grow by 8% in 2010.[102]

The Indian ICT industry

The contribution of the ICT sector to GDP was 3.42% in 2004:[103]

The overall profile of the sector shows the overwhelming strength of Computer Services and Software (CSS) activity, as can also be indirectly deduced from the profile of Indian ICT exports, which are largely dominated by these CSS activities (91.6% in 2005-06).[104]

The industry is dominated by the larger players with the top two hundred firms contributing 86% of the total revenues. ICT firms are located in six prominent clusters, Bangalore (Karanataka), Mumbai & Pune (Maharastra), Chennai (Tamil Nadu), Hyderabad (Andra Pradesh), and the National Capital Region which is composed of New Delhi (Delhi), Noida (Uttar Pradesh) and Gurgaon (Haryana). Over 90% of export revenues come from these regions.[105] The top 10 Indian IT services firms generated revenues of almost

101 Based on Malik P., Vigneswara Ilavarasan P. (2011) and Mita Bhattacharya, Graham Vickery, (2010).

102 Mita Bhattacharya, Graham Vickery, (2010).

103 According to the latest available official data at national level.

104 Source: Statistical Year Book 2005-06, Electronics and Computer Software Export Promotion Council, Government of India. Quoted in: Mita Bhattacharya, Graham Vickery, (2010).

105 However, there is no direct data available on the region wise revenue distribution of the industry. According to Nasscom, seven Indian cities account for 95% of export revenues, there is now a focus on developing 43 new locations to emerge as IT-BPO hubs.

Table 6-4: Indian ICT R&D expenditures profile (2004[106])

Total GERD	€ 3.8 billion[107]
Total GERD/GDP	0.69%[108]
Total BERD	€ 0.76 billion
ICT BERD	€ 0.27 billion
ICT BERD / Total BERD	35.9%
ICT R&D employment	15 000 people

Source: Adapted from data in: Malik P., Vigneswara Ilavarasan P., (2011).

USD 23 billion in 2009. This is almost 36% of the overall revenue of the Indian IT services industry. Tata Consulting Services (TCS), Wipro and Infosys Technologies are the biggest firms, accounting respectively for 27%, 24% and 21% of the top 10 revenues in 2009.

The Service sub-sector, composed of Computer Services and Software, and of Telecommunications Services has kept on growing when compared to the manufacturing sector.

ICT R&D in India

The overall level of R&D investment is low. Total GERD in India reached some € 3.8 billion in 2004, representing around 0.7% of GDP, from 0.58% in 1990-91 and growing to 0.89% in 2005-06.[109]

The level of ICT R&D in India is very modest. Consequently, one of the major short comings of the Indian ICT sector, repeatedly discussed by existing studies, is the scarcity of R&D expenditures and activities performed by firms in the Indian ICT industry.[110]

Since the Indian ICT sector concentrates on services, innovation is predominantly on processes. Service process innovation is also crucial in explaining the success of the Indian telecom sector. Tailoring tariff packages in line with the affordability profiles of Indians and also outsourcing network expansion were the first of their kind but have yet to become a global trend.

FDI-led ICT R&D

During this period 1996-2000, R&D investment worth USD 1.13 billion has flowed into India. Out of these investments, the US invested most (some 860 million USD) in R&D centres, followed by countries like the UK, Japan and Germany with much smaller amounts.[111] There are multiple reasons for the US dominance. The US is the major consumer of software services that originate from India. Firms that explored the Indian market for off shoring are from US.

R&D and innovation in ICT hardware is skewed towards embedded software, especially in the telecom domain. Poor manufacturing capabilities, lack of adequate supportive infrastructure and competitive producers like China, Taiwan and Korea will make the Indian ICT industry focus largely on Services in the future.

106 Latest official statistics available.
107 In Banerjee, 2009: GERD = € 3.2 billion for 2002-03.
108 Stated to be 0.8% (with no reference year) in Bhattacharya M., Vickery G., (2010).
109 To compare with the € 30 billion (2006) observed in China. In the EU27, GERD was above € 200 billion and US GERD above € 300 billion at the time.
110 There is no reliable recent data on ICT R&D expenditures, neither on research personnel in the Indian ICT industry. Estimates are pointing at very low numbers. Mita Bhattacharya, Graham Vickery, (2010):state the following: "Attempts in deducing the data using proxy and projection measures shows that there is growth in full time personnel who are involved in the research and development from 3651 in 2000 to 15045 in 2004". Such low estimates might be due to two possible reasons: the large public sector (estimated recently to account for 1208 R&D centres) could host a majority of not-accounted for researchers, as well as the importance of services where again, research is little or not accounted for.
111 Data from TIFAC report, presented in Banerjee 2009, p.144. Full analysis by the Technology Information Forecasting and Assessment Council (2006). See at: TIFAC.org.in.

Indian ICT R&D off-shoring

Contribution of the Indian ICT sector in outward FDI, measured through values of mergers and acquisitions (M&A), is significant. The total number of deals involving Indian ICT firms is increasing and amounts to significant total investments (USD 3.4 billion in 2008 from USD 2.9 billion in 2007).[112] Acquisitions are typically made in the software development and semiconductor design areas, followed by associated business processing domains, underlining again the specialisation of the Indian ICT sector in CSS, and its drive towards the niche market of IP Core design.[113]

Conclusion

It is difficult to conclude that R&D capabilities are created. Indian firms continue to cater to the western clients in terms of software product development or engineering services and innovate for in-house consumption, rather than developing products for open markets.

6.6 Conclusions

Building on the methodology presented in Section 6.2, the current chapter analyses 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 uses a framework that disentangles the innovation value chain and divides it into two stages. The first stage covers the input side of the inventive process, observed in this chapter through the location of R&D centres and the allocation of semiconductor design expenditures. The second stage covers the output of international inventive activity according to internationalisation measures based on patent applications.

112 Nasscom, 2009.
113 Tuomi, 2009.

The above analysis provides a number of insights with respect to the internationalisation of ICT R&D input and output. These insights need to be taken with some caution because of the explicit limitations of the available data. Finally, country-level observations on selected countries complement the perspective with concrete examples and data.

The analysis presented in this chapter confirms, above all, that the internationalisation of R&D is a complex phenomenon and requires detailed observation. Hence, this justifies the decomposition of the R&D process into various stages and their individual analysis.

Some of the most important findings are summarized below.

Internationalisation of ICT R&D input

- Independently of the world region in which a firm has its headquarters, the majority of firms tend to locate most of their R&D centres in their home region. However, there are some differences between firms from the five regions. For example, companies from Asia (excluding Japan) have the least internationalised R&D centre distribution, whereas EU, US and Japanese firms have the most internationalised R&D centre infrastructure.

- Similarly, ICT companies, irrespectively of their region of origin, tend to invest the largest share of their semiconductor design expenditures within their home region. However, some regions receive a higher share of foreign expenditures than others. For example, whereas Japanese companies are responsible for 95% of the semiconductor design expenditures made in Japan, 35% of the spending on semiconductor design in Asia (excluding Japan) comes from foreign companies. Regarding the EU, over 80% of semiconductor design expenditures invested in the EU were made by domestic companies.

Also, EU companies spent 70% of their semiconductor design budget within the EU. As regards the trend of these expenditures, the EU and Japan are the only regions whose share of total expenditures on the design of semiconductors is declining.

