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# Internationalisation of ICT R&D

Authors: Giuditta De Prato, Daniel Nepelski and Juraj Stancik

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

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



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# Preface

It is an undisputable fact that the ICT industry and ICT-enabled innovation in non-ICT industries and services make an important contribution to the economic growth of advanced economies. In the EU, and also in the USA and Japan, the ICT sector is by far the largest R&D-investing sector of the economy. The EU ICT sector is therefore a significant contributor to the ambition of achieving the target of investing 3% of GDP in R&D in the EU. But, when comparing ICT expenditures over GDP, the USA, Japan, and also Taiwan and Korea, are investing significantly more in ICT R&D than the EU. These characteristics and observations have provided the rationale for the PREDICT research work (PREDICT stands for "Prospective insights on ICT R&D"), which aims to gain a deeper understanding of the dynamics of research in the ICT industrial sector. This in turn can provide important policy insights and options.

The PREDICT research and analysis is carried out by the Information Society Unit at JRC-IPTS and co-financed by IPTS and the Information Society & Media Directorate General of the European Commission. PREDICT 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. Where this data still contains gaps, rigorous cross-checking and estimating methods are applied by JRC-IPTS to provide the study with the necessary set of data. PREDICT results have been reported in a series of report published annually since 2008. This multiannual analysis allows us to confirm the consistency of the data over time and offers a privileged view of the major ICT R&D trends across recent years. PREDICT results have been used, among others, in the preparation of EU policy initiatives aimed to support ICT R&D in Europe.

2011 marks the publication of the fourth annual report. For the first time this year the annual PREDICT report is complemented by a series of three thematic reports presenting more detailed analyses of some of the themes included in the annual 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. This report presents the results of a multiannual analysis of the internationalisation of ICT R&D.

All reports published under the PREDICT project are available at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html

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# 1 Executive summary

This report analyses empirically the internationalisation of ICT R&D. It assesses the levels of collaborative R&D in the ICT industry in five major world regions. It also investigates the increasing role of developing countries in the field of technologically advanced R&D and, hence, the growing competition for R&D resources. In the context of the EU, policy makers are concerned that the location of EU companies' R&D facilities in non-EU countries could have a negative impact on domestic R&D expenditures, employment and the knowledge base. This concern is emphasised by the fact that the internationalisation of R&D is primarily taking place in knowledge intensive industries, such as the ICT, chemical or pharmaceutical sectors. 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.

Although the internationalisation of R&D has received a lot of attention, the process has not been captured by official data yet and the available empirical evidence remains scarce and often contradictory. This, of course, puts the decision-making process at risk by giving a partial view of reality. A better grasp of the internationalisation process and the corresponding data could help to give a better view of the relevant processes and their implications.

In order to address the complexity of R&D internationalisation, this report uses a framework that disentangles the innovation value chain and divides it into two stages. The first stage covers the input side, observed 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.

Regarding the level of internationalisation of R&D input, the following is observed:

- ICT firms still locate most of their R&D activities in their home country.
- Despite the existence of strong linkages between Japan, the US and the EU, Asia seems to be very attractive as a location for R&D centres for ICT companies from the EU, the US, Japan and Asia itself. This is a sign that Asian countries are highly attractive as locations, not only for production or service facilities, but also for R&D-related activities.

Regarding the level of internationalisation of R&D output, the following results are worth emphasising:

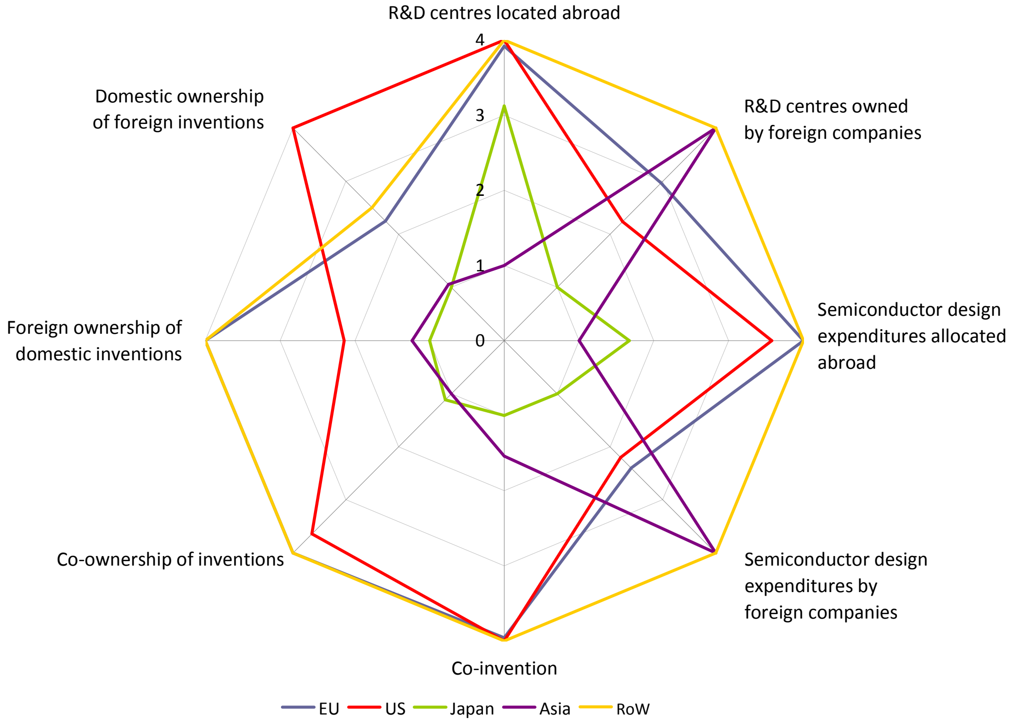
- Although the number of international ICT patents has steadily increased since the early 90s, the level of international collaboration output remains very low.
- Considering the relatively high level of foreign ownership of EU inventions, the EU is an important source of innovations for companies from other parts of the world.
- As compared to the US, EU firms exhibit a lower propensity to search and acquire new knowledge abroad.
- US firms own significantly more patents with 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, 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.
- The level of output of inventive collaboration with Asian economies is still very low, though increasing over time.

- The US exhibits an advantage, as compared to other regions, in tapping the inventive resources of Asian countries, whereas the level of inventive collaboration between EU and Asia remains continuously low.

Figure 1-1 provides a snapshot of the R&D internationalisation levels for each dimension used in this study and each region. This consolidation of the data leads to the following observations:

- In general, the EU, the US and the RoW regions exhibit higher levels of internationalisation across all measures than Japan and Asia.
- There are considerable differences in R&D internationalisation strategies adopted by each region and/or gaps in the advancement in the process of internationalising R&D activities. For example, whereas the EU and the US exhibit similar levels of the internationalisation of R&D input, i.e. R&D centres and semiconductor design expenditures, these regions show very different patterns with respect to cross-border ownership of inventions. In particular, the share of US-owned foreign ICT inventions is significantly higher than the corresponding measure for the EU. Similarly, although Japan and Asia show relatively similar levels of internationalisation of R&D input, they exhibit much lower levels of internationalisation of R&D output, as compared to the RoW, the EU and the US.

**Figure 1-1: Eight dimensions of ICT R&D internationalization across regions**




*Note*: Relative regions' 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.

The analysis presented in this report allows us to conclude that the process of R&D internationalization is a multifaceted issue which is far from understood. Furthermore, it is still not clear what the implications of ICT R&D activity internationalisation at firm and country level are. In particular, there is the question of what is the overall effect of R&D activity migration on local production and inventive capacities at the country level. 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.

# 2 Introduction

This report analyses the internationalisation of ICT R&D. Its main focus is the question of how the innovation process is taking place in the ICT industry across five major world regions (the EU, the US, Asia, Japan and the RoW) and where the EU stands in this process. The reasons for taking up the subject of internationalisation of ICT R&D activities are manifold. This analysis is partly 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). Though most EU firms' international R&D activities 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 growing 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.

Second, there is a concern 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 state and development of the knowledge economy in Europe.

However, the internationalisation of R&D may also have positive effects on the EU economy. For example, by accessing a wider pool of knowledge, EU companies may benefit from positive spillover effects at home which could improve their competitiveness (Branstetter, 2006; Todo, 2006). Furthermore, by building up research facilities abroad, firms get access to potentially relevant knowledge located outside 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 may positively affect the overall knowledge creation balance, the inventive capacities of individual countries and the growth perspectives of EU companies.

This report is organised as follows: Sections 3 and 4 discuss the concept of R&D internationalisation and aspects such as drivers and barriers to this process together with the problems related to empirical assessment of this phenomenon. This discussion serves as a framework and as a starting point for a set of empirical analyses of R&D internationalisation in the ICT sector in Section 5. In particular, Section 5.2 analyses the internationalisation of R&D input, such as R&D centre location and semiconductor design expenditures, and Section 5.3 describes the level of internationalisation of the output of research activities based on patent statistics. Section 6 illustrates the processes in play in two major emerging economies: China and India. Together these sections offer complementary views at statistical, company and country levels. Section 7 summarizes the main results and offers conclusions.

# 3 The concept of the internationalisation of R&D

Over the last few decades, an intensive process of redistribution of production across the world has been observed (van der Zee F., 2006; Dachs B., 2007, Meijers, H, 2008, OECD, 2008; UNESCO, 2010). This process is an illustration of how the allocation of production resources responds to disparities in regional conditions of production (Massey, 1979). The outcome of these flows is an increasing internationalisation of the environment in which companies operate. Trade, foreign direct investment (FDI) and the offshoring of manufacturing have been the most visible forms of this internationalisation (OECD, 2008; UNESCO, 2010). As a result of the above, the transformations in the production process and the structure of economy have accelerated the process of spatial redistribution of labour according to the requirements of each activity and the pattern of regional conditions. This, in turn, has led to the internationalisation of production.

As part of the process of spatial division of economic activity, a number of large corporations have complemented their strategy of locating production facilities abroad in order to manufacture products developed in their home county at a lower cost and have begun to seek new knowledge opportunities worldwide (Bartlett and Ghoshal, 1990; Dunning, 1994). These companies are said to be increasingly building a new kind of competitive advantage by discovering, accessing, mobilising, and leveraging knowledge from a number of locations across the globe (Doz, Santos and Williamson, 2001). This means that more and more firms are present in various locations around the world with the purpose of performing R&D. This type of spatial division of labour reflects the increasing transfer of sophisticated, knowledge-intensive activities by companies to locations other than their domestic markets.

## 3.1 *Drivers and barriers to internationalisation of R&D*

Although there are many aspects that a firm takes into account when making choices as regards R&D-related investment, recent studies on R&D investment show that three main criteria determine the final decision (Dunning, 1988; Dunning, 1994; Tübke, 2009). The first criterion is the access to resources that, in most cases, are non-transferable and location-specific. Furthermore, access to these resources must be perceived as vital to a firm's activities. Examples of such resources include inputs to R&D activity, e.g. scientists and universities, or the knowledge about customers and markets. As a result, in general, firms are more likely to locate their foreign R&D units close to existing production facilities or institutions that contribute to their activities. The second criterion is related to the macroeconomic environment of the host country and includes, for example, a reliable legal framework for R&D and macroeconomic and political stability. Cost seems to be the third criterion for choosing a location for a new R&D unit. This issue is particularly important in the context of moving R&D units to developing countries. In such cases, firms expect to benefit from lower labour costs and/or government incentives, including exemptions from certain taxes. Firms are paying more attention to the cost consideration as knowledge spreads around the world and as technological tasks become easier to separate, modularise, and divide into distinct phases (Brusoni, et al., 2001). These changes allow firms to allocate different parts of R&D projects to various R&D units, depending on their expertise and cost advantage.

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

## 3.2 *R&D internationalisation strategies*

A relevant way of analysing R&D internationalisation is to distinguish between the exploitation of home base-generated knowledge and the exploitation of external sources of knowledge (Kuemmerle, 1997; see also Niosi, 1999 and Gassmann and von Zedtwitz, 2002). The former is called *asset-exploitation* strategy and the latter *asset-seeking* strategy.

Regarding *asset-exploitation* strategy, it is argued that the process of building knowledge creation units abroad is the natural step a firm makes after having established its presence through either export or production activities in a new market (Niosi, 1999; Boutellier, Gassmann and von Zedtwitz, 2008). By creating learning capacities in these regions or countries, companies seek ways to acquire knowledge about these markets. This allows them to, for example, customize their products to better serve customer needs, and hence increase their revenues. Companies are likely to follow this strategy in developing markets, such as the European Union or Asia, to adapt their products to meet local requirements. In other words, the expertise on foreign markets *extends the knowledge* that was generated at headquarters. In this case, firms focus in their knowledge acquisition process mostly on the 'D' element of R&D (Kuemmerle, 1997).

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

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

To sum up, access to new knowledge (asset-seeking) and transfer of knowledge (asset exploitation) between various locations are driving the strategies of internationalisation of R&D activities. These reasons together with rapid innovation and strong market adaptation needs are driving the process of R&D internationalisation in knowledge-intensive sectors, such as the ICT industry.

# 4 Capturing the dimensions of R&D internationalisation

The process of R&D internationalisation has not been captured by official data yet, which creates a challenge for informed policy making. Moreover, R&D internationalisation challenges the available tools for measuring inventive performance. As observed in a study on company R&D (European Commission, 2009), mainly BERD data and company data are used to track inventive activity. However, as such data is typically assigned to a particular geographical location or company, it fails to capture the full dynamics of the inventive process that is increasingly taking place across national or regional borders. 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).[1] This, of course, puts the decision-making process at risk by giving a partial view of reality. A better grasp of the internationalisation process and the corresponding data could help to disentangle these dynamics.

Also the picture of R&D internationalisation that emerges from academic research is not completely clear. Despite the fact that the topic of R&D internationalisation has already attracted considerable attention, there is still relatively little empirical evidence of the outcomes of this type of activity. For example, in one of the pioneer studies on the subject, by analysing the patenting activity of U.S. firms, Patel and Pavitt (1991) found that the technological activities of multinational firms are concentrated in their home countries. More recent studies do not show significant changes with respect to the internationalisation of R&D activity either (Picci, 2008; Di Minin, 2006). In other words, the observed output of international inventive activity apparently remains low. Similarly, Ariffin and Figueiredo (2006) report results that run counter to some existing generalisations concerning the direction of knowledge and expertise flows between developed and developing countries. They conclude that a number of Malaysian and Brazilian firms managed to develop significant levels of innovative technological capabilities without external stimulus.

There are, however, some common findings that emerge from available research results. First of all, regarding the demographics of firms that internationalise their R&D activities, large multinational companies (MNCs) are the unquestionable leaders (Doz, Santos and Williamson, 2001). This does not come as a surprise considering that typically about 80% of business R&D activities are concentrated in large firms with 10 000 or more employees (Patel and Pavitt, 1991). A United Nations survey of world trade activities reaches a similar conclusion (UNCTAD, 2005). Consequently, it is mainly large multinational firms that seem to drive the process of R&D internationalisation. The fact that SMEs may also be involved in global value chains does not seem to influence the leadership of MNCs significantly.

Another important observation of the available studies on R&D internationalisation is that this process remains apparently limited to a small number of developed countries and economies in transition (UNCTAD, 2005). R&D-related investment flows remain concentrated mainly within and between the highly developed countries: the US, Japan and EU countries. This, however, is forecasted to change over time (OECD, 2005). As the process of changing the geography of technology-intensive industry continues, Asian countries are becoming an essential link in the global value chain and their importance and attractiveness as locations for higher value-added firm activities such as R&D are growing. There are already signs that

[1] For example, the recent Eurostat (2010) attempt to map international R&D activities is a 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.

Asia is becoming the target for new innovative collaboration initiatives from both Asia and OECD-based ICT firms (OECD, 2008; UNESCO, 2010; OECD, 2010).

Furthermore, despite the unclear picture that emerges from data and research, there is also broad agreement that the process of R&D internationalisation will intensify over time. Moreover, it will spread more widely, including to developing countries. Consequently, this calls for more attention to the process of R&D internationalisation and motivates the following analysis.