- Although it has been confirmed that there are very strong linkages between the triadic countries, i.e., Japan, the US and the EU, Asia seems to be a very attractive location for R&D centres for ICT companies from the EU, the US, Japan and Asia itself. For example, although the EU seems to be the most attractive for American firms for the location of R&D centres abroad, Asia hosted only 5% less US-owned R&D centres than the EU (16% versus 21%) in 2009. EU companies also seem to find Asia very attractive. Asia hosts the same share of R&D centres owned by EU companies as the US does (18%). This is a sign of the high attractiveness of Asian countries as a location not only for production or service facilities but also for R&D-related activities.

- The Asia region also receives the highest share of expenditures by both foreign and domestic firms, in semiconductor design and, furthermore, Asia seems to be one of the main destinations for semiconductor design expenditures for all firms –after the home country or region - regardless of their region of origin.

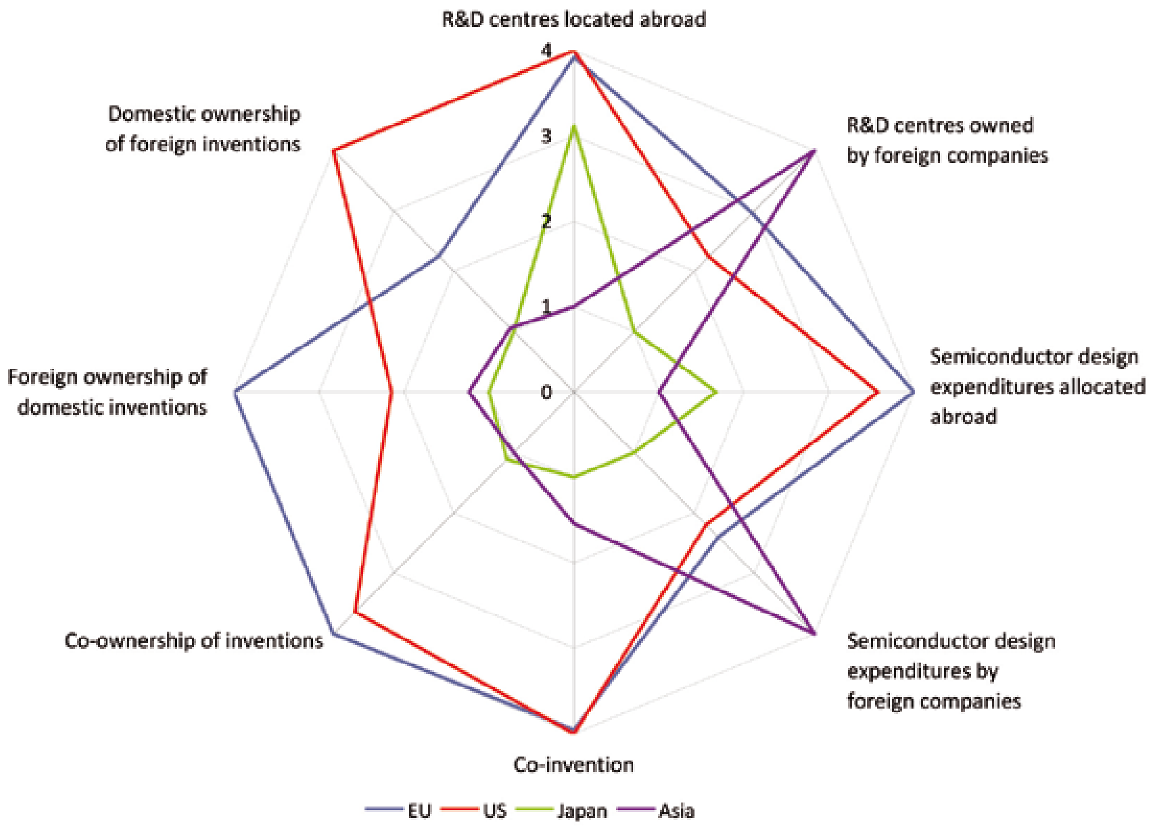
Internationalisation of ICT R&D output

- Although the output of international ICT inventive activity has steadily increased since the early 90s, ICT research is still highly local and the level of international collaboration, proxied by the number of patent applications, remains very low. For example, in 2007, 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 levels of cross-border ownership of inventions are however higher. Consequently, although Europe may 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.

- Regarding the comparison between 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 benefit more 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.

- Regarding Asia, the level of inventive collaboration with Asian economies in developing ICT inventions was still very low in 2007, though it has been increasing over time. Here it can also be concluded that the US clearly dominates in collaborating with Asian partners, whereas the level of collaboration between EU and Asian seems

Figure 6-7: Eight dimensions of ICT R&D internationalization across regions



Note: The regions' relative positions in internationalization measures are displayed. The values are normalized on a scale from 0 to 4, where 0 represents the lowest value and 4 the highest value of each indicator. Last available year for each metric is used.

to be relatively low. These observations may indicate a strong presence and advantage of the US in tapping the inventive resources of the Asian region.

Regional comparison

Detailed analysis of the internationalisation of ICT R&D shows that the EU and the US exhibit the highest levels of ICT R&D internationalisation, when compared to Japan and the rest of Asia (see Figure 6-7).

There are however important differences, even between the EU and US, when different R&D internationalisation measures are taken into account. For example, whereas the EU and the US exhibit similar levels of location of ICT R&D centres abroad and of cross-border allocation of product design expenditures, these regions show very different patterns with respect to, e.g., cross-border ownership of inventions (as was also pointed out in Figure 6-4).

There are even more considerable differences when considering Japan and the rest of Asia. Whereas Japan exhibits higher *outward* ICT R&D internationalisation (e.g., in terms of locations of Japanese R&D centres abroad) and lower *inward* internationalisation (e.g., in terms of location in Japan of ICT R&D activity of foreign firms), the reverse can be observed for the rest of Asia.

These observations would tend to indicate that internationalisation of R&D activities depends on both the ICT R&D internationalisation 'path' (and policies) followed by each region and the actual strategies and capabilities of companies from different regions to develop ICT R&D activities at global level.

In conclusion, despite the limitations of the data and methodology used in the current chapter, the preceding analysis contributes to a better 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 the 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, the preceding analysis 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 issue of R&D internationalisation is far from fully understood and there are still a number of open questions. For example, it is 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 is worth spending more effort on better understanding this phenomenon and its consequences.

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7 Conclusions

This report provides a unique analysis of the EU ICT sector, the R&D investments by top R&D-investing ICT companies globally, the performance of ICT R&D in the EU, and the increasing internationalisation of ICT R&D. The report also benchmarks the EU's performance with that of its main competitors. Three complementary perspectives are combined in the report: national statistics on the size and structure of the ICT sector, data on top R&D-investing ICT companies, and technology-based indicators such as patent data.

This last chapter presents the most important conclusions of the report and makes several broader observations.

The EU ICT sector

In 2008, the EU ICT business sector contributed to 4.7% of EU's GDP, and with 8.3 million jobs represented 'only' 3.6% of total employment in the EU, explained by significantly higher labour productivity than in the rest of the EU economy. Compared to other major economies of the world, the EU's ICT sector has a lower weight in the economy, and –as is also the case in the US- is much more specialised in ICT services, than, for example, the ICT sectors of Japan, Korea, Taiwan or China.

The share of ICT services in the EU ICT sector continued to increase in 2008, reaching 80% of value added (VA) and 71% of employment, an increase driven by the Computer Services and Software ICT sub-sector that alone represents 46% of ICT employment. Stagnating, or even declining, value added and employment in other ICT sub-sectors, such as in the ICT manufacturing sub-sectors and Telecom services, do not necessarily reflect a declining volume of activities. This could be the result instead of increased labour productivity, declining hardware prices due to technological innovation in ICT manufactured products, and also increased price competition following the liberalisation of telecoms.

Within the EU in 2008, the four largest economies (Germany, France, the UK and Italy) produced together 2/3 of the EU ICT sector VA. However, Finland, Ireland, Hungary and Sweden, four countries where the ICT sector has an important weight in the economy, produced together less than 7% of the EU ICT sector VA, i.e., roughly the same contribution as Spain alone. Compared to the EU average, Finland, Ireland and Hungary are more heavily dependent on ICT manufacturing, while France, the UK and Spain are more heavily dependent on ICT services. Germany, Sweden and Italy are closer to the EU average.

The share of EU ICT VA produced by the 12 most recent EU entrants is steadily increasing, and reached 11% in 2008. Although ICT manufacturing activities have been relocated from Western to Eastern European countries in the last decade, the 'EU12' countries as a whole do not have stronger ICT manufacturing specialisation than the rest of the EU.

Impact of the economic crisis on the EU ICT sector

The 2008-2009 financial crisis slowed down the world economy profoundly and the ICT sector and ICT R&D activities were no exception. By the end of 2010, the negative effect of the crisis on the ICT sector appeared, however, to have largely waned. But recovery dynamics have differed across the ICT sub-sectors. While some ICT industries experienced only a minor reduction in growth rates (e.g., Internet, Software), others such as Computer Services or Telecom Equipment were struggling in 2010 to recover pre-crisis levels of growth.

As the post-crisis picture of the ICT sector is only beginning to emerge (particularly given the delayed availability of official statistics), it may take more time before the complete impact of the crisis on the ICT sector is fully understood.

Top R&D-investing ICT companies

As observed in previous editions of the report, EU ICT sector companies made very substantial R&D investments in 2008 also and showed similar R&D intensities[114] per ICT sub-sector to those of their US competitors. At an aggregate level, however, EU ICT companies invested less half the amount invested by companies from the US in R&D. This lower level of cumulative investment can most probably be explained by the lower number of large EU ICT sector companies compared to the number of large US ICT sector companies. Indeed, out of the 428 top global R&D-investing ICT companies that make up the 2008 *ICT Scoreboard*, more than half are from the US, while only 15% of them are EU companies.

In 2008, EU companies' R&D investments were concentrated in Telecom Equipment and Telecom Services, whereas R&D investments by US companies were strong in IT Components, Computer Services and Software, and also Telecom Equipment. R&D investments by Japanese companies were important in IT equipment, IT Components, and particularly in Multimedia Equipment where they led over companies from other regions. Companies from the rest of Asia essentially had a strong presence in IT Components, but with lower aggregate investments than companies from the US or from Japan.

Concerning the growth of R&D expenditures from 2005 to 2008, EU and US firms showed similar growth rates (10% and 11% respectively), while the R&D growth rate of Japanese companies was the lowest (3%). Companies from the rest of Asia and from the rest of the world reported the highest relative increase in R&D investments (14% and 17% respectively) but started from comparatively lower values.

ICT patenting

Data on priority patent applications submitted to patent offices worldwide is used in the report as a proxy measure of inventive output. This year's analysis -with data up to 2007- shows that while the annual number of ICT applications by EU and US inventors has remained stable since its peak value of 2001 (i.e., just after the burst of the dot.com bubble), this number has strongly increased for China, overtaking the EU in 2004 and the US in 2006, and approaching Korea in 2007. ICT applications by inventors from Korea kept on increasing until 2004 and have slightly decreased since. The number of ICT applications by inventors from Japan has also slightly decreased in recent years, but in absolute values remains by far the highest: three times the number of ICT applications by US inventors in 2007, itself twice the number of ICT application by EU inventors.

Within the EU, the number of ICT applications by the best performers (Germany, France, the UK, Finland, Sweden and the Netherlands) has remained stable or slightly decreased in the 2000s. In 2007, applications by inventors from Germany, France and the UK accounted together for 80% of all applications by EU inventors, with Germany-based inventors alone generating half the total ICT applications for the EU. Among other western EU Member States, the numbers of ICT applications by inventors from Portugal,

114 Company R&D intensity is measured by the ratio of R&D investment over sales.

Greece and Spain are rising, although they are still comparatively low, especially when weighted by capita or GDP. Among eastern EU Member States, performance is varied: the numbers of ICT applications have risen for Estonia, Bulgaria, the Czech Republic and Slovenia, and decreased for Hungary, Romania, Latvia, and especially Poland.

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.

Internationalisation of ICT R&D

Building on a first analysis of this topic in last year's edition of the report, the present edition further analyses and explores ICT R&D internationalisation between the EU and other regions of the world and the position of EU companies in this process.

This analysis indicates that ICT R&D is still highly local (when analysed at the level of world regions). ICT companies tend to locate the majority of their R&D facilities in their home region. However, some rather clear internationalisation patterns are emerging. For both EU and US companies, the destination of choice for locating R&D activities outside their regional borders is the other side of the Atlantic. The EU and the US are important locations for ICT R&D activities. They attract not only US and EU firms, but also Japanese and Asian ones. The next location of choice for international ICT R&D activity is Asia, with the exception of Japan where only a very small share of ICT R&D is controlled by non-Japanese firms.

The level of international ICT inventive activities, as measured by the number of international patent applications in ICT (i.e., patent applications with inventors or applicants from different world regions), has steadily increased since the early 1990s, but is still low. For example, the share of EU ICT inventions co-developed in collaboration between EU and non-EU inventors was only 2% in 2007. This share was the same for US ICT inventions.

A large share of the foreign ICT inventions owned by US firms were invented in the EU, although since the early 2000s the share of those invented in Asia has increased, while the share of those invented in Japan has decreased. Concerning non-EU inventions owned by EU firms, almost half of them were developed by US inventors and only a small proportion by Asian or Japanese inventors.

It is remarkable that US firms, as an aggregate, own significantly more ICT foreign inventions than EU firms do. US firms appear therefore to be better able to take advantage of the process of internationalisation of ICT inventive activity than EU firms. This observation has however to be interpreted cautiously, since as noted elsewhere in the report, the number of US top R&D-investing ICT companies is significantly larger than the number of the EU top R&D-investing ICT companies, and the issue at stake is therefore most probably not the ability of *individual* EU or US firms to take advantage of the process of internationalisation of ICT inventive activity, but that of the entire *group* of EU and US firms to do so.

Although the innovative capacity of emerging Asian economies is growing and countries such as China or India are increasingly present in the global ICT landscape, ICT R&D in India and China is still modest and still largely dependent on foreign multinational companies.