# 5 Empirical analysis of ICT R&D internationalisation

## 5.1 *Methodology to study the internationalisation of R&D*

In spite of the abundance of anecdotal evidence regarding R&D internationalisation, 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 various reasons 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, tangible outputs of international inventive collaboration remain scarce 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 5-1.

To put is simply, 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 the output side of R&D activity. Such 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 can be analysed separately.

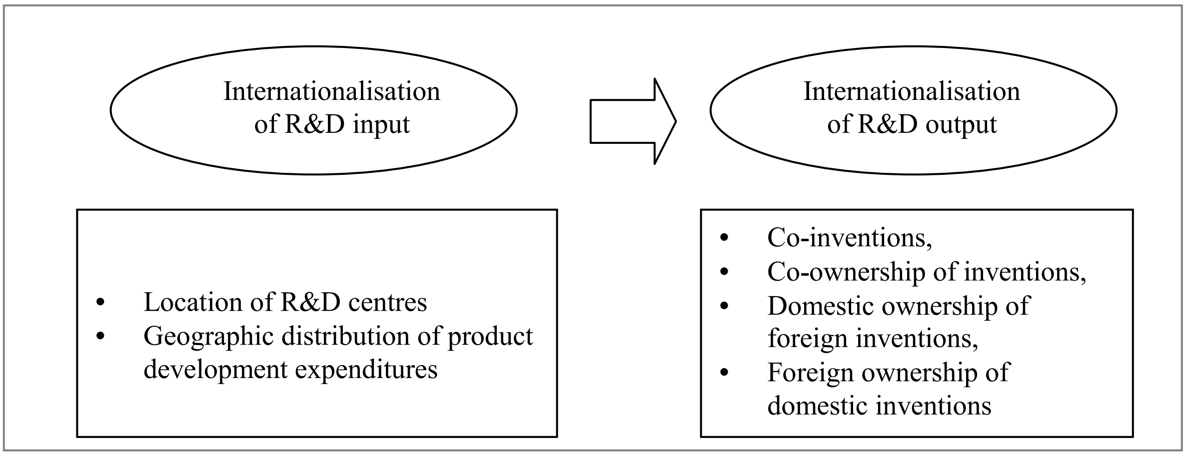
In this report, the main measures used to assess the internationalisation of the R&D input-side include the data on the location of R&D centres (Section 5.2.1) and the geographic allocation of semiconductor design expenditures (Section 5.2.2) by ICT companies. Concerning the R&D output side, ICT patent data are used (Section 5.3).

In the absence of official statistics on R&D internationalisation, this analysis makes use of unique data in order to build a comprehensive source of information on ICT companies' R&D internationalisation level. Hence, for example, in Section 5.2.2 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 information has 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.[2] Moreover, the information on R&D activities relates 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 companies included in these datasets. Similarly, patents are used as a proxy of R&D output, which imposes some limitations on the interpretation of the results. Therefore, the evidence presented here should be interpreted with caution.

[2] 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 methodological box below), and aims in the longer term to cover exhaustively the top ICT R&D spenders worldwide.

**Figure 5-1: Methodology used to study the internationalisation of R&D**




## 5.2 *Internationalisation of ICT R&D input: R&D centres and expenditures*

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 7.5.2.1) and the allocation of semiconductor design expenditures across the world (Section 7.5.2.2). The analysis is based on information extracted from the *2010 JRC-IPTS ICT R&D Internationalisation Database* (see Box 5-1).

**Box 5-1: The 2010 JRC-IPTS ICT R&D Internationalisation Database**

The *2010 JRC-IPTS ICT R&D Internationalisation Database* is an IPTS company-level dataset specifically dedicated to observing the internationalisation of ICT R&D at company level. The current version includes 176 multinational ICT companies and tracks financial data and 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,[3]
- 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 in the *2010 JRC-IPTS ICT R&D Internationalisation Database* is based on the iSuppli[4] semiconductor value chain database developed through 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 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 on the R&D centres of 132 firms and on the semiconductor design expenditures of 176 firms.

Companies included in the database are considered by iSuppli as major 'semiconductor design stakeholders' and therefore essential industrial actors in the ICT value chain.

[3] This information is currently available for only 132 firms, which still represents 55% of the R&D expenditures made by ICT Scoreboard companies.

[4] iSuppli is an ICT industry consultancy. For iSuppli presentation, see at http://www.isuppli.com.

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, these are represented in the current database. Some of the companies included in the sample are Alcatel-Lucent, Ericsson, Nokia and Siemens for the EU; Apple, Cisco, HP Microsoft and IBM for the US; Hitachi, NEC and Sony for Japan; Huawei, LG and Lenovo for Asia. A detailed list of companies can be found in Annex 1.

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.[5] 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.

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.[6]

#### 5.2.1 Location of ICT R&D centres

The analysis of the internationalisation of ICT R&D input starts with a 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 listed in the above box, 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.

Figure 5-2 shows the distribution of ICT R&D centres across the previously defined regions. First, the figure (blue bars) indicates the absolute number and the share of R&D centres owned by companies from each region. Second, it shows (red bars) the number and percentage of R&D centres located in each region, and therefore the companies' preferences for location of their R&D activities.

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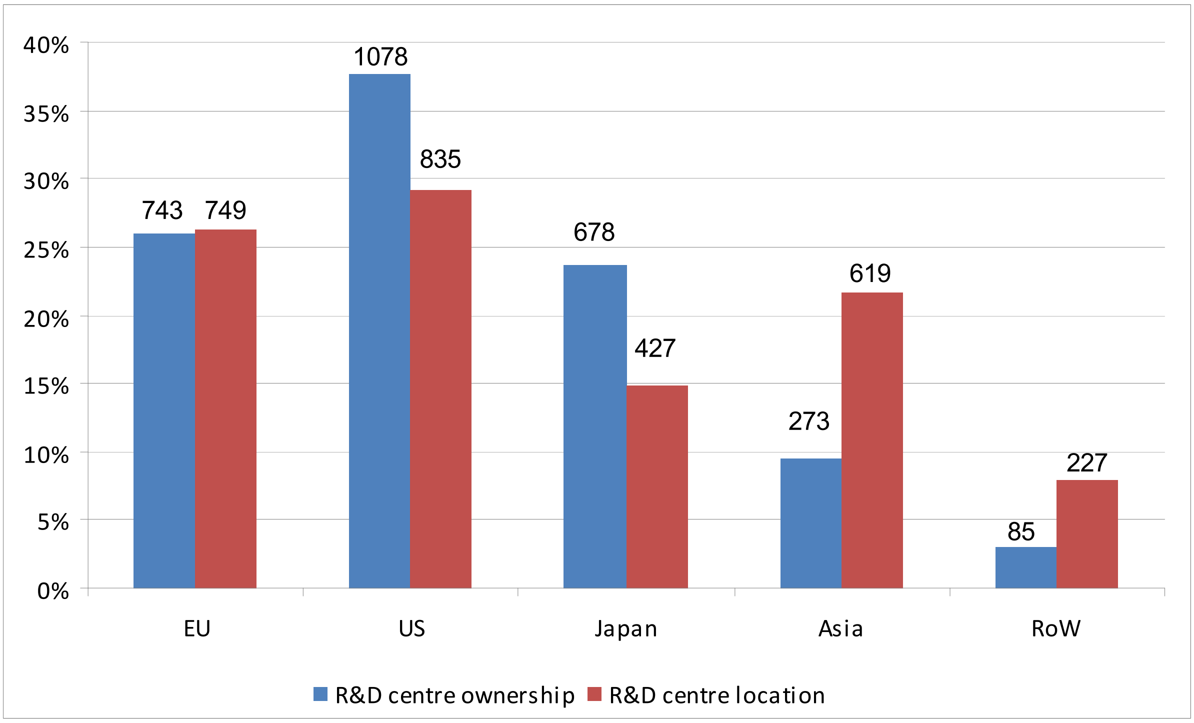
5 For more information in the *ICT Scoreboard*, please see: Nepelski D., Stancik J. (2011). 'The top world R&D-investing companies from the ICT sector – a company-level analysis'. JRC Scientific and Technical Report EUR 24841 EN. Institute for Prospective Technological Studies, Joint Research Centre, European Commission. Available at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=4379

6 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 in South and Central America, the other countries in Asia including the Middle-East, and Africa.

**Figure 5-2: ICT R&D centres by region of ownership and by location, 2009, in %**




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

Concerning the **location of ICT R&D centres** (red bars), Figure 5-2 indicates that 25% of all ICT R&D centres are located in the EU and nearly 30% in the US. Japan hosts 16% of ICT R&D centres and 22% are located in Asia. The remaining 7% are located in the countries grouped in the RoW region.

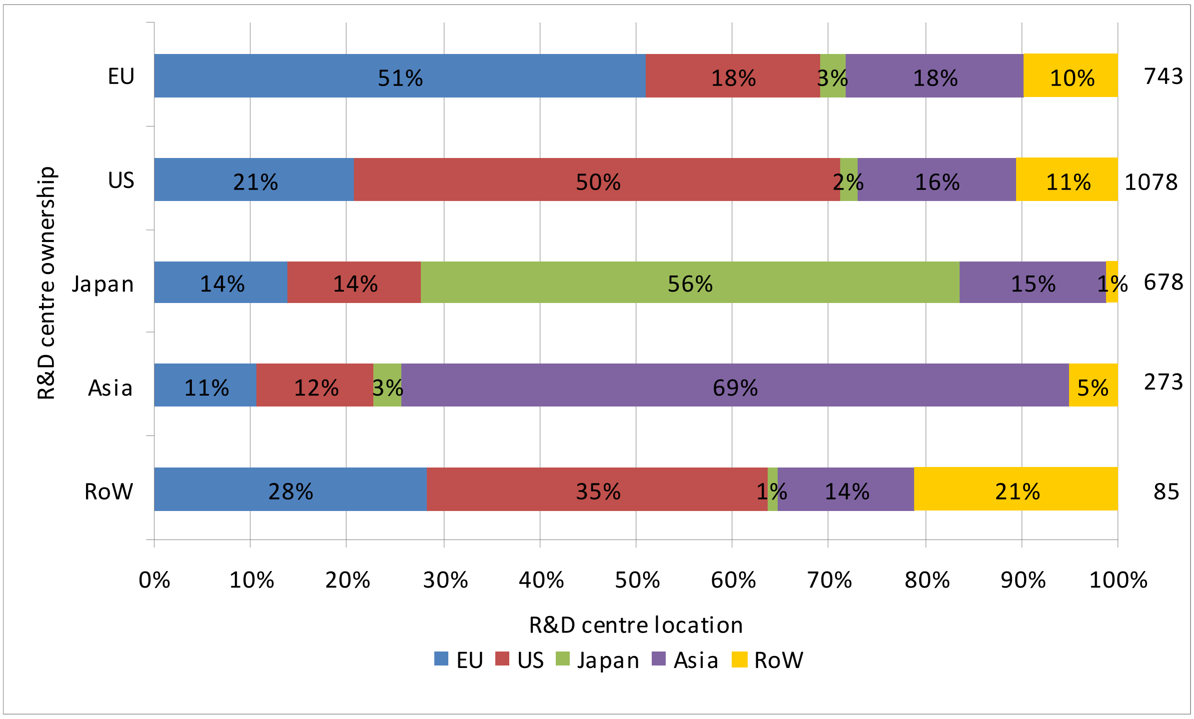
Concerning the **ownership of R&D centres** (blue bars), Figure 5-2 indicates that US companies own the most ICT R&D centres (above 35%). Firms with headquarters in the EU own nearly one fourth of all R&D centres included in the *JRC-IPTS ICT R&D Internationalisation Database*. This is nearly the same for firms from Japan, which comes second in the number of R&D centres owned by domestic firms. Companies from the Asia region own slightly above 10% of all ICT R&D centres.

The above data concerning the location and ownership of ICT R&D centres reveals that only in the US and Japan is the number of R&D centres owned by companies from the region greater than the number of centres located there. In Asia and the RoW region, the reverse can be observed. Concerning the EU, the proportion of R&D centres owned by domestic companies is similar to the proportion of R&D centres located in the EU.

***Where do ICT companies locate their R&D centres?***

Figure 5-3 shows where companies from different regions tend to locate their R&D centres.

**Figure 5-3: Location of ICT R&D centres by region of ownership, 2009, in %**




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

**Out of 743 R&D centres owned by EU companies,** Figure 5-3 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 the EU or the US, which each host 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 locations 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 headquarters is very common among all firms, as usually described in the 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.

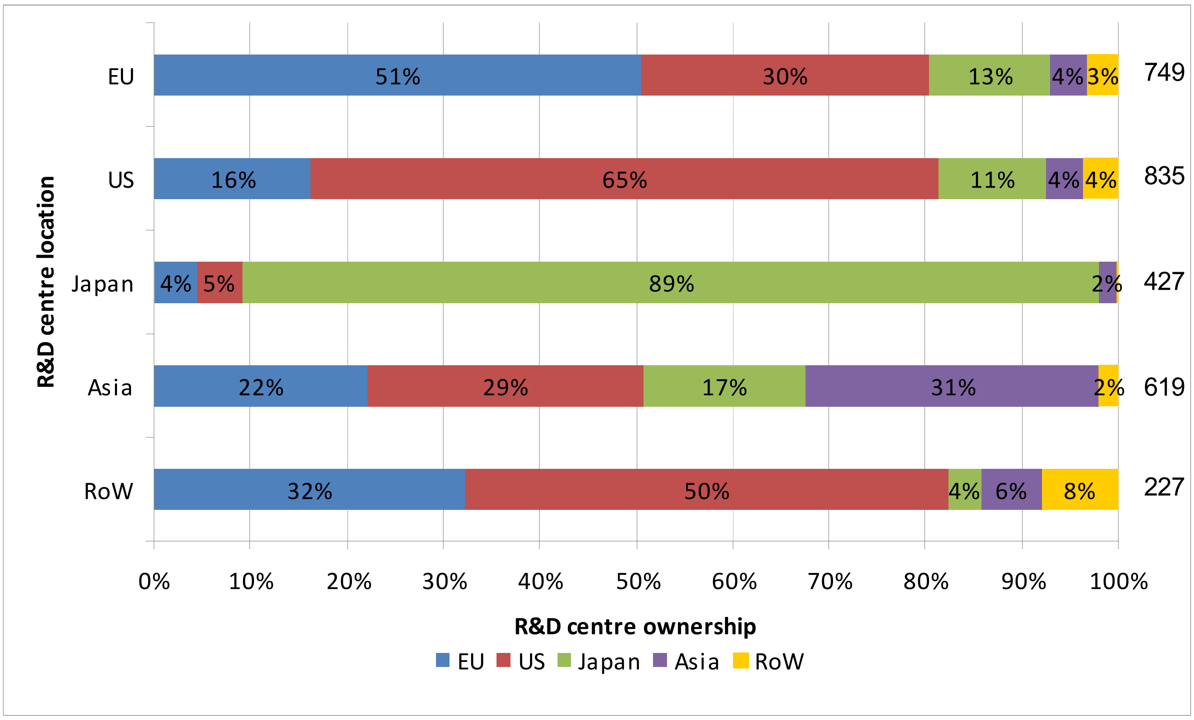
The data also confirms the existence of strong linkages between the EU and the US. As of 2009, of all the foreign locations, US ICT firms seem to consider the EU countries as most attractive for locating R&D centres outside the US. 21% of all US-owned research sites are located in the EU (16% in Asia, 11% in RoW and only 2% in Japan). Very similarly, EU ICT firms seem to consider the US and Asia as the most attractive location for R&D centers. Each of these regions hosts 18% of all EU-owned research centers, whereas there are only 10% of EU-owned R&D centers in the RoW and only 3% in Japan. Each of these regions hosts 18% of all EU-owned research centres, whereas there are only 10% of EU-owned R&D centres in the RoW and only 3% in Japan.

Regarding the Asian countries, the analysis clearly shows their importance as a destination of R&D expenditures of foreign companies, particularly US and EU ones. 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 R&D activities.