Broader observations

Our analysis shows that EU ICT R&D investment was (less than) half that of the US during the whole observed period. Moreover, due to the prominence of ICT R&D investment in overall R&D investment both in the EU and in US, this ICT investment 'gap' accounts for a substantial part of the difference between EU and US R&D total investment. Therefore, understanding the current and future dynamics of EU ICT R&D investment is crucial for reaching the R&D and economic goals presented in the EU 2020 Strategy.

Issues of economic structure and industrial composition in a global economy

For several years, our analysis, in line with that developed by other Commission[115] and academic bodies,[116] has shown that:

- The comparison of the economic structure of the EU and the US (size of the ICT sector in the total economy), of the composition of their ICT industries (share of each ICT sub-sector), and of the overall size and number of their ICT companies (and particularly the scarcity of large, globally-operating EU companies - with the notable exception of Telecom Services sector companies) largely explains why there is an ICT R&D investment gap between the US and the EU.

- Individual EU ICT companies' R&D investments are roughly equivalent to those made by comparable US firms in comparable sub-sectors. These investments are driven by an industrial logic where, in order to remain competitive, the companies have to invest in R&D, taking into account the behaviour and competitive assets of their competitors, worldwide.[117]

- The globalisation process has transformed the industry and its markets across all regions. The last decade has been marked by the emergence of strong ICT activities in Asian countries, affecting both of the above points: industrial structure and company strategies.[118]

Hence, to deepen our understanding of ICT R&D statistics, it is necessary to elaborate on the above structural differences. Four possible contributory factors are described in the paragraphs below.

– ***The re-composition of the ICT industry in advanced economies***

The reallocation of ICT manufacturing from mainly the EU and the US to Asia has been taking place for several years, and it is likely that manufacturing activities remaining in the EU and the US will need to position themselves in niche markets and in high value-added, cutting-edge technological activities. But it is also the case that cheaper ICT products manufactured in Asia fed the worldwide demand for ICT goods,[119] including the growing demand in the EU and the US, and created the conditions for the consequent accelerated development of ICT services and ICT-enabled products[120] in our advanced economies.

On the world markets, the competitive battle in ICT between the most advanced economies - the EU, the US and Japan - is therefore taking place in the fields of

115 Such as for example the Industrial scoreboard issued by the Knowledge for Growth Unit of the JRC-IPTS. See at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3819

116 Such as, for example: http://aei.pitt.edu/14847/

117 See Chapter 4.

118 See Chapter 6 and JRC-IPTS reports on Asia at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/AsiaICT.html

119 China has become the 1st largest country producing ICT products.

120 We refer here to embedded ICT in Transport, Energy, Health etc. - related solutions.

advanced technology in ICT hardware, in Computer Services and Software and in specific ICT-enabled products. Availability and quality of Telecom services is also seen as a prerequisite, a basic enabling infrastructure (strongly correlated with GDP) which allows the ICT business to expand and ICT to be integrated into the products of other industrial sectors. This justifies the policy emphasis on the deployment of infrastructure such as ultra high speed broadband, and the adoption of national broadband plans by advanced economies worldwide.

In this competitive battle, EU ICT Manufacturing still has a good performance, active mainly in the Components, Telecom Equipment and Instrumentation industries, but often heralding only few large companies.[121]

Production from Computer Services and Software in the EU, the US and Japan is still much bigger than it is in Asia. Competitive pressure is pushing companies from the advanced economies towards strategies that ensure they keep the edge on international markets. Over the last few years, these strategies have included the promotion of innovative services and the reintegration of customised hardware and software into services hubs (e.g., smart phones and apps stores; cloud computing).

The ICT industry in Europe continues to depend on both Manufacturing – still an important engine of productivity growth - and Services, a strong locus of innovation and revenues. But it has also shown weaknesses on both sides: in the competition with Asia in Manufacturing and with the US in Services.

121 Such as ST Microelectronics in Components, Nokia or Alcatel-Lucent in Telecom Equipment, etc.

– ***Innovative waves and changing ICT industrial ecosystem***

The US have confronted the recent crisis with a Computer Services and Software sector 1.4 times bigger than the EU's, and a faster R&D investment growth trend for several years, as noted in this and earlier PREDICT reports. In US Internet-related businesses alone, R&D investments have grown from virtually nothing to about € 2.5 billion/year in just a few years.

This sub-sector has definitely demonstrated its contribution to the high rates of revenue growth of the US ICT industry during the crisis years. It has allowed the US industry to surf on the latest innovation wave – that of smart phones and apps stores - while showing the way forward to a renewed industrial ecosystem where roles and revenues are redistributed between hardware and software, telecoms equipment and services, software development and internet companies, and between the EU and the US. The iPhone platform wrested smart phone leadership from Nokia's Symbian platform. This also moved the centre of the smart phone eco-system from the EU to the US. Then, the Google Android platform opened the door for other smart phone hardware suppliers (Nokia's competitors) to compete with the iPhone eco-system. Similarly, one can expect that the current cloud computing innovation wave will further boost US hardware and software companies and their financial results.

It is essential to understand why European companies have missed these successive innovation waves,[122] even more

122 The JRC-IPTS is currently running two research projects which aim to answer these questions. The first project integrates the findings of the seven ICT innovation reports of the COMPLETE project (http://is.jrc.ec.europa.eu/pages/ISG/COMPLETE.html), and the second sets out to compare US and EU industrial policies, paying particular attention to their impact on the growth of small companies into large global ones.

so as those innovation waves build upon widely recognised European strengths such as mobile devices and wireless telephony.

– ***Revised role vis-à-vis the emerging economies***

As we have seen in earlier editions of this report, and again this year, while Europe and the US remain essential locations for ICT R&D, globalisation is leading to the reorientation of ICT R&D to emerging economies. These economies are perceived not only as huge potential markets but also, progressively, as sources of original domestically-produced knowledge. US companies seem to have opted for a more rapid internationalisation of their R&D activities, benefiting from a first-mover advantage in Asian markets.[123] It remains to be seen whether US companies will repeat this fast move in the remaining BRICS countries: Brazil, Russia, South Africa, etc. First observations indicate, however, that companies from the Asian countries themselves, particularly China, are taking a large share of these markets.[124]

Besides the access-to-market motivation, it is also essential to understand that the innovative capacity of Asia, and China in particular, is developing, and that its large companies and market are rapidly evolving. Though the statistics (value added, revenues, BERD, etc.) still look modest, the overall industrial and innovative capacity is growing very rapidly, supported by strong ambitions and policies (demand as well as supply oriented). Major examples of domestically developed innovations and standards are already emerging in the telecom sector, Indian telecom operators have introduced a major business innovation: the budget telecom model or 'bottom of the pyramid' (BOP) model. Mobile rates are the lowest in the world. Apple's iPhone illustrates the shift by Taiwanese ICT Firms from end-product manufacture to component manufacture to form an ICT hub in the global value chain. Additionally, these very large emerging markets have leapfrogged fixed lines and rely on infrastructure which supports massively mobile wireless internet.