***Who owns the ICT R&D centres and where?***

Figure 5-4 shows the ownership structure of ICT R&D centres located in the five world regions.

**Figure 5-4: Ownership of ICT R&D centres by regions of locations, 2009, in %**




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

**ICT R&D centres located in the EU:** Figure 5-4 indicates that in 2009, 51% of the 749 ICT R&D centres located in the EU are owned by EU companies and 30% of them belong to companies with headquarters in the US. The remaining R&D centres belong to companies headquartered in Japan (13%), Asia (4%), and RoW (3%).

**ICT R&D centres located in the US:** the pattern of ICT R&D centres located in the US is similar to that of those located in the EU. That is, the largest percentage (65%) of 835 ICT R&D centres located in the US is owned by domestic companies and 16% belong to EU firms. Companies based in Japan and Asia own 11% and 4% of R&D centres located in the US. The remaining 4% belong to companies from the RoW.

**ICT R&D centres located in Japan:** The large majority of R&D centres located in Japan (89%) belong to domestic companies. Whereas EU and US firms have nearly equal shares of R&D centres in Japan, 4% and 5% respectively, Asian firms own only 2% of the R&D centres located in Japan.

**ICT R&D centres located in Asia:** Only one third of R&D centres located in Asia belongs to domestic companies. This low share of ownership by domestic companies is exceptional among the analysed regions, excluding the RoW region. Companies from the US and the EU own 29% and 22% of R&D centres located in Asia respectively, while their Japanese counterparts own 17% of the R&D centres located in Asia.

In general, the above analysis shows that domestic companies own the highest share of R&D centres located in each region. However, considerable differences between the ownership patterns exist. For example, whereas about half of the ICT R&D centres located in the EU are foreign owned, only 11% and 35% of the ICT R&D centres located in Japan and the US respectively are owned by foreign companies, and as much as two thirds of the ICT R&D centres located in Asia (excluding Japan) are foreign owned. Furthermore, although the data indicates the existence of strong linkages between the triadic countries, the role of Asia as one of the major R&D locations is considerable.

### 5.2.2 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. 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.

The analysis is based on the data stemming 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. The methodological note (see Box 5-2) describes in detail the definition of semiconductor design expenditures and the methodology used for collecting the data.

**Box 5-2: 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.[7]

Semiconductor design expenditures are attributed to various countries that "influence" decisions on parts or vendor selection when Original Equipment Manufacturers (OEM) 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), the design activities of OEMs can come from internal design teams, external design teams or Original Design Manufacturers (ODM).

As a generic example, assume an OEM spends a $ 100 million 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 an ODM in Taiwan. The applied methodology would apportion the $ 100 million across those entities according to the amount of influence they have by application and by country.

The information collected and processed according to the above methodology casts more light on the internationalisation of R&D, as it allows us to answer critical questions such as:

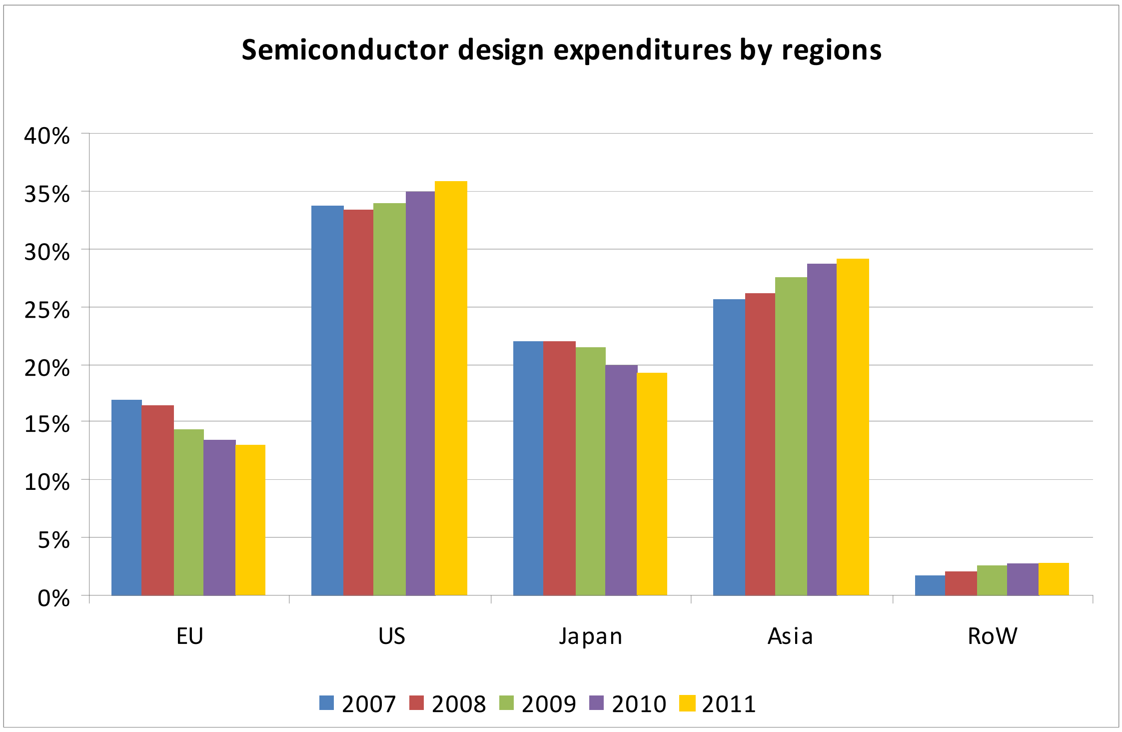
- Where in the world do the top ODMs have their systems designed?
- How does the process of allocation of semiconductor design resources change over time?
- Which countries/regions are gaining or loosing ground in the area of designing and developing core elements of ICT products such as semiconductors and integrated circuits?

7 A full list of companies can be found in Annex I.

***Allocation of semiconductor design expenditures***

Figure 5-5 shows the allocation of companies' semiconductor design expenditures across the five regions for the period between 2007 and 2011.

**Figure 5-5: Allocation of semiconductor design expenditures by region, 2007-2011, in %**




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

According to Figure 5-5, the EU share of total expenditures on the design of semiconductors is declining continuously and is expected to reach around 13% of the world total in 2011. A similar trend can be observed for Japan, where multinational ICT companies spend around 20% of their semiconductor design budget. In contrast, in the US, Asia and the RoW expenditures are increasing. The US and Asia are the regions with the highest shares of semiconductor design expenditures. In addition, Asia has exhibited a very strong growth rate over the period between 2007 and 2011 with a global share that is set to increase from 25% to about 30%.

***Destination of semiconductor design expenditures***

In order to cast more light on semiconductor design expenditure patterns across the geographic regions, Figure 5-6 presents the allocation of semiconductor design spending according to their source.

In 2008, EU companies spent 70% of their 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.

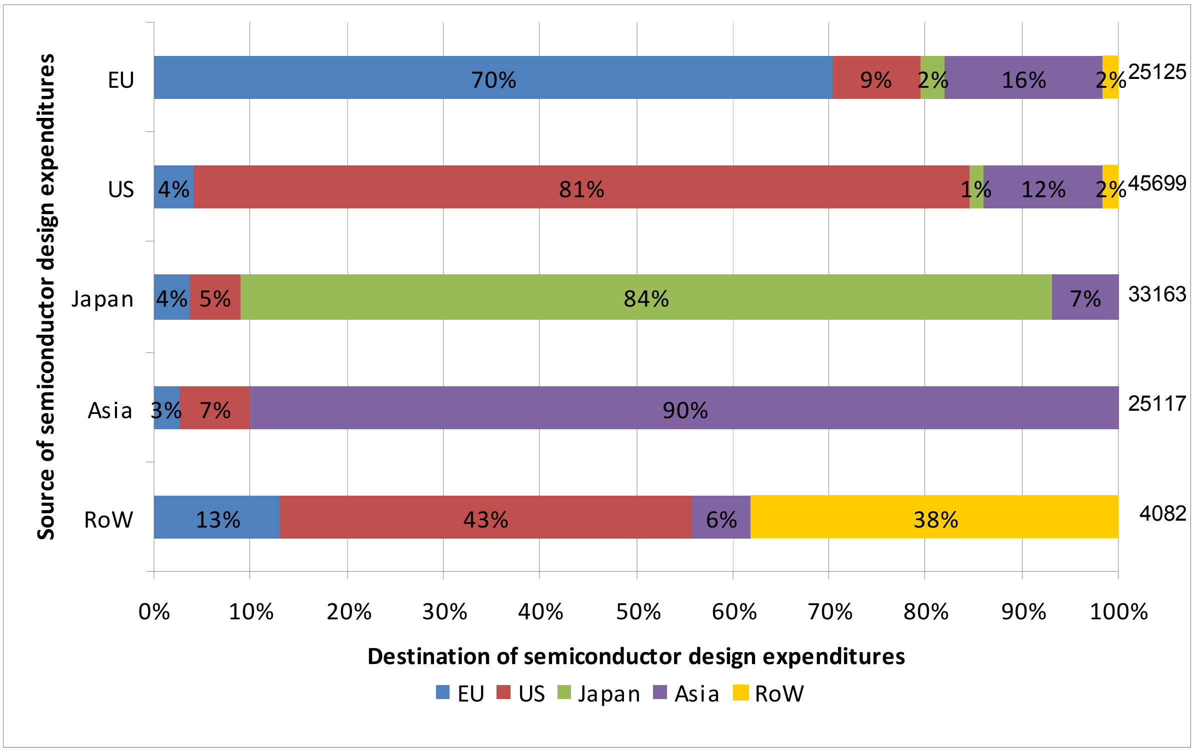
Despite some slight differences, US companies show similar allocation patterns of their semiconductor design expenditures to their EU counterparts. The majority of the expenditures (81%) were invested in the home country and, for US companies; Asia seems to be the most attractive foreign location for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

Like EU or US firms, Japanese companies spend the majority of their semiconductor design expenditures within their own 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 Japanese companies' semiconductor design budget. In comparison, the US and the EU obtained 5% and 4%.

The data also points to the fact that Asian companies concentrate their semiconductor design expenditures within their own region, where they spent 90% of their budget in 2008. Among foreign destinations of their semiconductor design 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, irrespectively 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. As indicated in Figure 5-5, its importance in this respect can be expected to further increase in the very near future.

**Figure 5-6: Destination of semiconductor design expenditures by source, 2008, in % (absolute values on the right hand side in € million)**




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

***Source of semiconductor design expenditures***

Figure 5-7 provides information on the source of semiconductor design expenditures in the five regions in 2008.

Concerning the EU, the major source of semiconductor design expenditures are EU companies. In 2008, over 80% of semiconductor design expenditures in the EU were made by domestic companies. Regarding the remaining sources, 8% and 6% came from the US and Japanese companies respectively, the largest foreign semiconductor design spenders in the EU.

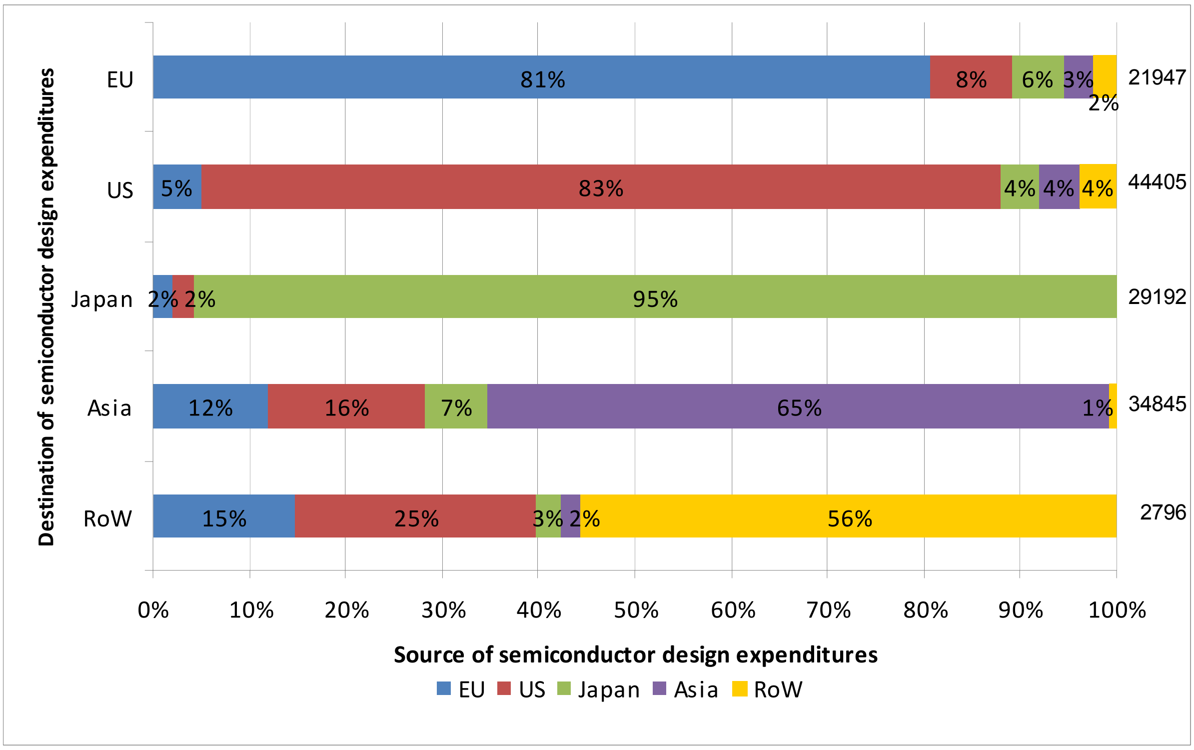
In the US, domestic companies are the largest semiconductor design investors and, in 2008, their share of semiconductor design expenditures invested in the US amounted to 83%. Among foreign companies, EU firms are the major investors in the US (5%). Firms from the remaining regions contributed equal shares of 4% to the total semiconductor design expenditures invested in the US.

Regarding Japan, the major investors of semiconductor design in this country are again local companies. In 2008, they contributed 95% of the total expenditures on semiconductor design. Among companies from other regions, only EU and US companies made notable contributions to semiconductor design spending in Japan. Companies from each of these regions accounted for 4% altogether of semiconductor design expenditures in Japan. This makes Japan the country with the lowest share of semiconductor design expenditure made by foreign companies.

Asia and the RoW show quite different patterns of semiconductor design expenditure composition from the other regions. In 2008, the Asian company share in the region's semiconductor design expenditures was 65% and for the RoW it was 56%. Both values are the lowest among the analysed regions. EU and US companies are the largest foreign semiconductor design investors in Asia and the RoW. For example, expenditures by EU companies amounted to 12% of the total spending on semiconductor design in Asia. For comparison, American companies contributed 16% to expenditures in the same region. Consequently, companies from these regions are the largest foreign contributors to the spending on semiconductor design in Asia.

The above data confirms that, in general, domestic companies contribute the most to expenditures on the design of electronic systems in each region. However, a detailed investigation reveals that some regions receive a higher share of foreign expenditures than others. For example, whereas only 5% of the semiconductor design expenditures in Japan are invested by foreign companies, the share of semiconductor design expenditures of foreign firms in Asia (excluding Japan) is 35%.

**Figure 5-7: Source of semiconductor design expenditures by region, 2008, in % (absolute values on the right hand side in € million)**




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

## 5.3 *Internationalisation of ICT R&D output: patents-based evidence*

The previous section provides a mapping of the allocation of ICT R&D input resources, such as R&D sites and semiconductor design expenditures. Following the logic of the R&D value chain as described briefly in Section 7.5.1, 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.[8]

Using patent data to identify internationalisation patterns is a long-standing tradition in innovation research (see, among others, Patel and Pavitt, 1991; Patel and Vega, 1999, and Le Bas and Sierra, 2002). However, while most of the previous studies have considered the patent portfolios of firms, here patents are attributed to countries, by exploiting the fact that patent data provide separate information on the places of residence of the inventors and the applicants. Thus, it is possible to track the output of inventive activity conducted by actors residing in different countries and regions. A methodology of constructing measures of internationalisation based on information included in patent applications is described in

[8] 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.

**Box 5-3: Patent-based measures of internationalisation**

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

**Cross-border ownership of inventions**: There are two concepts associated with this type of internationalisation that capture the notion of cross-border ownership of patents:
1) A domestic invention is owned by a foreign applicant. This concept captures foreign ownership of domestic inventions. It is used to construct a relative measure of *foreign ownership of domestic inventions*. This measure is defined as a share of a country's inventions owned by applicants residing outside of the country, in the country's total number of inventions (according to the inventor criterion).
2) A domestic applicant owns a foreign invention. This concept captures domestic ownership of foreign inventions. It is used to construct a relative measure of *domestic ownership of foreign inventions*. This measure is defined as a share of a country's ownership of foreign inventions in the country's total number of inventions (according to the applicant criterion).

OECD (2008a) and Annex II. The methodology description (see Box 5-3) gives a short description of internationalisation measures applied in the current study. The source of the data here is the European Patent Office's 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).

The remainder of this report is organised as follows: Section 5.3.1 compares the levels of international co-invention, co-ownership and cross-border ownership of inventions across the major world regions. Section 5.3.2 analyses in detail the patterns of internationalisation in each of the five world regions, the EU, the US, Japan, Asia and the RoW. [9]

[9] The RoW group includes altogether 78 countries that, in 2007, produced 7 423 ICT patent applications (as compared to 16 776 EU ICT patents). Although this group includes very heterogeneous countries, only few of them play some role in terms of the number of ICT patents. 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).

### 5.3.1 Internationalisation of ICT inventive output in global perspective

The current analysis starts with a general assessment of the internationalisation of the ICT inventive activity for the period 1990 to 2007. It is performed on five world regions: the EU, the US, Japan, Asia (excluding Japan) and the Rest of the World (RoW). Figure 5-8 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 the above methodological box.

***ICT Co-inventions***

Figure 5-8a presents the levels of international co-invention. In this case, each line represents collaboration of inventors from one particular region with inventors from remaining four regions, i.e. collaboration between 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, and 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).

***Co-ownership of ICT inventions***

In a similar fashion, Figure 5-8b 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 remaining four regions, i.e. co-ownership of EU and non-EU applicants, US and non-US inventors, etc. Comparing this kind of collaboration with co-invention (described above), one can see that although the ranking of regions stays the same (except for the period 1998-2001 when EU and US co-ownership shares exceeded the RoW), the levels are much lower. RoW applicants again have the highest share of RoW inventions co-owned with non-RoW applicants 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***

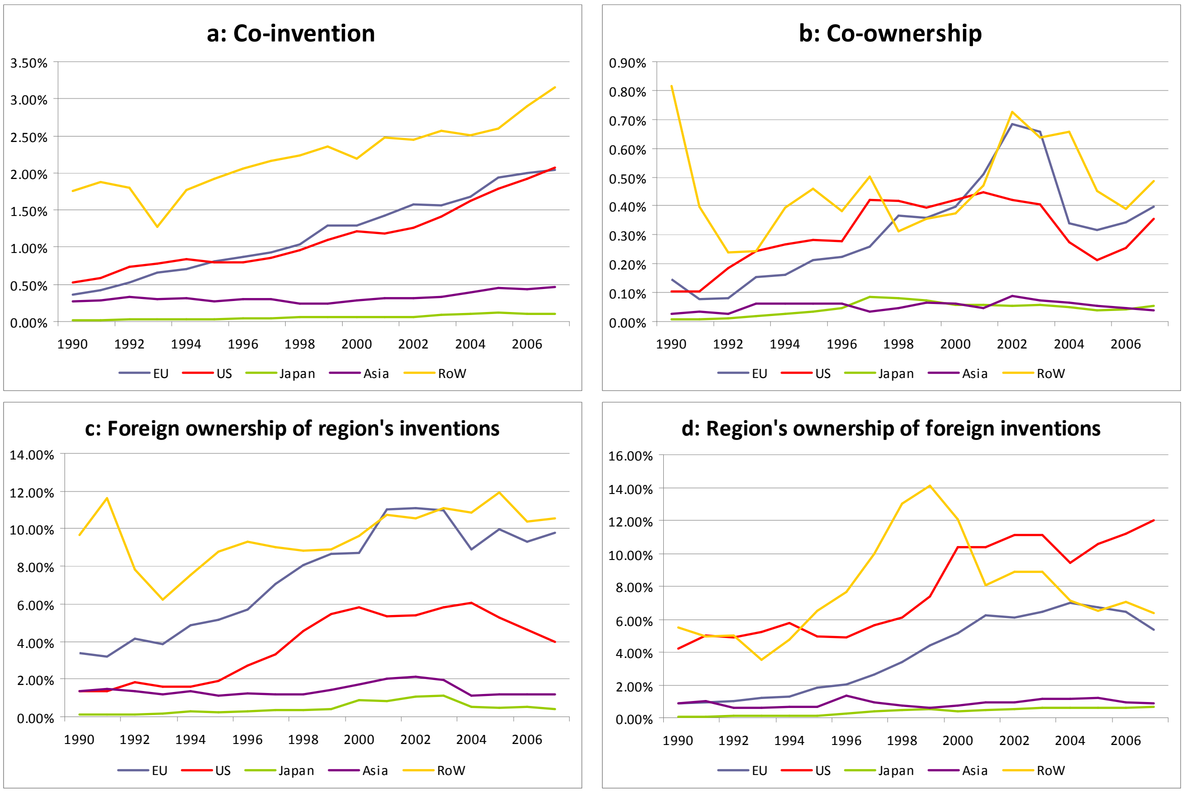
With respect to the levels of cross-border ownership of ICT inventions, Figure 5-8c presents the share of foreign ownership of region's ICT inventions in the total number of region's ICT inventions, i.e. non-EU ownership of EU ICT inventions, etc. Between 1990 and 2007, this share grows for every region except Asia. As in the previous picture, peaks occur during the period 2000-2005. The RoW again shows the highest level of collaboration as 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 others. US collaboration is only at about 5%; Japan and Asia are again at the bottom of this ranking.

***Domestic ownership of foreign ICT inventions***

Finally, Figure 5-8d presents the opposite relationship between inventors and applicants. It depicts the share of a region's ownership 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. Here, US applicants own about 5-6% more of non-US ICT inventions compared to EU applicants who own non-EU ICT inventions. Furthermore, the RoW region is no longer in the leading position and drops 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 shares below 1%.

An analysis of this data allows us to draw the following conclusions. First, there are significant differences between 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, though opposite, 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 5-8c) is higher than the share of non-EU ICT inventions owned by EU applicants (Figure 5-8d) indicates the relatively high importance of extra-EU applicants in the EU inventive activity. The typical case reflected by these data is a non-EU firm owning a R&D lab in Europe and filing patent applications either in Europe or in the US. Alternatively, as regards the gap in the case of the US, the share of US ICT inventions owned by non-US applicants (Figure 5-8c) is lower than the share of non-US ICT inventions owned by US applicants (Figure 5-8d). This highlights the important role of US firms in global inventive activity.

**Figure 5-8: 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.

### 5.3.2 The internationalisation of the ICT inventive output across regions

This section takes a closer look at the data analysed in the previous section. A detailed regional analysis is provided for each combination of region and metric. Previously used terms, i.e. *remaining four regions* and *foreign,* are now replaced by concrete regions.

#### 5.3.2.1 The case of the EU

***ICT Co-inventions***

Figure 5-9a 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 5-8a, is further examined by analysing the contribution of each remaining region to this level. This figure shows that US inventors are the most important 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 the opposite with Japan's 4% contribution.

***Co-ownership of ICT inventions***

Figure 5-9b 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 5-8b, 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 obscure. 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 the other four regions, which is 0.3% on average. On the other hand, exactly the opposite applies to the contribution of RoW applicants to EU co-ownership which starts at 51% in 1990, drops down to 9% in 2001 and rises again to 45% in 2007. Contributions by Japan and Asia are similarly volatile, but lower in magnitude.

***Foreign ownership of EU ICT inventions***

Regarding the levels of cross-border ownership of ICT inventions, Figure 5-9c 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 5-8c, is further examined by analysing the contribution of each of the other regions to this level. The main foreign owners 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 a 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 rising even though their contribution is still below 10%. The remaining two regions (Japan and the RoW) evenly contribute about 16% in 2007.

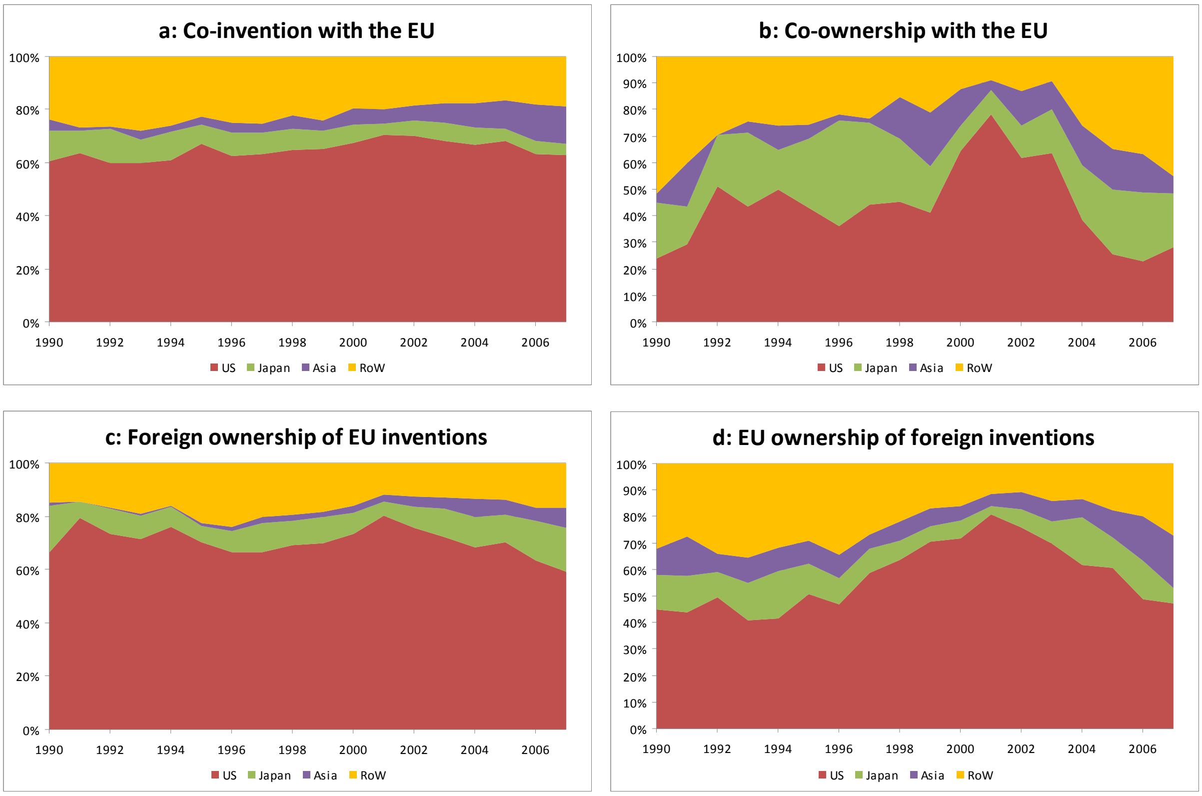
*EU ownership of foreign ICT inventions*

Figure 5-9d presents the opposite relationship between inventors and applicants. It 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 5-8d. The overall pattern here is very similar to the one shown in

Figure 5-9b. 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 the 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 followed by the RoW. One also cannot miss the growing role of Asia, and the shrinking role of Japan.

**Figure 5-9: 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.

#### 5.3.2.2 The case of the US

***ICT Co-inventions***

Figure 5-10a 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 5-8a, is further examined by analysing the contribution of each of the other regions to this level. This figure shows that although EU inventors are the major partners for their US colleagues at the beginning of 90s, their role has 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 a small part of US 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 5-10b 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 5-8b, is further examined by analysing the contribution of each of the other regions to this share. Figure 5-10b shows that the majority of US inventions that are co-owned 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 and 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 the other four regions, which is 0.3% on average). EU and Asian applicants then follow with 20% and 10% respectively. The situation, however, changes in 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, regional co-ownership has never returned to its 90s’ level and is much more diversified now. In 2007, three regions each have contributions over 20% – Japan (48%), Asia (28%), the EU (23%). Here, the only region that makes a decreasing contribution is the RoW.

***Foreign ownership of US ICT inventions***

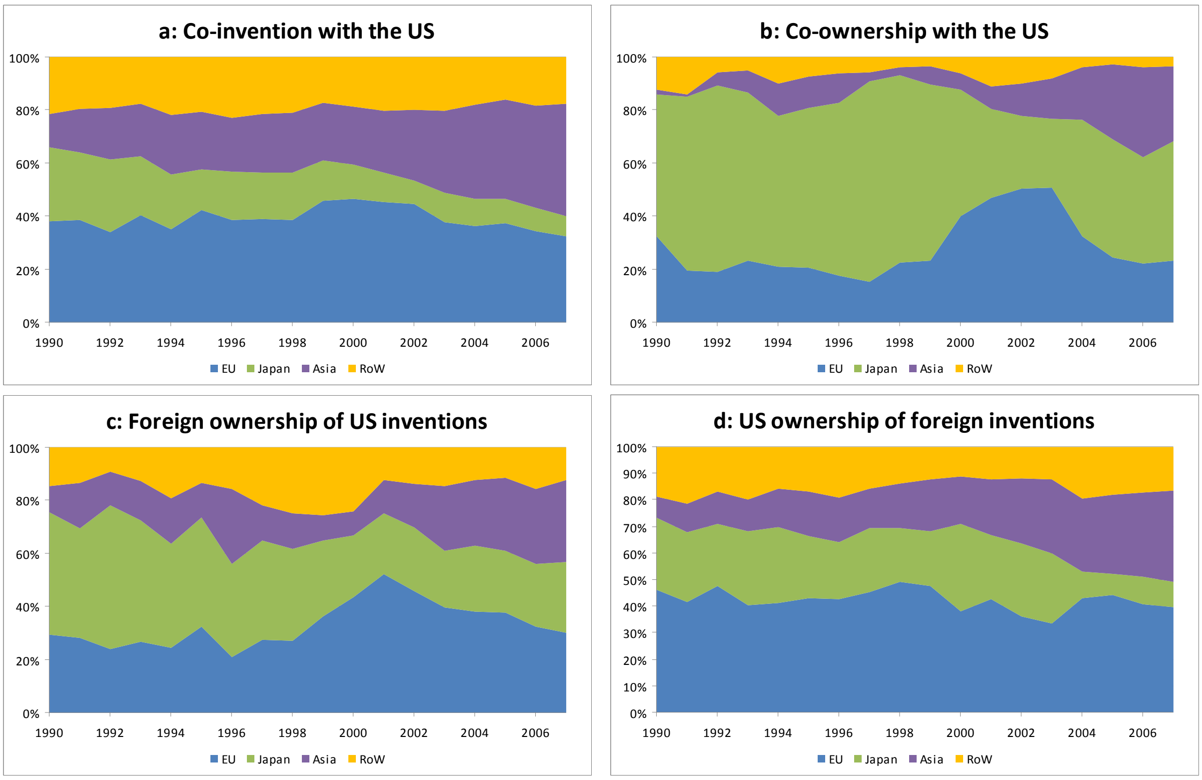
Regarding the levels of cross-border ownership of US ICT inventions, Figure 5-10c presents the international distribution of applicants owning US ICT inventions. In other words, the level of foreign ownership of US ICT inventions, presented in the previous section as a red line in Figure 5-8c, is further examined by analysing the contribution of each of the other regions to this level. This figure shows an almost exact analogy with the previous paragraph – a significant role is played by Japan in the 90s, which decreases from 2000, and an increasing role is played by the EU and Asia. The difference here 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, i.e. about 1.2% of all US inventions. Japan follows with a 27% contribution.