From an operational point of view, though dozens of European companies have chosen to ensure their early presence in these markets, it seems that Europe lacks a broad coordinated strategy in its relations with these regions and countries. As a result, EU companies compete on a weaker basis than their US counterparts, which are better supported by US institutions (such as the US Chamber of Commerce) or simply by a clearer agenda.[125]

One should also stress that this new role of emerging economies is accompanied by changes in trade patterns. For instance, the ICT industry illustrates the growing role of China in global production networks. Emerging trade relationships between Asia and Brazil have displaced previous relationships with other regions like the EU and the US. Not only does intraregional trade in Asia affect the global trade streams but it allows Asia to play a growing role in an increasingly sophisticated global value chain, as a supplier of intermediate inputs. For instance, China coordinates assembly networks taking inputs from other countries like India, and ships products, while Taiwan acts as a facilitator for China.

123 See Chapter 6.

124 See Simon J. P. (2011 forthcoming), BRIC Report 1 (Brazil, India and China), JRC Scientific and Technical Report, Institute for Prospective Technological Studies, Joint Research Centre, European Commission.

125 For more see at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/AsiaICT.html

- ***The competitive asset of ICT R&D in non-ICT sectors of the EU economy***

Following up on the above industrial analysis, one has to consider the importance of 'embedded' ICT for the other sectors of the economy. A substantial share of ICT R&D is carried out in other sectors of the economy (for example, in Automotive, Media, Pharmacy, Aeronautics, etc.) but this is not presented here, nor is it measured by currently available statistics.[126]

Deeper sector-level analysis, showing the fundamental role of ICT R&D in the future competitiveness of the European automotive sector,[127] has shown the pervasive impact of ICT-enabled hi-tech products on European industry performance and the EU economy. ICT, complementing the diversity of European industrial activities, play a growing and essential role as key enabling technologies. This complementarity enhances existing goods and services, giving those companies that embed ICT in their products and services the opportunity to develop (or maintain) the competitive edge on a global scale.

Policy issues

The combination of these various aspects creates a new dynamic that goes beyond the ICT sector. The pervasive impact of ICT, its inherent R&D magnitude and intensity, its innovation performance and global dynamics, confirm the central role ICT play in the world economy, the EU economy and the EU's economic recovery. Furthermore, this report indicates that the European comparative under-investment in ICT R&D is a complex industrial issue resulting from a multitude of contributory factors. These factors include the competitive battle for the ICT industry among advanced economies, the innovative tensions affecting the industry ecosystem, the emergence of new large ICT markets and ICT knowledge flows, and the progressive transformation of the ICT industry from an engine of direct growth into a competitive asset as a key enabling technology for other sectors of the EU economy. These factors will shape Europe's economic and industrial ICT structure.

All these aspects call for a policy mix that goes beyond ICT R&D and innovation policies, and favours industrial high-tech, high-growth, high added-value sectors fuelled by ICT-enabled innovations designed for global markets and supported by global research and production value chains. Targeted policies can help creating a strong lead in science and technology, without necessarily picking winners in the form of national champions, but by consistently earmarking support for particular sectors deemed to define the future.

126 The JRC IPTS has established an economic methodology allowing a first approach to this issue, and a first estimate for one national economy (Germany). Report available at: http://is.jrc.ec.europa.eu/pages/ISG/documents/FINAL-17March2011.pdf. Earlier, the OECD had 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.

127 Such as Advanced Driver Assist Systems and its software. See more in: Juliussen E., Robinson R. (2010). Is Europe in the Driver's Seat? The Competitiveness of the European Automotive Embedded Systems Industry. JRC Scientific and Technical Report EUR 24601 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3780

Annex 1: Definition of the ICT sector

The ICT sector is defined according to the Frascati Manual (OECD 2002[128]), based on NACE classification[129] Rev 1.1 in two versions: the comprehensive definition and the operational one.

1. The NACE rev1.1 industries included in the ICT Sector (OECD, 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

In this report, we use the operational NACE Rev. 1.1 definition.

128 OECD (2002), Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development. Sixth edition, Paris.

129 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.

Annex 2: 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 here are taken when possible, from the National Accounts Statistics Data, EUROSTAT, OECD STAN Database and EU KLEMS project.[130] National Accounts data, as published by EUROSTAT are also used for the data on prices and employment. Employment is expressed in thousand people employed, prices relative to 2000 and value added at basic prices.

Figure 1, Annex 2: Valuation of value added

Value added at **Factor costs**

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

= Value added at **Basic prices**

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

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

\+ taxes, less subsidies, on imports

\+ Trade and transport costs

\+ Non-deductible VAT

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

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

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

When not directly available, value added data for Romania, Bulgaria, India, China and Taiwan are extracted from dedicated research projects.

Value added, volumes and prices in National Accounting

This section aims to clarify the concepts of nominal vs. real value added.

130 The EU KLEMS project estimates value added according to the NACE Rev 1.1 classification for countries as Japan and Korea, ensuring comparability between those countries, that do not normally use industrial classifications compatible with the NACE, and the US and EU. 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.

***Value added**,* as measured by the National Accounting methodology[131] is, in a nutshell, the sum of factor revenues: wages, profits, certain taxes and the return to capital (including capital goods, land, and other property).

GDP aggregates the value added of all industries (i.e., economic sectors, including the ICT sector), to give a measure of net wealth creation in the economy.

The value added at industry (or economic sector) level, as well as the overall GDP, can be measured in current prices or in constant prices.

Nominal value added **or** ***value added in current prices*** is calculated by substracting the value of intermediate consumption (i.e., material purchases) from the value of total output (i.e., sales), based on the prices of materials and output when respectively bought or produced. Consequently, the value added can be as well broken down into real value added (a 'volume' measure that reflects the volume of output obtained from the given volume of intermediate inputs), and a 'price', both mathematical combinations of input and output volumes and prices.

$$va = q_t^{out} * p_t^{out} - q_t^{ic} * p_t^{ic} == q_t^{va} * p_t^{va},$$

where *q* stands for quantity, *t* for the current time period, *p* for prices, *out* for output, *ic* for intermediate consumption and *va* for value added .

Real value added **or** ***value added in constant price,*** is value added expressed in prices of a previous period (in order to adjust for inflation).

$$va = q_t^{va} * p_{t-n}^{va}$$

Consequently from the above:

- Value added growth between two periods is measured as the variation of *real value added*, or *of value added in constant prices* and reflects the dynamics of physical amount of production and the volume of inputs consumed in the production process between the previous period and the current one.

$$I^{va} = \left(\frac{q_t^{va}}{q_{t-n}^{va}}\right) * \left(\frac{p_{t-n}^{va}}{p_{t-n}^{va}}\right) = \left(\frac{q_t^{va}}{q_{t-n}^{va}}\right)$$

- The official rate of GDP growth from one period to another aggregates the growth rates of *real* value added over all the economic sectors.

131 http://epp.eurostat.ec.europa.eu/portal/page/portal/national_accounts/methodology

Annex 3: Methodology for company data

The company data set is primarily based on the 2009 EU industrial R&D *Scoreboard*[132] (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 2008.[133]

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. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes any R&D investment made by associated companies or joint ventures. 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.

	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 1 000 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	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

Note: 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 2008.
Source: Adapted mainly from Azagra Caro and Grablowitz (2008).

132 http://iri.jrc.ec.europa.eu/research/Scoreboard_2009.htm
133 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 .