*US ownership of foreign ICT inventions*

Finally, Figure 5-10d 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 5-8d. There is an analogy here as well where the overall pattern is very similar to the one shown in Figure 5-10a. It is characterized by the important and stable role of the EU (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 more important than Japan.

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

**Figure 5-10: 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.

#### 5.3.2.3 The case of Japan

***ICT Co-inventions***

Figure 5-11a presents the international distribution of Japanese ICT co-inventive activities. In this case, the level of co-inventive activity by Japanese and non-Japanese inventors, presented in the previous section as a green line in Figure 5-8a, is further examined by analysing the contribution of each of the other regions to this level. This figure shows that US inventors are the major partners for their Japanese colleagues. It also shows that although their role decreases and is even overtaken by Asian inventors in 2005, it still reaches about 50% in 2007. Additionally, because of the gradually growing role of Asia, their joint contribution almost never drops below 80% during the whole period 1990-2007. Obviously, when interpreting this number, one has to keep in mind that it represents only a small part of Japanese inventive activities. Thus, if the level of total co-invention between Japanese and non-Japanese inventors in 2007 is 0.1%, the corresponding level between Japanese and joint US & Asian inventors is 0.08%. To be more precise, 0.08% of the total number of Japanese ICT inventions is co-invented with US or Asian inventors. The remaining portion of Japanese collaboration is split between the EU and the RoW (14% and 4% in 2007 respectively).

***Co-ownership of ICT inventions***

Figure 5-11b presents the international distribution of co-ownership with Japanese applicants. Here, the share of Japanese inventions (from the total Japanese inventions) co-owned by Japanese and non-Japanese applicants, presented in the previous section as a green line in Figure 5-8b, is further examined by analysing the contribution of each of the other regions to this share. Until 2002, US applicants owned about 80% of all Japanese ICT inventions that were co-owned by Japanese and foreign applicants. Again, one has to keep in mind that this number represents only contributions to the overall Japanese co-ownership level, i.e. the share of Japanese inventions co-owned by Japanese applicants with applicants from the other four regions, which is 0.04% on average. From 2002, however, the number of EU and Asian contributions to the overall Japanese level of co-ownership increases. Furthermore, the joint contribution of these two regions overtakes the US level in 2006 (52% vs. 48%). As one can see, the role of the RoW is only marginal.

***Foreign ownership of Japanese ICT inventions***

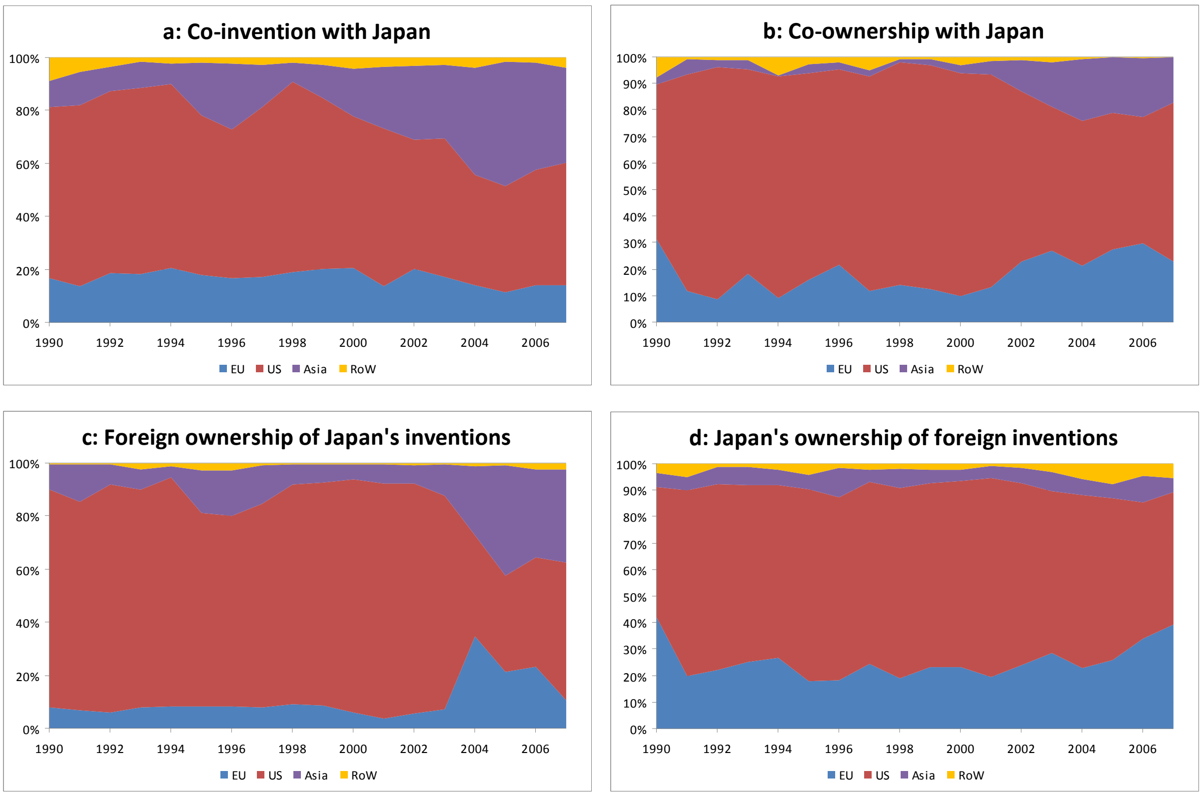
Regarding the levels of cross-border ownership of ICT inventions, Figure 5-11c presents the international distribution of applicants owning Japanese ICT inventions. In other words, the level of foreign ownership of Japanese ICT inventions, presented in the previous section as a green line in Figure 5-8c, is further examined by analysing the contribution of each of the other regions to this level. The main foreign owners of Japanese ICT inventions are US applicants with about an 80% contribution (until 2003), although their share decreases from then (reaching 52% in 2007). Thus, in 2007, 0.4% of Japanese inventions are owned by foreign applicants, and US applicants own more than half, i.e. about 0.2% of all Japanese inventions. On the other hand, the contribution of EU and Asian applicants increases substantially from 2003. This increase is clearly evident when, in 2003, the previous 80% US contribution is suddenly split between the EU and Asia, resulting in almost equal share for each of these three regions. This interesting and sudden shift will be the subject of further research.

*Japanese ownership of foreign ICT inventions*

Finally, Figure 5-11d presents the opposite relationship between inventors and applicants. It depicts the international distribution of the share of Japanese ownership of foreign ICT inventions in the total number of foreign ICT inventions. This share is presented in the previous section as a green line in Figure 5-8d. Here, the situation is far more stable in comparison with that of the previous graphs. The contribution of the US to the inventions portfolio owned by Japanese applicants is again very important and oscillates around two thirds. Since about 0.38% of all inventions in this portfolio are foreign in 2007, US inventions represent about 0.25% of all ICT inventions owned by Japanese applicants. The second most owned foreign inventions are those from the EU (about a 25% contribution on average, reaching 39% in 2007 though). Interestingly, Asia continues to play a small role (5% in 2007).

Based on the analysis presented above, we can conclude that the US region plays a dominant foreign role in Japanese ICT inventive activity. However, the growing role of the EU and Asia cannot be overlooked.

**Figure 5-11: Regional distribution of Japan 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.

#### 5.3.2.4 The case of Asia

***ICT Co-inventions***

Figure 5-12a presents the international distribution of Asian ICT co-inventive activities. In this case, the level of co-inventive activity by Asian and non-Asian inventors, presented in the previous section as a violet line in Figure 5-8a, is further examined by analysing the contribution of each of the other regions to this level. For Asia, the most important partner for collaboration in terms of co-invention is the US region. This region plays an almost stable role during the whole period, making a contribution of about 65-70% to the overall level of Asian co-inventive activity. Again, it goes without saying that when interpreting this number, one has to keep in mind that it represents only a small part of Asian inventive activities. Thus, if the level of total co-invention between Asian and non-Asian inventors in 2007 is 0.46%, the corresponding level between Asian and US inventors is about 0.3%. To be more precise, 0.35% of the total number of Asian ICT inventions is co-invented with US inventors. The remaining portion of Asian collaboration is split mostly between the EU and Japan. The EU contribution to this collaboration level is about 12% in 2007.

***Co-ownership of ICT inventions***

Figure 5-12b presents the international distribution of co-ownership with Asian applicants. Here, the share of Asian inventions (from the total Asian inventions) co-owned by Asian and non-Asian applicants, presented in the previous section as a violet line in Figure 5-8b, is further examined by analysing the contribution of each of the other regions to this share. However, as one can see, the situation is so complicated and volatile that it is impossible to draw any conclusion.

***Foreign ownership of Asian ICT inventions***

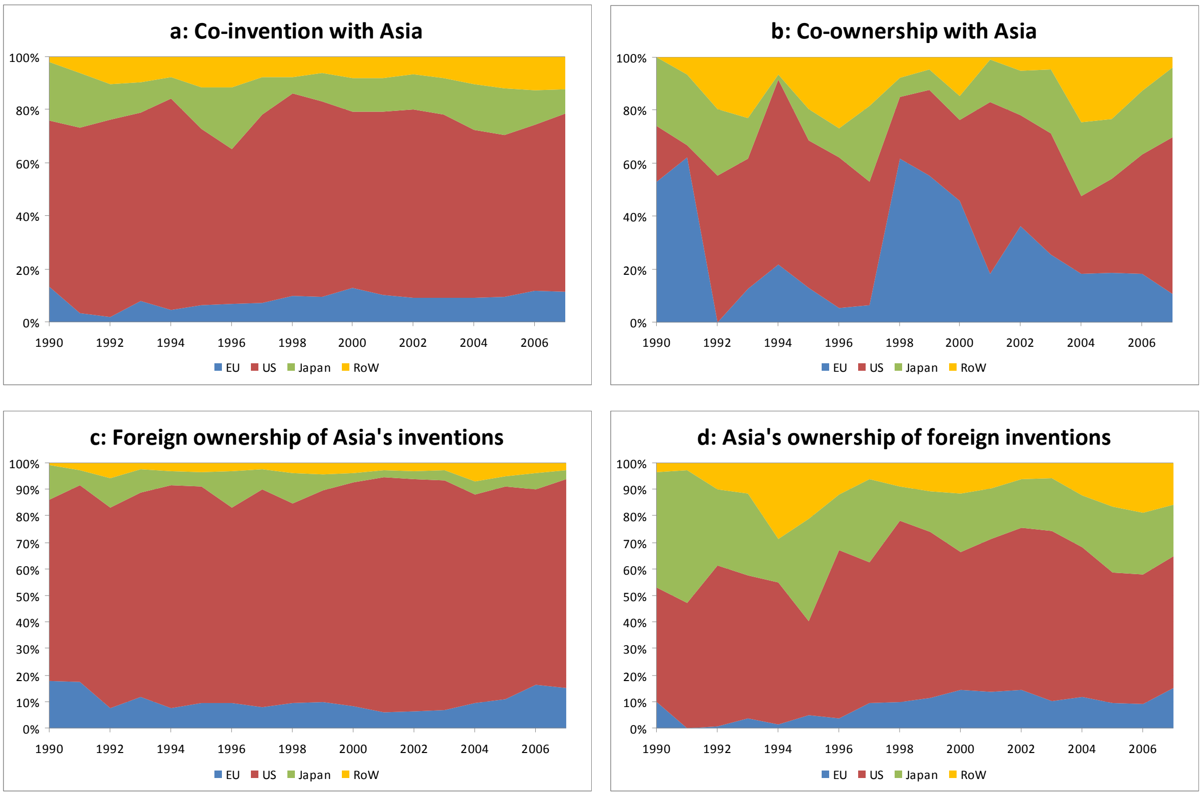
Regarding the levels of cross-border ownership of ICT inventions, Figure 5-12c presents the international distribution of applicants owning Asian ICT inventions. In other words, the level of foreign ownership of Asian ICT inventions, presented in the previous section as a violet line in Figure 5-8c, is further examined by analysing the contribution of each remaining region to this level. The overall pattern is very similar to the one presented in Figure 5-12a. The main foreign owners of Asian ICT inventions are US applicants with almost an 80% average contribution to the level of foreign ownership of Asian ICT inventions. Thus, if on average 1.4% of Asian inventions are owned by foreign applicants, US applicants own 80% of that, i.e. about 1.1% of all Asian inventions. On the other hand, the role of EU applicants stays below 20%.

***Asian ownership of foreign ICT inventions***

Finally, Figure 5-12d presents the opposite relationship between inventors and applicants. It depicts the international distribution of the share of Asian ownership of foreign ICT inventions in the total number of foreign ICT inventions. This share is presented in the previous section as a violet line in Figure 5-8d. The contribution of the US to the inventions portfolio owned by Asian applicants is again very important (almost 50% in 2007). Although it was quite volatile in 90s, overall, it has an increasing trend. When interpreting this 50%, one has to recall that in 2007 about 0.9% of all inventions owned by Asian applicants are foreign. Thus, US inventions represent about 0.45% of all ICT inventions owned by Asian applicants. The opposite trend can be seen in the case of Japan. While Japanese contribution was at the level of the one by the US in 1990, it is less than half in 2007. On the other hand, the contribution of the EU has been on rise, reaching almost the level of Japan in 2007.

Based on this analysis, we can conclude that the US is the most significant foreign region for Asian ICT inventive activity. The US is followed by the EU, which is more significant than Japan despite Japan's geographic proximity with the other Asian countries.

**Figure 5-12: Regional distribution of Asia 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.

#### 5.3.2.5 The case of the Rest of the World

***ICT Co-inventions***

Figure 5-13a presents the international distribution of RoW ICT co-inventive activities. In this case, the level of co-inventive activity by RoW and non-RoW inventors, presented in the previous section as a yellow line in Figure 5-8a, is further examined by analysing the contribution of each of the other regions to this level. Similarly to previously analysed regions, this figure shows that US inventors are the major partners for their RoW colleagues. Despite the fact that the RoW level of co-invention is gradually growing and it is by far the biggest among all regions, the contribution of US inventors to it remains stable at around 50-55%. Numbers of co-inventions with the EU are declining and drop to 27% in 2007. When interpreting these numbers, one has to keep in mind that they represent only a small part of the RoW inventive activities. Thus, if the level of total co-invention between RoW and non-RoW inventors in 2007 is 3.2%, the corresponding level between RoW and US (EU) inventors is 1.8% (0.9%). To be more precise, 1.8% of the total number of RoW ICT inventions is co-invented with US inventors. The remaining portion of RoW collaboration is mostly with Asia (21% in 2007). Japan's role is only marginal.

***Co-ownership of ICT inventions***

Figure 5-13b presents the international distribution of co-ownership with RoW applicants. Here, the share of RoW inventions (from the total RoW inventions) co-owned by RoW and non-RoW applicants, presented in the previous section as a yellow line in Figure 5-8b, is further examined by analysing the contribution of each of the other regions to this share. After the relatively even and stable results of previous paragraph, the situation in this case looks much more complicated. While co-ownership by EU applicants is about 80% at the beginning of our sample and 90% at the end, it drops to 30-40% twice. Moreover, in between it rises again to almost 70%. Again, one has to keep in mind that these numbers represent only contributions to the overall RoW co-ownership level, i.e. the share of RoW inventions co-owned by RoW applicants with applicants from the other four regions, which is 0.5% on average. In an exactly opposite pattern, the contribution of Asian applicants to RoW co-ownership starts and ends at almost 0%, while reaching two peaks of around 30-40% and dropping to 0% in between. Similarly volatile are contributions by US applicants, varying between 5% and 65%.

***Foreign ownership of RoW ICT inventions***

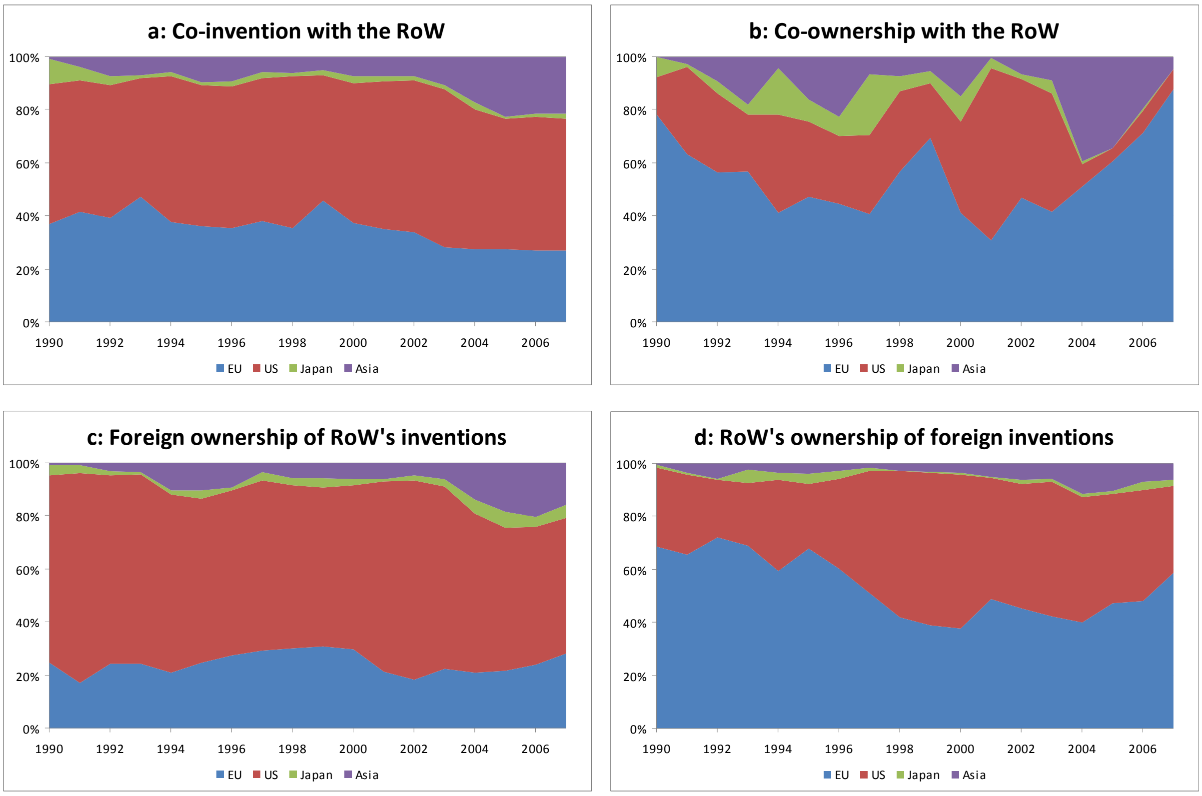
Regarding the levels of cross-border ownership of ICT inventions, Figure 5-13c presents the international distribution of applicants owning RoW ICT inventions. In other words, the level of foreign ownership of RoW ICT inventions, presented in the previous section as a yellow line in Figure 5-8c, is further examined by analysing the contribution of each remaining region to this level. The overall pattern here is very similar to the one shown in Figure 5-13a. The main foreign owners of RoW ICT inventions are US applicants with about 65% average contribution to the level of foreign ownership of RoW ICT inventions. Thus, if on average 9.6% of RoW inventions are owned by foreign applicants, US applicants own about 6.2% of them. The EU follows with a 25% average contribution. The remaining two regions (Japan and Asia) contribute less than 10% (on average), although the contributions of both of these regions are rising.

***RoW ownership of foreign ICT inventions***

Finally, Figure 5-13d presents the opposite relationship between inventors and applicants. It depicts the international distribution of the share of RoW ownership of foreign ICT inventions in the total number of foreign ICT inventions. This share is presented in the previous section as a yellow line in Figure 5-8d. The overall pattern here is a bit different from the one shown in Figure 5-13a or Figure 5-13b. In Figure 5-13d, the EU is the biggest contributor to the inventions portfolio owned by RoW applicants (59% in 2007), although there is a noticeable decreasing trend here. Thus, in 2007, almost 60% of the total number of innovations owned by RoW applicants is invented by EU innovators which represent about 4.7% in the inventions portfolio owned by RoW applicants. The second most owned foreign inventions are the ones from the US (about a 33% contribution in 2007). The fact that, on average, these two regions contribute more than 90% highlights the importance of the role they play.

Based on the analysis presented above, we can conclude that both the US and the EU regions play a significant foreign role in RoW ICT inventive activity. The other two regions (Japan and Asia) are far less important. Overall, contributions to the level of collaboration are much more stable than for other regions.

**Figure 5-13: Regional distribution of RoW 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.

# 6 ICT R&D in emerging economies: the cases of China and India[10]

This section offers a country-level approach to ICT R&D internationalisation by analysing the ICT industry in China and India, the two largest emerging economies. This approach provides concrete country cases which illustrate the trends analysed in the earlier sections.[11] As the internationalisation of ICT R&D within the triad, and particularly on the EU-US axis, can be considered as a mature and already well-observed phenomenon, the recent roles tentatively taken by China and India become important subjects for observation.[12] As stated by the OECD, "*in 2009, OECD countries' share of the ICT world market declined to 76% (from 84% in 2003), as growth in non-OECD economies decoupled from growth in OECD countries. As part of this shift the top 250 ICT firms include more non-OECD firms, among them manufacturing firms in Chinese Taipei, which have partly driven the rise of China as the major exporter of ICT goods, IT services firms from India, and telecommunication services providers from a range of non-OECD economies*."[13]

This section is an excerpt from a set of reports on the ICT industry and its R&D in emerging economies.[14] The data provided here is based on specific research complemented by desk research, expert workshops and interviews. Since the analysed countries are not members of the OECD, it is probably needless to state that the data, when available, are heterogeneous, not very comparable and usually based on non-governmental statistics. The authors tried as far as possible to make the figures as valid and consistent as possible.

The following sections are structured as follows. They provide first a brief overview on the country, and then analyse the national ICT industry. Finally they present its R&D, and inward and outward FDI flows.

## 6.1 *China*[15]

China is a giant country. With a population of 1 328 million inhabitants (2008) and an area of 9.6 million square kilometers, the People's Republic of China is the most populated country in the world and the largest country in Asia. It is the third largest in the world, after Russia and Canada.

China is also a country that has been going through accelerated reforms and economic growth since the early 80s. At the same time, it has opened its doors to global trade, commercial agreements at WTO and outside WTO, and to FDI flows. Since the reforms and the opening-up policies developed after 1978, the Chinese economy moved from a centrally planned system to a more market-oriented economy with a rapidly growing private sector. China is

[10] This chapter was written by Jean-Paul Simon and Marc Bogdanowicz, JRC-IPTS, European Commission.

[11] With globalisation, the emergence of new large actors in Asia but also in South America (Brazil), Africa (South Africa) or even Europe (Turkey)[11] leads to a potential recomposition of the past division of labour and to a new role for the ICT industry and its R&D in Europe. As already emphasised, an intensive process of redistribution of production across the world has taken place, accelerating in Asia in the post Asian financial crisis of the late 90s. On this, see also Van der Zee, 2006.

[12] See also: Dach B. (2007), Meyers and al. 2008, Von Tunzelmann and al (2011). All three sources are based on work commissioned by JRC-IPTS.

[13] OECD, 2010. p.14.

[14] Ling Wang, Shiguo Liu (2011) (forthcoming); Malik P., Vigneswara Ilavarasan P. (2011) (forthcoming); Shin-Horng Chen, (2011) (forthcoming); Simon J-P (2011) (forthcoming). All three sources are based on work commissioned by JRC-IPTS.

[15] This section is largely based on data from: Ling Wang, Shiguo Liu, 2010; Stephan Pascall, 2010.

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.[16] China's GDP, close to US$ 5 trillion[17] in 2009, is now similar to that of Japan, the 2nd largest in the world after the US.[18] Still, GDP per capita lags behind at a very low level, ranking China far behind the equivalent measure for the US or the EU.[19]

### The Chinese ICT industry

The ICT sector is certainly representative of the massive changes in the Chinese industry and economy. It has developed a strongly growing manufacturing arm, with large inward and outward FDI flows and export-led activities.

The ICT industry reached 8.4% of GDP in 2006 and employed over 6 million people, with manufacturing taking the major share (see Table 6-1).

**Table 6-1: 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 in Euros from data in: Ling Wang, Shiguo Liu, 2010 (forthcoming).

The Chinese ICT sector builds on the presence of foreign multinationals but also on the emergence of large national champions, having already developed a global reach. The industry shows high concentration with the emergence of large companies dominating the market, and is also concentrated geographically in only a few regions of China. During the last two decades, large multinationals, in particular Taiwanese, have taken 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, e.g., Huawei Technologies, Lenovo, and ZTE (see the list of the top twenty firms: Table 6-2). Huawei and ZTE are main players in the GSM, CDMA,[20] optical and DSLAM[21] equipment markets. Huawei Technologies has become a leading provider of

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[16] World Bank, WDI Databases, 2009.

[17] US: $10^{12}$

[18] Nominal. US: US$ 14.1 trillion; and, if taken into account as an economic entity, total EU27: US$ 16.4 trillion.

[19] See, for example, the rankings of the IMF and the World bank at: http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita .

[20] CDMA (Code Division Multiple Access): A method for transmitting multiple digital signals simultaneously over the same carrier frequency (the same channel). Although used in various radio communications systems, the most widely known application of CDMA is for cellphones. As of 2009, there were more than 460 million CDMA cellular users worldwide, with more than half in Asia. Verizon and Sprint are CDMA carriers in the U.S., while TELUS uses CDMA in Canada. QUALCOMM designs the chips for the CDMA air interface. (Source: http://www.pcmag.com/encyclopedia_term/0,2542,t=CDMA&i=39462,00.asp).

[21] DSLAM: Digital Subscriber Line Access Multiplexer) is a network device, usually at a telephone company central office, that receives signals from multiple customer Digital Subscriber Line connections and puts the signals on a high-speed backbone line using multiplexing techniques. DSLAM enables a phone company to offer business or homes users the fastest phone line technology with the fastest backbone network technology. (Source: http://searchtelecom.techtarget.com/definition/DSLAM).

telecommunications networks and is increasingly challenging established EU and US competitors like Siemens, Cisco, and Alcatel. Lenovo has become a global leader in the PC market since it acquired the IBM Personal Computing branch.

## Table 6-2: Top 20 ICT firms in China
## (Ranked by revenues from principal business, 2006)[22]

| Rank | Company | Revenue (Bn Euros) | Emp'ts (Heads) | Location of Headq. In PRC | Nationality of ownership | Registration Status[d] | Subsector/main products |
|---|---|---|---|---|---|---|---|
| 1 | China Mobile Communications Co. | 29.42 | 138 368[a] | Beijing | PRC | State holding | Telecom |
| 2 | China Telecom Corporation Ltd. | 17.49 | 243 072 | Beijing | PRC | State holding | Telecom |
| 3 | Hongfujin Precision Industry (Shenzhen) Co., Ltd. | 15.64 | 131 864 | Shenzhen, Guangdong | Taiwan, China | Solely owned | Computer peripheral equipment |
| 4 | China Unicom Ltd. | 9.62 | 463 000[a] | Beijing | PRC | State holding | Telecom |
| 5 | Motorola (China) Electronics Ltd. | 8.50[a] | 16 987[a] | Tianjin | USA | Solely owned | Mobile phones, walkie-talkie etc. |
| 6 | Nokia (China) Investment Co., Ltd. | 7.79 | 3 496 | Beijing | Finland | Solely owned | Mobile phones etc. |
| 7 | Huawei Technology Co., Ltd. | 6.56 | 35 673 | Shenzhen, Guangdong | PRC | Private owned | Program-controlled switchboards, software |
| 8 | Fu Tai Hong Precision Industry Co., Ltd. | 5.24 | 60 834 | Shenzhen, Guangdong | Taiwan, China | Solely owned | Mobile handset accessories |
| 9 | Inventec Technology Co., Ltd. | 4.60 | 10 221 | Shanghai | Taiwan, China | Solely owned | Notebooks, servers, storage products, etc. |
| 10 | Hisense Group Co., Ltd. | 4.34 | 12 924 | Qingdao, Shandong | PRC | State holding | Color TV, cell phone |
| 11 | Shanghai Dafeng Computer Co., Ltd. | 3.81 | 6 948 | Shanghai | Taiwan, China | Solely owned | Notebook, servers, mobile phones etc.. |
| 12 | Shanghai Dagong Computer Co., Ltd. | 3.79 | 7 515 | Shanghai | Taiwan, China | Solely owned | Computer and notebooks |
| 13 | Lenovo Information Products (Shenzhen) Co., Ltd.[b] | 3.50 | 4 563 | Shenzhen, Guangdong | PRC/USA | Solely owned | Computers |
| 14 | Shanghai Daye Computer Co., Ltd. | 2.80 | 5 084 | Shanghai | Taiwan, China | Solely owned | GSM mobile, micro-computer etc. |
| 15 | Lenovo (Beijing) Co., Ltd.[b] | 2.78 | 4 130 | Beijing | PRC/USA | Solely owned | Computers, software, etc. |
| 16 | Flextronics Industrial (Zhuhai) Co., Ltd. | 2.77 | 11 040 | Zhuhai, Guangdong | USA | Solely owned | Printed Cirruit Board +Assembly |
| 17 | Panda Electronics Co., Ltd. | 2.74 | 11 629 | Nanjing, Jiangsu | PRC | State holding | Wireless base stations, TV, cell phone etc. |
| 18 | Qun Kang Science and Technology (Shenzhen) Co., Ltd. | 2.73 | 16 020 | Shenzhen, Guangdong | Taiwan, China | Solely owned | Display production, semiconductors & components , etc. |
| 19 | Beijing SonyEricsson Putian Mobile Communications Co., Ltd. | 2.69 | 10 444 | Beijing | Sweden/ Japan | Joint venture | Mobile |
| 20 | LG Philip LCD (Nanjing) Co., Ltd. | 2.60 | 6 056 | Nanjing, Jiangsu | Korea/Netherlands | Solely owned | LCD Monitor |

*Note*: a. Data on revenue and employment of China Mobile Communications Corporation and China Unicom Ltd.for 2008, Data on Motorola (China) Electronics Ltd. for 2007.
b. Both Lenovo Information Products (Shenzhen) Co., Ltd. and Lenovo (Beijing) Co., Ltd. belong to Lenovo Group. According the origins of registered capital, Lenovo Group is classified as an American firm.
c. The nationality of firms are identified by the controlling owner of its registered capital.
d. *State-owned enterprises* (SOEs) are non-incorporation economic units which are funded completely by the State who owns all assets. *State-funded corporations* (SFCs) are mainly funded by the State as the controlling owner of all assets. *State-owned joint-operation enterprises* are funded partly by the State who is rather ordinary owner than controlling owner. *Enterprises with Funds from Hong Kong, Macao and Taiwan* refer to all enterprises with funds from Hong Kong, Macao and Taiwan. *Foreign Funded Enterprises* (FIEs) refer to all industrial enterprises with foreign funds. The latter two subcategories must be registered as the joint-venture, cooperative, sole (exclusive) investment enterprises and limited liability corporations.
e. It means the number of staffs in China Mobile Group Design Institute Co., Ltd in 2008. See http://www.cmdi.chinamobile.com.
*Sources*: *Yearbook of China's large industrial enterprises 2007*(NBSf, 2007); Data for China Mobile Communications Corporation from www.chinamobileltd.com; Data for China Telecom Coporation Ltd. from www.chinatelecom-h.com; Data for China Unicom Ltd. from www.chinaunicom.com.hk. Data on the location of headquarter, nationality and registered status from *Searching System of the General Book of the Registration data of the Nationwide Foreign Invested Enterprise (*Registration Bureau of Foreign-Invested Enterprises of State Administration for Industry and Commerce, 2005）. *Main Source*: Based on data from Ling Wang, Shiguo Liu, 2010 (forthcoming)

[22] ZTE, a major Chinese provider of global fixed and mobile telecommunications equipment and network solutions could also appear in this Top 20 ranking. Nevertheless, various sources position its revenues (2006) just below LG Philips, ranked 20th. ZTE claims to employ around 40 000 staff, and spend over a third of its revenues on ICT R&D. For more information see at: http://wwwen.zte.com.cn/endata/magazine/ztetechnologies/2007year/no9/articles/200709/t20070921_161868.html

### ICT R&D in China

ICT R&D in China seems to be in its infancy and largely foreign-led. 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 R&D intensity growing rapidly 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).[23] An estimated 20% of Total GERD was dedicated to ICT R&D.