Scoreboard figures are nominal and expressed in Euros, and all foreign currencies have been converted at the exchange rate of 31 December 2008. For example, a € 1 = $ 1.39 exchange rate has been used, not only for 2008, ***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 a 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 2008, the R&D investment threshold for the EU 1 000 group was about € 4.3 million and that for the non-EU 1000 group about € 31.5 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 350 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 in the *Investment Scoreboard*. Extracting the relevant ICT companies generated a sub-set of 428 ICT companies (out of 1 350).

Annex 4: List of countries per world region[134]

EU	US	Japan	Asia	RoW
Austria	USA	Japan	China	Australia
Belgium			Hong Kong	Bermuda
Denmark			India	Brazil
Finland			Singapore	Canada
France			South Korea	Cayman Islands
Germany			Taiwan	Croatia
Hungary			Thailand	Iceland
Ireland				Israel
Italy				Liechtenstein
Luxembourg				Mexico
Netherlands				New Zealand
Portugal				Norway
Slovenia				Russia
Spain				Saudi Arabia
Sweden				South Africa
UK				Switzerland
				Turkey

134 This list includes only those countries in which there are registered headquarters of ICT Scoreboard companies.

Annex 5: Methodology for patent data

A brief description of the PATSTAT database

The results presented in Chapter 5 and part of Chapter 6 are based on analysis performed on a subset of the PATSTAT database. The PATSTAT database is the European Patent Office (EPO) Worldwide Patent Statistical Database; it provides a snapshot of the data available in the EPO's 'master bibliographic database DocDB' at a specific point in time, and it is updated twice a year. Data extracted from the source database cover nearly 90 national Patent Offices, the World Intellectual Property Organisation (WIPO) and the EPO.

A brief description of main methodological aspects follows. For a more complete and detailed description of the methodology followed, please refer to Chapter 8 of the 2009 Report (Turlea et al., 2009), to Annex 8 of the 2010 Report (Turlea et al., 2010), and to Picci (2009).

Priority applications

A number of steps have to be taken in the process of patenting an invention. When the application is first filed at a patent office by an applicant seeking patent protection, it is assigned a priority date (in the case of a first filing in the world) and a filing date. The filed application could become a granted patent, being then assigned a grant date, if no reasons for refusing the application have been raised during the process of analysis of the subject, novelty, non-obviousness and industrial applicability of the invention.

The indicators proposed in this report aim to provide the best measure of the inventive capability of countries, rather than of the productivity of patent offices. To achieve this objective, patent applications are taken into account, rather than granted patents. The reasons behind this choice are manifold and documented in the scientific literature on patent statistics. In the present report, therefore, references made to 'patents' always mean 'patent applications'. Moreover, the considered subset of data includes only 'priority patent applications'; this means that only the first filing of an invention is considered and all the possible successive filings of the same invention to different patent offices are not counted again. An invention is therefore counted only once. 'Priority patent applications' are considered a more suitable proxy measure of inventing capability, even though a number of shortcomings have been pointed out by the literature (OECD, 2009; de Rassenfosse et al., 2009).

Data set considered: patent offices and years covered

The analysis proposed in the present report is based upon the April 2010 release of the PATSTAT database. The subset of data considered included all priority applications filed in any of the Patent Offices taken into account: the EPO, USPTO, JPO; national patent offices of the 27 EU Member States; the national patent offices of Arab Emirates, Australia, Brazil, Canada, Chile, China, Columbia, Croatia, Hong Kong (Hong Kong SAR), Iceland, India, Indonesia, Israel, Korea, Malaysia, Mexico, New Zealand, Norway, Pakistan, Philippines, Puerto Rico, Russia, Singapore, South Africa, Switzerland, Taiwan (Taiwan Province of China), Thailand, Turkey, and Vietnam. To avoid taking into account data affected by delays in the updating procedure of the database, the analysis considers only the period between 1990 and 2007, even though more recent data is available.

Methodological improvements compared to the analysis in the 2010 PREDICT Report (Turlea et al., 2010)

The present analysis encompasses several methodological improvements in comparison with the one proposed in the 2010 PREDICT Report (Turlea et al., 2010). Those improvements can be grouped in four main areas:

(i) **The consideration of 59 patent offices** -versus 29 in the 2010 report- constitutes a major improvement in the coverage, allowing for more valid comparison when using patent applications as a proxy for the inventive prowess of countries, that otherwise would be affected by a serious 'home country bias'.[135] The importance of the Japan Patent Office (JPO), the Patent Offices of China, India and Brazil among others is clear, not only when considering the related countries, but also in the comparative global analysis of performance and internationalisation.
(ii) **The coverage of analysed countries** in which inventors are based is also much larger. In addition to EU and the US, the present analysis also includes Japan, and the following groups of countries: Asia and Rest of the World (RoW).
(iii) **The methodology applied to attribute the patent applications to the above countries** by using the country of residence of the inventors or of the applicants who have legal title to the patent has been improved as well, following the most recent literature.[136] This represents an important step as the increase in the number of Patent Offices taken into account brought to light several additional criticalities[137] in the data, and the need to deal with a much larger amount of missing information.[138]
(iv) The adoption of **a different software tool for query, extraction and organisation of data** from the PATSTAT database allowed the coverage and flexibility of the analysis to be increased.

Finally, taking into account the April 2010 release of the PATSTAT database not only allows us to include **more recent data (up to year 2007), but also provides updated data for previous years.**

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 2010 report.

Assigning patents to countries (or regions): inventors vs. applicants

The literature commonly refers to the possibility of adopting two alternative criteria in order to assign patents to countries: it is possible to refer to either the declared country of residence of the inventor(s) ('inventor criterion') of a patent, or to that of the applicant(s) ('applicant criterion').[139] 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.

135 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).
136 The methodology is the one detailed in Picci (2009) and in de Rassenfosse et al. (2009).
137 Criticalities are coming from the different quality of data provided by some of the patent Offices taken into account, in spite of the effort by EPO to improve data completeness and congruence to a reasonable level.
138 The issue of 'missing' information is a relevant one, to the extent of this analysis, in particular when information about the country of residence of the inventors (and / or applicants) is missing. Literature progressively agreed on procedures to be applied in order to be able to collect such an information from other sources (e.g., from subsequent filings of the same applications when available, or from other parts of the applications records). In some cases, the information about the country of residence of inventors (and / or applicants) is proxied with that of the country where the applications have been filed. This is done in cases known to be affected by this lack of information for procedural reasons, for example, in the case of the JPO.
139 'EU-based' inventors are inventors (persons or companies, as declared in the patent applications) whose country of residence (or that of registration for companies) is one of the 27 EU Member States. Please note that, notwithstanding the effort by European Patent Office (EPO) for a constant and effective improvement of the quality and coverage of data provided, only 50% of country codes are present in the database (European Patent Office, 2010). The missing countries of residence are attributed by means of several procedures, continuously updated and discussed in literature (OECD, 2009; Picci, 2010; de Rassenfosse

Several applicants could hold rights on a patent application, and they would have legal title to the patent once (and if) it is granted. In the same way, several inventors could have taken part in the development process of the invention, and be listed in the patent application. A *fractional count* is applied in order to assign patents to countries in cases where several inventors (or applicants) with different countries of residence have to be considered for the same application.

In Chapter 6, the adoption of the inventor criterion has been chosen. In general, the choice of the criterion depends on the perspective from which innovative capability is being investigated.