**Table 6-3: Chinese ICT R&D expenditures profile (2006[24])**

| | |
|---|---|
| **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 in Euros from data in: Ling Wang, Shiguo Liu, 2010 (forthcoming).

ICT R&D expenditures and ICT R&D employment followed similar growth trends. R&D expenditures in manufacturing reached close to € 6 billion with services representing only a very low share. There were some 150 000 R&D employees in 2006, most of them also in manufacturing.

ICT R&D expenditure in China is more focused on the development and applications side (observers estimate that 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 processors, digital TV, etc.

At the early stage, foreign R&D centres' main activities included services for the local market, conducting applied research, and developing new adaptive technology. In recent years, the focus of foreign R&D centres seems to be gradually shifting, striking a balance between local market demand and the companies' global strategy.

When comparing ICT R&D in China with that of developed countries, "*the technical innovation ability of the ICT industry in China is still poor, technology breakthrough is limited, (…). Most innovation focuses on peripheral technology rather than core technology, (…). On the other hand, there is no dispute that Chinese indigenous innovation capabilities are increasing. More and more enterprises have their own independent intellectual property rights and brands. Some enterprises have become players in the global market, such as Huawei and ZTE in Telecommunication equipment, or Lenovo in Computer and peripherals equipments*."[25]

To sum-up, China's ICT R&D activity seems to be still at an early stage of development, with low investments by international standards, but high growth and ambitions for the mid-term future. It is largely FDI based, and market adaptation oriented.

***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,

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[23] 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.

[24] Latest official statistics available.

[25] Adapted from the Conclusions section of: China Country Report, by Ling Wang, Shiguo Liu, 2010 (forthcoming).

followed by India (sixth) and Singapore (ninth).[26] For some observers, China is expected to become an even more attractive location for future R&D investments than the United States (Dieter, 2008).

According to Monika (2007), the reasons why high-tech companies envisage increasing R&D activities in China include access to human resources, proximity to customers/markets, and the benefits provided by China's R&D-friendly environment. Monika reports that the most important reason multinational companies make R&D investments in China is to acquire high quality human resources. They also hope to benefit from the level of Chinese economy development, the market scale and opportunities, and science and education development. China is emerging as an important source of R&D personnel.

Much of R&D offshoring to Asia is concentrated in the electronic industry, with –in line with previously mentioned observations- China as the most popular location for R&D for hardware. Practically all global ICT industry leaders have located some R&D activities in China. The main R&D centres concentrate on the manufacturing of Multimedia and Telecom Equipment (NACE 3220 and 3230) such as the Motorola China Research and Development Institute, the Ericsson China R&D Institute and the Nokia R&D Centre. There are also R&D centres belonging to multinational companies in China's software industry (e.g. Microsoft Research Asia, Microsoft China R&D Group, 3M China Research & Development Centre, Cisco China Research & Development Centre, eBay China Development Centre and EMC-Oracle China Technology Development Centre).

FDI in China is mainly located in the Eastern coastal areas, such as Guangdong, Zhejiang and the Fujian Provinces. However, many FIEs (Foreign invested enterprises)[27] locate only labour intensive activities in these areas. Most R&D centres set up by MNCs are located in the largest cities such as Beijing, Shanghai, Guangdong. Other important cities such as Tianjin and Xi-An have also attracted large amounts of foreign R&D investment.

***Chinese ICT R&D off-shoring***

China is also becoming a major source of outward foreign direct investment (OFDI). Starting from no OFDI at all in 1979, the initial year of China's open door policy, China had accumulated over US$ 117.91 billion of OFDI by the end of 2007 (ECCOM, 2009). China's OFDI flow and stock is now 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 into China, China's OFDI has less scale and is still at an early stage.

Chinese companies target three different groups of OFDI locations in the world. The first is industrialized economies, especially the US. The second destination is the newly industrialized economies and other transition economies, including Hong Kong and Macao. Along with overseas investments in Russia and Middle Asia, this second group accounts for more than 70% of the total OFDI. The third destination is developing countries, especially South Asian economies (Vietnam, Cambodia, and Laos) and African countries. China has become a leading source of FDI in Africa (ECCOM, 2009).

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[26] UNCTAD, 2005.

[27] Foreign Invested Enterprises (FIEs) refer to foreign companies, enterprises and other economic organizations which have establishments or places in China according to Chinese law and engage in production or business operations, and which, though without establishments or places in China, have income from sources within China. It includes 'Chinese-foreign joint venture enterprise', 'Chinese-foreign cooperative joint venture' and 'Foreign sole-source investment enterprise'. Sources: State Department of China, Requirements With regard to business registration division, http://www.gzas-l-tax.gov.cn/taxlaw/show.asp?id=1952).

To sum-up, the 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 ahead, considering that the absolute level of R&D expenditure is still modest.

## 6.2 *India*[28]

India is the seventh-largest country by geographical area, and the second most populated country in the world with over 1.18 billion people. India is a federal constitutional republic with a parliamentary democracy consisting of 28 states and seven union territories.

The Indian economy is the world's eleventh largest economy by nominal GDP (US$ 777.74 billion in 2007–08). The GDP growth rate has been impressive for the last two decades with 9.1% in 2007-08 and it was forecasted to grow by 8% in 2010.[29] Since the introduction of market-based economic reforms in 1991, India has become one of the fastest growing major economies in the world. The contribution made by agriculture to the national economy is declining slowly (still 17.5% of the national income in 2009) and there is a rise in the service and manufacturing sectors.

With 64% of the population in the working age group (15-60 years) and growing per capita revenue, India is becoming a major market opportunity.

**The Indian ICT industry**

The macroeconomic picture in India "*reveals also the importance of the services sector in the Indian economy. The ICT sector mirrors this as it is dominated by the services sector, with manufacturing forming a very small proportion of the activity. It is in this context that ICT R&D, internationalisation of ICT and the ICT innovation system have to be situated*".[30]

According to the National Association for Software and Services (Nasscom),[31] a major stakeholder of the ICT sector in India, the sector has the following profile:

- Total IT-BPO industry[32] was expected to reach aggregate revenues of US$ 73.1 billion in 2010, with the IT software and services industry accounting for US$ 63.7 billion of revenues. As a proportion of national GDP, the sector *revenues* grew from 1.2% in 1998, to 5.2% in 2007, 5.8% in 2008 and could reach an estimated 6.1% in 2010.
- Its share of total Indian exports (merchandise plus services) increased from less than 4% in 1998 to almost 26% in 2010.[33]

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28 This section is largely based on Malik P., Vigneswara Ilavarasan P. (2010) (forthcoming); and Mita Bhattacharya, Graham Vickery, (2010).

29 Mita Bhattacharya, Graham Vickery, (2010).

30 Malik P., Vigneswara Ilavarasan P. (2010), p.5.

31 Nasscom Industry Trends, 2008 data, accessed September 2010. Information on Indian ICT industry is abundant, but surprisingly access to macro level data in national accounts or micro level firm data is difficult. The major source is the National Association for Software and Services Companies (NASSCOM). Firm level data in the NASSCOM annual directories are not available beyond 2003. NASSCOM provides only aggregate data and a limited break up details.

32 The sector is analysed as "IT-BPO" – BPO standing for Business process outsourcing. These important but non-official statistics do not match perfectly usual taxonomies. In particular, while seen as similar, IT-BPO data cannot be assimilated to the standard NACE-based Computer Services and Software sub-sector. Still, considering the low availability of (recent) data, it is useful to use and contrast all such sources, notwithstanding the divergences in definitions and collecting methodologies.

33 Nasscom Strategic Review 2010, last accessed October 2010.

- During this period, direct employment in the ICT sector is expected to reach nearly 2.3 million.

According to the latest available official data at national level,[34] the contribution of the ICT sector to GDP is more modest than the one claimed by NASSCOM,[35] with 3.42% in 2004 (see Table 6-4):

**Table 6-4: 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 in Euros from data in: Malik P., Vigneswara Ilavarasan P., 2010 (forthcoming). Employement data from NASSCOM, quoted by Mita Bhattacharya, Graham Vickery, (2010).

The overall profile of the sector, as described by official statistics, is similar to the one presented by NASSCOM, with an overwhelming dominance of the Computer Services and Software activity as can also be indirectly deducted from the profile of Indian ICT exports, largely dominated by those CSS activities (91.6% in 2005-06).[36]

Recent evolution of the Indian ICT sector can be mapped approximately in three phases. In the first phase, up until 1984 the state attempted to run the industry and tried to pre-establish its technological trajectories. This resulted in the absence of a commercial private sector. During this phase, there was no great differentiation between software and hardware. During the second phase (1984-90), software was targeted by the government as a viable option for income generation and technological capability enhancement. Since 1990, the software export industry has blossomed, aggressively promoted by both national and sub-national governments, and the hardware sector has been relegated to a secondary role. The Indian ICT sector became seen predominantly as a software services exporter.[37] However, this might change with time as the activities of the sector are now evolving from providing low-end onsite services to high-end offshore services, and investments in semiconductor manufacturing are also increasing.

The industry is dominated by large players with the top two hundred firms contributing 86% of the total revenues (see the top twenty: Table 6-5). ICT firms are prominently located in six major clusters, Bangalore (State of Karanataka), Mumbai and Pune (State of Maharastra), Chennai (State of Tamil Nadu), Hyderabad (State of Andra Pradesh), and the National Capital Region which consists of New Delhi (State of Delhi), Noida (State of Uttar Pradesh) and Gurgaon (State of Haryana). Over 90% of the export revenues come from these regions.[38] A comparison of the major ICT clusters shows that the Bangalore cluster presents a more mature

34 Barnjee, 2009, p.138. “The latest available report by the Department of Scientific and Industrial research (…) captures industrial R&D expenditure data up to 2002-03.”

35 As calculated in official statistics on value added and not on revenues contribution to GDP, in line with international statistical standards.

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

37 Source: Adapted from data in: Malik P., Vigneswara Ilavarasan P., 2010 (forthcoming).

38 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.

ecosystem for the ICT industry when compared to the others.[39] Due to its historical advantages, it has an specialised labour market, proximity with top-level research institutes, government research labs; presence of venture capital; and a mix of large domestic firms, multinationals and suppliers of various sizes.

**Performance of IT services firms in India**

Demand for IT and business process outsourcing (BPO) continued during the recent crisis, with firms taking further advantage of (offshore) outsourcing to reduce their costs. Indian IT services firms have benefited from this trend. However, decreasing total contract value (in 2009 it was the lowest since 2001) and increasing competition from other offshore locations such as Brazil, China and the Philippines have put the revenue growth of Indian IT services providers under pressure.

**The Indian IT services industry** (including IT services, BPO, and software and engineering) has grown at two-digit rates year on year since the late 1990s. Only in 2010 has year-on-year revenue growth slowed to one digit (6%). Between 2000 and 2010, annual revenue in the industry grew at 27% a year to reach almost US$ 64 billion in March 2010.

**The top 10 Indian IT services firms** generated almost US$ 23 billion in annual revenue 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. Quarterly revenues of the top 10 Indian IT services firms have been increasing year on year (33% on average), since the 3% year-on-year decline in the first quarter of 2001. In the first quarter of 2009, however, quarterly revenue growth turned negative (around –5%) and remained slightly below zero in the following quarters of 2009.

*Source*: OECD, 2010a. IT Outlook, p.32.

"*Until the early 1990s, MNCs relied on interim IT service contractors in India, known as 'body shopping'. Currently more than 500 major international firms have IT operations in Bangalore alone, and other centres such as Hyderabad have rapidly increased in importance. Major IT MNCs, IBM and Oracle have Indian development centres as part of all global application development projects - for example IBM has six such centres, and Electronic Data Systems and Computer Sciences Corporation have substantially increased their presence. Other major MNCs with Indian subsidiaries that export IT services include Microsoft, Hughes, Hewlett-Packard, Siemens, Lenovo, Genpact, Nortel, Motorola, Intel, i2 and Cisco*".[40]

As seen above, the Service sub-sector, composed of Computer Services and Software, and Telecommunications Services, has kept on growing when compared to the Manufacturing sector. India has adopted a strategy in the ICT sector, concentrating more on services (exports) than on manufacturing.

[39] For a discussion, see for example: Vang J., Chaminade C. (2006).
[40] Mita Bhattacharya, Graham Vickery, (2010).

**Table 6-5: Top 20 ICT firms in INDIA (Ranked by revenues, 2007-08)**

| Rank | Name of the company and location | Revenue (million Rs.) 2007– 08 | Empl. | Location | Starting year | Products and services |
|---|---|---|---|---|---|---|
| 1 | Tata Consultancy Services (TCS) | 212,150 (93% export and 7% domestic) | 126 150 | Bangalore. | 1968 | Software services, IT consulting, and BPO |
| 2 | Wipro Technologies | 168,840 (76% export and 24% domestic) | 108 071 | Bangalore | 1981 | IT services, product engineering services, technology infrastructure services, consulting services, BPO |
| 3 | Infosys Technologies | 155,310 (99% export and 1% domestic) | 104 850 | Bangalore | 1981 | IT services, IT products, BPO, consulting |
| 4 | HP India | 154,540 (18% export and 82% domestic) | 31 656 | Bangalore | 1989 | Enterprise servers, software & storage, hardware, imaging and printing, IT services & solutions |
| 5 | IBM | 101,010 (58% export and 42% domestic) | 76 000 | Bangalore | 1992 | IT services, BPO, servers, storage, middleware, and systems software |
| 6 | Cognizant Technology Solutions | 63,100 (100% export) | 48 000 | Chennai | 1994 | IT Services and BPO |
| 7 | Ingram Micro | 86,200 (100% domestic) | 1 200 | Mumbai | 1996 | Distribution of IT products and consumer electronics |
| 8 | HCL Technologies | 62,000 (93% export and 7% domestic) | 51 979 | Noida | 1991 | Software, infrastructure, and BPO |
| 9 | HCL Infosystems | 50,580 (100% domestic) | 6 077 | Noida | 1976 | Computers, storage systems, managed systems, infrastructure, office automation, software and network integration |
| 10 | Redington India | 62,800 (100% domestic) | 1 700 | Chennai | 1993 | Distributor of PCs, servers, peripherals, consumables, and networking equipment and components |
| 11 | Cisco India | 58,370 (92% export and 8% domestic) | 4,850 | New Delhi | 1995 | Networking |
| 12 | Oracle India | 58,080 (N.A.) | 24 000 | Gurgaon | 1993 | Database, middleware, application software |
| 13 | Intel India | 43,100 (90% export and 10% domestic) | 2 500 | Bangalore | 1988 | Processors, platforms, boards, R&D |
| 14 | Accenture | 38,000 (93% export and 7% domestic) | 40 000 | Bangalore | 1987 | IT services & Consulting |
| 15 | SAP India | 32,600 (79% export and 21% domestic) | 5 424 | Bangalore | 1996 | Packaged Software and services |
| 16 | Dell India | 32,000 (100% domestic) | 13 000 | Bangalore | 2000 | Desktops, Laptops, and servers & storage |
| 17 | Tech Mahindra | 36,370 (98% export and 2% domestic) | 24 318 | Pune | 1986 | Software services & BPO |
| 18 | Microsoft India | 32,630 (90% export and 10% domestic) | 5 300 | Gurgaon | 1981 | IT services, software & consulting |
| 19 | MphasiS | 18,810 (100% export) | 33 810 | Bangalore | 1992 | IT services, BPO |
| 20 | Patni Computer Systems | 25,690 (99% export and 1% domestic) | 14 479 | Mumbai | 1978 | Application development, infrastructure management services, BPO, engineering design & embedded systems |

*Source*: Quoted by Malik P., Vigneswara Ilavarasan P., 2010 (forthcoming) from Dataquest, 2009. http://dqindia.ciol.com/dqtop20/2009/CompanyRanking/default.asp (accessed 8 May 2010).
*Note*: Data was given voluntarily by the firms to Dataquest. The composition may differ from the NASSCOM data where detailed information on firms is not given.