As mentioned above, the dataset includes all priority applications filed at selected 59 Patent Offices. **It must however be made clear that**, in the cases where the inventor criterion is used, we call 'EU applications', those applications in which **EU-based inventors** are involved, and **not all applications to EU patent offices** (which can involve EU-based or non-EU-based inventors). In the same way, **'US applications' are those involving US-based inventors rather than those filed to USPTO** (which can involve US-based or non-US-based inventors). Moreover, the application of the fractional count implies that, in the case where an application has several inventors with different countries of residence, for that specific application a value lower than a unit will be assigned to each of the respective countries. The use of fractional count of patent applications, by assigning 'fractions' of a patent application to different countries depending on the country of residence of each of the inventors (or applicants), produces, as a consequence, decimal figures in the number of patent applications per country.

Technology classes

With regard to the identification of ICT patent application technology classes, the same approach as in the 2010 edition of the report has been followed, considering the taxonomy of the International Patent Classification (IPC) technology classes proposed by the OECD (OECD, 2008). The mentioned taxonomy links four categories of ICTs to groups of technology classes. The four categories, and the corresponding IPC classes, are the following:

- **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**: IPC codes G11B, H03F, H03G, H03J, H04H, H04N, H04R, H04S;

- **Computers and Office Machinery**: IPC codes B07C, B41J, B41K, G02F, G03G, G05F, G06, G07, G09G, G10L, G11C, H03K, H03L;

et al., 2010). This fact stands as one of the main reasons behind some differences in figures in the time series of each annual report (other reasons have to be found in the constant updating and refining of data provided by Patent Offices to EPO and in turn by EPO by means of PATSTAT, and in the minor intrinsic effect of applying a different software tool). EPO works on reducing the amount of missing country information (by filling the missing codes with the country of publication in the next editions), but at present time the attribution of country codes by means of a set of subsequent procedural steps is the only alternative commonly adopted worldwide. It must be noticed that the lack of information about the country of inventors (and applicants) has noticeable consequences in the case of Japan, as EPO does not receive this information on Japanese data and therefore for Japanese documents PATSTAT does not explicitly indicate the country (European Patent Office, 2010), which is then assigned in all possible cases by means of procedures. Thus, the huge number of Japan-based inventors could hide a share of inventors resident in countries different from Japan, but which it is not possible presently to identify. Finally, the country does not necessarily hold a reference to the 'nationality' of inventor or applicant (European Patent Office, 2010).

- **Other ICT**: IPC 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.

As a consequence, the distinction between ICT and non-ICT technologies is related to neither the ISIC classification of economic activity nor to NACE codes.

The *fractional counts* approach has also been applied in case of applications referring to more than one technology class.

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Annex 6: IPTS ICT R&D Internationalisation Database

Database description

The *2010 JRC-IPTS ICT R&D Internationalisation Database* is an IPTS company-level dataset specifically dedicated to observe the internationalisation of ICT R&D at company level. It includes in its current version 176 multinational ICT companies and tracks financial data as well as location information of their R&D centres. In particular, it provides the following R&D-related information:

- Company location,
- The location and ownership of over 2,800 R&D centres worldwide in 2009,[140]
- Geographical allocation of company level semiconductor design expenditures broken down by country where expenditures are carried out for the period between 2007 and 2011.

The initial selection of companies included in the *2010 JRC-IPTS ICT R&D Internationalisation Database* is based on the iSuppli[141] semiconductor value chain database developed by both primary and secondary research to create regional development profiles for each company. These surveys were reinforced with significant secondary research from a variety of sources around the world. The database is constantly expanding and each year new companies are being added. For example, in the last edition of the dataset, only 80 firms and around 1,800 R&D centres were covered. The current edition has information of R&D centres of 132 firms and on semiconductor design expenditures of 176 ones.

Companies included in the database are considered by iSuppli as major 'semiconductor design stakeholders' and therefore essential industrial actors in the ICT value chain. Consequently, although some companies, such as Bosch Group or Siemens, are not ICT companies according to the NACE classification, their activities include large ICT-related operations and, hence, are represented in the current database. Among other the companies included in the sample are, for example, Alcatel-Lucent, Ericsson, Nokia or Siemens for the EU; Apple, Cisco, HP Microsoft or IBM for the US; Hitachi, NEC or Sony for Japan; Huawei, LG or Lenovo for Asia. A detailed list of companies can be found in Table 1 of this Annex.

In spite of the fact that the database does not cover the entire ICT industry, the ICT firms contained in the dataset represent at least 55% of the 2008 R&D budget of all ICT companies included in the *ICT Scoreboard* or 28% of the full *Scoreboard* sample.[142] Also, in 2009, these firms accounted for more than 30% of all patent applications to the USPTO. Consequently, this information allows for a relatively representative illustration of the R&D-related behaviour of large multinational ICT companies.

140 This information is currently available for only 132 firms, which still represents 55% of the R&D expenditures made by ICT Scoreboard companies.
141 iSuppli is an ICT industry consultancy. For iSuppli presentation, see at http://www.isuppli.com.
142 For more information in the *ICT Scoreboard*, please see: Nepelski, D. and Stancik, J. (2011). The Top World R&D-investing Companies from the ICT Sector: A Company-level Analysis. JRC Scientific and Technical Report EUR 24841 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

Regarding the regional coverage, the dataset covers 49 countries grouped, as in the PREDICT 2011 report, into the following five regions. These countries/regions are: the EU, the US, Japan, Asia and the RoW.[143]

Definition and estimation of semiconductor design expenditures

The data on semiconductor design expenditures included in the *2010 JRC-IPTS ICT R&D Internationalisation Database* is based on the information collected by iSuppli, an ICT business consultancy, and presented in the Design Activity Tool. This tool provides detailed information on expenditures related to the design and development of semiconductors, integrated circuits and electronic chips used by 176 global ICT companies in their products.

The semiconductor design expenditures are attributed to various countries that 'influence' decisions on part or vendor selection when the OEMs develop electronic products. This is done based on the knowledge of where engineering teams are and where the decisions concerning systems design and selection take place. It needs to be noted that, as described in the detailed analysis of the semiconductor value system (Tuomi, 2009[144]), the design activities of OEMs can come from internal design teams, external design teams or ODMs.

As a generic example, assume an OEM spends a $100M a year on semiconductors and they have in-house design centres in the US, France, and China, a procurement office in Hong Kong, and use a ODM in Taiwan. The applied methodology would apportion the $100M across those entities based on the amount influence they have by application and by country.

The information collected and processed according to the above methodology casts some more light on the internationalisation of R&D, as it allows for answering such critical question as:

- Where in the world do the top ODMs have their systems designed?
- How does the process of allocation of semiconductor design resources changes over time?

Which countries/regions are gaining or loosing ground in the area of designing and developing such core elements of ICT products as semiconductors and integrated circuits?

Geographical coverage

Table 1, Annex 6 includes the list of companies included in the *IPTS ICT R&D Internationalisation Database*, created on the basis of the information provided by iSuppli to JRC-IPTS during the period 2008-2009.[145] Due to the difficulty of the task concerning the collection of data on companies' R&D sites location and their R&D expenditures, the dataset has some missing observations. An asterisk indicates companies for which information on R&D sites are available and '#' on the other hand indicates companies for which only data on semiconductor design expenditures is available.

143 Asia includes India, China, South Korea, Taiwan, Singapore; and the RoW covers Australia, Canada, other countries from Europe (Switzerland, Turkey, Russia, and Norway), the other countries of South and Central Americas, the other countries from Asia including the Middle-East, and Africa.

144 Tuomi, I. (2009). The Future of Semiconductor Intellectual Property Architectural Blocks in Europe. JRC Scientific and Technical Report EUR 23962 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://ftp.jrc.es/EURdoc/JRC52422.pdf

145 See at: http://www.isuppli.com/

Table 1, Annex 6: List of companies included in the IPTS ICT R&D Internationalisation Database by region of headquarter origin

	EU		US		Japan		Asia		RoW
1	ASML#	1	3Com	1	Aisin Seiki	1	ASUSTeK Computer	1	ABB
2	Agfa-Gevaert	2	Abbott Laboratories#	2	Alps Electric	2	AU Optronics	2	Arcelik#
3	Alcatel-Lucent	3	Agilent Technologies	3	Brother Industries	3	Acer	3	EMBRAER#
4	Autoliv	4	Apple	4	Canon	4	Creative Technology#	4	Garmin
5	BAE Systems	5	Applied Materials#	5	Casio Computer	5	Delta Electronics	5	Itautec
6	Bosch Group	6	Avaya	6	Denso	6	Elitegroup Computer	6	Logitech International#
7	Bull#	7	Boeing	7	FUJIFILM	7	Haier Group	7	Magna International#
8	Continental	8	Bose	8	Fuji Electric#	8	Hannstar Display	8	RIM
9	EADS	9	Boston Scientific	9	Fujitsu	9	Hisense Group	9	Roche
10	Electrolux	10	Brocade	10	Funai Electric	10	Huawei Technologies	10	Seagate Technology
11	Ericsson	11	Cisco Systems	11	Hitachi	11	Humax	11	Sitronics#
12	Gemalto	12	Danaher	12	Kenwood#	12	Inventec	12	Thomson
13	Giesecke & Devrient	13	Dell	13	Konica Minolta	13	Konka Group#	13	Tyco Electronics#
14	HeidelbergCement	14	Diebold#	14	Kyocera	14	LG	14	Vestel Group#
15	Hella#	15	EMC	15	Matsushita Electric	15	Lenovo		
16	Indesit#	16	Eastman Kodak	16	Mitsubishi Electric	16	Lite-On It		
17	Ingenico	17	Eaton	17	NEC	17	MiTAC International#		
18	Invensys	18	Emerson Electric	18	Nikon	18	Micro-Star International		
19	Magneti Marelli / Fiat	19	General Dynamics	19	Nintendo	19	Midea Group		
20	Medion#	20	General Electric	20	OKI Electric	20	Mitac Group*		
21	Nokia	21	Harman International	21	Olympus	21	Pantech Group		
22	Nokia Siemens Networks	22	Harris#	22	Omron	22	Qisda		
23	Oberthur Technologies	23	Hewlett-Packard	23	Pioneer	23	Samsung Electronics		
24	Oce	24	Honeywell	24	Ricoh	24	Samsung Techwin		
25	Pace#	25	IBM	25	Sanyo Electric	25	Sichuan Changhong Electric#		
26	Philips Electronics	26	IGT#	26	Seiko Epson	26	Skyworth		
	SAFRAN	27	ITT#	27	Sharp	27	TCL		
28	Schneider	28	Ingersoll-Rand	28	Sony	28	Tatung#		
29	Siemens	29	Intel	29	Tokyo Electron#	29	VTech		
30	Smiths#	30	Intuitive Surgical#	30	Toshiba	30	Videocon#		
31	Sony-Ericsson	31	Johnson & Johnson#	31	Yamaha	31	ZTE		
32	Thales	32	Johnson Controls	32	Yokogawa Electric#				
33	TomTom	33	Juniper Networks						
34	Valeo	34	Kingston*						
35	Wincor Nixdorf	35	Kingston Technology#						
		36	Kla-Tencor#						
		37	L-3 Communications						
		38	Lexmark#						
		39	Lockheed Martin						
		40	Medtronic#						
		41	Microsoft						
		42	Motorola						
		43	NCR#						
		44	NetApp						
		45	Northrop Grumman						
		46	Novellus Systems#						
		47	Palm						
		48	Pitney Bowes#						
		49	Raytheon						
		50	Rockwell Automation						
		51	Rockwell Collins#						
		52	SPX						
		53	SanDisk						
		54	St Jude Medical#						
		55	TRW Automotive						
		56	Tellabs						
		57	Teradyne#						
		58	Textron#						
		59	Thermo Fisher Scientific#						
		60	Unisys#						
		61	United Technologies						
		62	Varian Medical Systems						
		63	ViewSonic						
		64	Western Digital						
		65	Whirlpool#						
		66	Xerox						

Annex 7: Patent-based internationalisation measures

Patent-based measures of internationalisation

Methodology of constructing measures of internationalisation based on information included in patent applications is described in OECD (2008a).[146] This methodology is based on the fact that 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. The 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. 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, for example, 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:

- **Co-invention**: 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).

- **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).

146 OECD (2008a), Compendium of Patent Statistics 2007, available online: http://www.oecd.org/dataoecd/5/19/37569377.pdf

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).

Data source

The source of the data here is the European Patent Office Worldwide Patent Statistical Database (PATSTAT). This database compiles raw patent data from over 200 countries. In the following analysis, the data from the April 2010 database release is used. Indicators were computed for the period 1990 to 2007. The analysis is carried out using a methodology that considers all priority applications filed at 58 national patent offices, including all EU member States offices, the US patent office (USPTO), and the European Patent Office (EPO).

Defining ICT patents

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.

Glossary

BERD	Business Expenditure on Research and Development
CAGR	Compound Annual Growth Rate
CIS	Community Innovation Survey
CSS	Computer Services and Software ICT sub-sector
EPO	European Patent Office
EU	European Union
EU27	The 27 Member States that were part of the EU when this report was published
EU12	The 12 Member States which joined the EU in 2004 (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia) and in 2007 (Bulgaria and Romania)
EU KLEMS	The EU KLEMS Growth and Productivity Accounts Database of the University of Groningen
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
GERD	Gross 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
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
RoW	Countries from the Rest of the World
STAN	Structural Analysis Database of the OECD
USPTO	United States Patent and Trademark Office
VA	Value Added

European Commission

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Abstract

This report provides an analysis of the state of Information and Communication Technologies (ICT) Research and Development activities in the European Union. This is the fourth report of a series which is published annually. This year's report provides data up to 2008.

The report starts with a presentation of general trends concerning the EU ICT sector in a global perspective and in the EU Member States, followed by an analysis of the impact of the recent financial crisis on the ICT sector. The report then analyses R&D in the ICT sector, using data from the EU Industrial R&D Investment Scoreboard, which tracks R&D spending by the top R&D-investing companies worldwide. The report also provides a unique overview of ICT patenting in the European Union and a comparison of ICT patenting performance, by Member State and with other world regions. Finally, the report presents a set of empirical analyses on internationalisation of R&D in the ICT sector, on which there is still scarce evidence available, particularly with regard to ICT R&D internationalisation with emerging Asian economies.

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