### 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.[41] Banerjee (2009, p.136) in addition states that "*both in nominal and real terms, there has been a decline in the overall GERD and the GERD to GDP ratio has declined during the post reform period*" and observes that the business enterprise sector shows sharp BERD increase, but still at only 20% of total GERD.

**Table 6-6: Indian ICT R&D expenditures profile (2004[42])**

| | |
|---|---|
| **Total GERD** | € 3.8 billion[43] |
| **Total GERD/GDP** | 0.69%[44] |
| **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 in Euros from data in: Malik P., Vigneswara Ilavarasan P., 2010 (forthcoming).

Consequently and based on available data, the level of ICT R&D in India is very modest. Also, its share of GERD ranks second to the pharmaceutical industry R&D (20% of total GERD). 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.[45]

There are two main sets of players who perform most of the ICT R&D activities – large domestic players and subsidiaries of multinationals (Malik P., Vigneswara Ilavarasan P., 2010). The large domestic players undertake two kinds of innovative activities. First, internal ones, targeting service delivery process improvements which are used by the firms themselves (R&D expenditures spent on these activities are not disclosed by the firms). Second, those activities performed for external clients who outsource their product development activities, called '*engineering services & R&D and Software products*', often presented as high-end work.

Although Indian firms are expanding their global reach and technology domains through acquisitions, it would be an exaggeration to conclude that these acquisitions aim at R&D capability transfers. Indian firms continue to cater to western clients through software product development or engineering services, and they innovate for in-house consumption rather than developing commercial products for the open market. This view is echoed by the Indian National Institute of Science, Technology and Development studies: "*The low investment in*

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41 To compare with the € 30 billion (2006) observed in China. In EU27 GERD was above € 200 billion and US GERD above 300 billion at the time.

42 Latest official statistics available

43 In Banerjee, 2009: GERD = € 3.2 billion for 2002-03.

44 Stated to be 0.8% (with no reference year) in Bhattacharya M. Vickery G., (2010).

45 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 3 651 in 2000 to 15 045 in 2004". Such lows estimates might be due to two possible reasons: the large public sector (estimated recently to account for 1 208 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.

*R&D is an indication that India is still involved in activities that are not creating higher value at different levels."*[46] This statement seems to apply particularly well to the ICT sector.

Since the Indian ICT sector concentrates on services, innovation is predominantly on processes. This service innovation is observed in areas such as: the transition from on-site to off-shore servicing (from sending people for project execution at the client's site to executing and managing projects in India); '*productised services*', in which Indian firms standardise the services provided to clients and sell them as productised services, just below the level of products that could be seen as off-the-shelf ones; virtual extension, in which Indian firms serve as sub-contractors but interact with primary clients directly. Service process innovation is also crucial in explaining the success of the Indian Telecom sector. India was the first to tailor tariff packages in line with the affordability profiles of Indians and also outsource network expansion but this has yet to become a global trend.

***FDI-led ICT R&D***

Foreign direct investment (FDI) followed three successive stages in India. The third most recent stage saw the establishment of R&D centres by established or new foreign companies in India. Analysis of data on total FDI shows that Singapore, with US$ 8 667 million invested, and the US (US$ 7 443 million) are major sources of FDI in India.[47] These investments occurred mostly during the period 1996-2000. In this period, R&D investment worth US$ 1.13 billion flowed into India.

Out of these investments, the US invested most (some US$ 860 million) in R&D centres, followed by countries like the UK, Japan and Germany to a much smaller extent.[48] Other countries with a presence are Switzerland, Sweden, South Africa, Norway, Netherlands, Mauritius, Denmark, Canada and Australia. A number of R&D investments (in the range of US$ 80 million to US$ 250 million) were announced in 2005–2006 in the telecom and networking sector by companies such as Alcatel, Ericsson, EMC Elcoteq, Flextronics, Nokia, Samsung, and Siemens (Mitra, 2007). The OECD concludes: "*Global ICT leaders such as Dell, Microsoft, IBM, Oracle, Ericsson, Unisys, Motorola, HP, Texas, Fujitsu, Siemens, and Bosch have invested in India*".[49]

There are multiple reasons for US industry dominance. The US are the major consumers of software services that are originating from India. Firms that explored the Indian market for off-shoring are from US. Also, historically, high-skilled Indians migrated to the US for higher studies, and later went back to work in the high technology sector in India. Reverse migration of Indian immigrants, who connected the demand in the US with the supply in India through their professional networks and understanding of market and technology, helped the industry to cement linkages between the US and India in the ICT sector.

By 2007, more than 250 Fortune 500 companies had forged R&D links with India. Of these, 150 have established global R&D centres in India (Satyanand, 2007). FDI in R&D has more than doubled since 2003 and now amounts to 25% of the total FDI inflow. Transnational

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46 Banerjee, 2009, p.139.

47 It remains difficult to understand what is hiding behind these data. Mauritius appears as the top investor during the period 2000-2009 with US$ 43 143 million. This is a statistical bias, probably similar to the case of Singapore, as those smaller states, offering favourable taxation schemes for such transactions, serve as apparent source for holding an intermediation role. Mauritius, for example, has a double taxation avoidance agreement with India (and is geographically close to India).

48 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

49 Mita Bhattacharya, Graham Vickery, (2010).

Corporations (TNCs) from the US have invested more than 70% of the total, followed by South Korea, Germany, Denmark, and the UK.

R&D and innovation in ICT manufacturing 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 pursue a dominant service strategy in the future.

***Indian ICT R&D off-shoring***

The contribution of the Indian ICT sector to outward FDI, measured through values of mergers and acquisitions (M&A), is increasing with the total number of deals involving Indian ICT firms amounting to significant total investments (US$ 3.4 billion in 2008 from US$ 2.9 billion in 2007).[50] Acquisitions are typically made in the software development and semiconductor design areas, followed by the associated business processing domains, underlining again the specialisation of the Indian ICT sector in CSS, and its (marginal) drive towards the niche market of semi-conductors IP design.[51] Apart from strengthening the variety of niche technology domains, Indian firms also use acquisitions to access different geographical regions.

There is little evidence of specific acquisition of R&D centres of multinationals by Indian firms. Though Indian firms are expanding their global reach and technology domains in services through acquisitions, it would be difficult to conclude that R&D capabilities are part of this strategy. 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.

***Conclusions***

The Indian ICT innovation system has a dynamic private sector with a significant number of multinational companies and R&D units. Efforts are also being made to nurture technology entrepreneurship by the government and increasing foreign investment in R&D. Yet, deeper examination suggests that within these apparent strengths are embedded a number of limitations.

Concerning the ICT industry, together with most observers, the OECD states: "*India has become the global front office, handling customer service calls, and back office, helping to process payments and run accounting and other computer systems. However, the current 'lift and shift' model will not continue in the long run. India needs to become one of the head offices –innovating new products and techniques or shaping major corporate strategies – and a provider of higher value added services in this changing environment, including in growth areas such as cloud computing, security and privacy*".[52]

Policy recommendations made by various authors and the OECD (2010a) stress the need for more public and private investments in R&D and innovation, better research output from the higher education system, more support to the high-technology sector, including SMEs, R&D–related spill-overs of foreign direct investment in R&D, and improved infrastructures. At the moment, the level of investment in ICT R&D is low and the balance between hardware and

50 Nasscom, 2009.
51 Tuomi, 2009.
52 Mita Bhattacharya, Graham Vickery, (2010).

software could keep the Indian ICT industry in a fragile global position in the long-term future.

# 7 Conclusions

Building on the methodology presented in Section 5.1, this report 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 report 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.

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 interpreted with some caution because of the explicit limitations of the available data. Nevertheless, further cross-checking allows us to consolidate most of those observations. Finally, the country-level observations of selected countries complement the perspective with concrete examples and data.

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

Regarding the level of internationalisation at the specific stages of R&D, some of the most important findings are summarized below.

***Internationalisation of ICT R&D input***

- Independently of the region of a firm's headquarters, most the firms analysed tend to locate most of their R&D centres in their home country or 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 centres, whereas EU, US and Japanese firms have the most internationalised R&D centre infrastructure.
- Similarly, irrespectively of the region of origin, ICT companies 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 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 shares of total expenditures on the design of semiconductors are declining continuously.
- 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 very attractive as a location for R&D centres for ICT companies from the EU, the US, Japan and Asia itself. For example, although for American firms, the EU seems to be the most attractive location for R&D centres abroad, in 2009 Asia hosted only 5% less US-owned R&D centres than the EU (16% versus 21%). EU companies also seem to find Asia very attractive. EU companies own the same share of R&D centres in Asia as they do in the US (18%). This is a sign that Asian countries are highly attractive as locations, not only for production or service facilities, but also for R&D-related activities.

- The Asia region is also the main foreign destination for expenditures in semiconductor design for all firms 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. The levels of foreign ownership of EU inventions are however more pronounced. 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 better benefit from the process of internationalisation of inventive activity because it captures inventions developed in overseas locations more successfully and also because of the relatively higher levels of collaboration with foreign researchers.
- Regarding Asia, the level of inventive collaboration with Asian economies in developing ICT inventions was still very low in 2007, though increasing over time. However, concerning the collaboration partners of Asian inventors and applicants, it can be concluded that the US clearly dominates, whereas the level of collaboration between EU and Asian researchers and applicants seems to be relatively low. These observations may indicate a strong presence and advantage of the US in tapping into the inventive resources of the Asian region.

In conclusion, despite the limitations of the data and methodology used in the current report, 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 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 phenomenon at hand is far from fully understood and there are still a number of open questions. For example, it is still not clear what the implications of ICT R&D activity internationalisation are at firm and country level. 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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# Annex I: IPTS ICT R&D Internationalisation Database

Table 0-1 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.[53] 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.

Table 0-1: 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 | | |
| 27 | 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 | | | | | | |

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

| | |
|---|---|
| 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 II: Patent-based internationalisation measures

**Fractional counting**

To present the way of assigning patents to countries or regions that is used in this study, first the concept of fractional counting of patents is reviewed (see for example Dernis et al., 2001). To help make the discussion as easy to follow as possible, a simple fictitious example is used. Three countries, United Stated (US), France (FR), and Germany (DE), are considered that in a given year produce a total of P=3 patents. Column I in Table 0-1 indicates the nationality of the inventors and applicants that contributed to these three inventions.

In order to assign patents to countries, two alternative criteria may be chosen: either according to the nationality of the applicant(s), or of the inventor(s). The former defines the 'applicant criterion' and the latter the 'inventor criterion'. Whenever an application has more than one inventor or applicant, some of them coming from different countries, patent assignment is carried out by resorting to fractional counts. So, for example, patent n. 1 counts as ½ German and ½ American according to the applicant criterion, and ½ American, ¼ German and ¼ French according to the inventor criterion.

Table 0-1: Fractional counts of three fictitious patents

| I | II | | | III | | | IV | |
|---|---|---|---|---|---|---|---|---|
| | $Inv_{US,p}$ | $Inv_{DE,p}$ | $Inv_{FR,p}$ | $App_{US,p}$ | $App_{DE,p}$ | $App_{FR,p}$ | $\sum_{i=1}^{N} Inv_{ip}$ | $\sum_{i=1}^{N} App_{ip}$ |
| **P=1:** Inv: DE, FR, US, US | 0.5 | 0.25 | 0.25 | | | | 1 | |
| **P=1:** App: DE, US | | | | 0.5 | 0.5 | 0 | | 1 |
| **P=2:** Inv: DE, DE, FR, FR | 0 | 0.5 | 0.5 | | | | 1 | |
| **P=2:** App: FR, US | | | | 0.5 | 0 | 0.5 | | 1 |
| **P=3:** Inv: FR, US | 0.5 | 0 | 0.5 | | | | 1 | |
| **P=3:** App: US, US | | | | 1 | 0 | 0 | | 0 |
| $Inv_i = \sum_{p=1}^{P} Inv_{ip}$ | **1** | **0.75** | **1.25** | | | | | |
| $App_i = \sum_{p=1}^{P} App_{ip}$ | | | | **2** | **0.5** | **0.5** | | |

**Measures of R&D internationalisation**

In the following, $Inv_{i,p}$ represents the fraction of patent *p* attributed to country *i* according to the inventor criterion, and $App_{i,p}$ the analogous measure according to the applicant criterion.[54] Column II and III of Table 0-1 report these measures for the three patents. For each patent application, the sum of all the country's contribution according to the inventor criterion has to be equal to 1: for each patent, $Inv_{US,p} + Inv_{DE,p} + Inv_{FR,p} = 1$, where the first subscript indicates the country and the second the patent. These sums are indicated in Column IV of Table 0-1.

The total fractional assignment of the three patents to each country is simply equal to the sum of the individual assignments:

(1) $$Inv_i = \sum_{p=1}^{P} Inv_{ip}$$

and:

(1') $$App_i = \sum_{p=1}^{P} App_{ip}$$

They are reported in the last two rows of Table 0-1. For example, Germany produced a total of 0.75 patents according to the inventor criterion, and of 0.5 patents according to the applicant criterion.

Having discussed the general concepts of Inventor, Applicant, and Inventor-Applicant internationalisation, the related measures are defined. For each patent, the strength of the relation between inventors in country *i* and *j* is expressed as the product of the attribution of that patent to the two countries:

(2) $$InvInv_{ijp} = Inv_{ip} \cdot Inv_{jp}$$

This measure attributes a greater weight to collaborations where the two countries have more similar weights. So, for example, the collaboration between the US and France is equal to ½ · ¼ = $^{1}/_{8}$ in patent n. 1 (where there are 1 French and 2 American inventors) and to ½ · ½ in patent 3 (where the total number of inventors, 2, is equally divided between the US and France. In fact, if *i* is different from *j*, $0 \leq InvInv_{ijp} \leq 1/4$, where the upper bound is reached when the total number of inventors is equally divided between two countries, and the lower limit applies when a patent is national.

The aggregate strength of the relation between the inventors of two countries is defined as the sum of the above, over all patents:

3) $$InvInv_{ij} = \sum_{p=1}^{P} Inv_{ijp}$$

Below, the values for all the combinations of the three patents in Table 0-1 are reported, where for clarity, instead of the indexes *i* and *j*, the acronyms of the countries are employed.

$$InvInv_{US,US} = 0.5 \cdot 0.5 + 0 \cdot 0 + 0.5 \cdot 0.5 = 0.5$$

$$InvInv_{US,DE} = 0.25 \cdot 0.5 + 0 \cdot 0 + 0 \cdot 0 = 0.125$$

[54] When considering the fictitious example, instead of the subscript i we will use the mnemonic symbol of the relevant country. Also, for clarity we omit in all cases a time subscript, that should always be present.

$InvInv_{US,FR} = 0.25 \cdot 0.5 + 0 \cdot 0 + 0.5 \cdot 0.5 = 0.375$

The top part of Table 0-2 shows the values of these interactions for all three cases. Note that $Inv_{ij} = Inv_{ji}$ (the order of the countries is irrelevant). Using (1), it is easy to see that:

(4) $\sum_{i=1}^{N} InvInv_{ij} = Inv_j$ and $\sum_{j=1}^{N} InvInv_{ij} = Inv_i$

For example, as predicted by (4):

$InvInv_{US,US} + InvInv_{US,DE} + InvInv_{US,FR} = 0.5 + 0.125 + 0.375 = 1 = Inv_{US}$

These sums are reported for all three countries in the last column and in the last rows of the top part of Table 0-2, and correspond to the values reported in Table 0-1. They show that the country patent portfolio, assigned according to the inventor criterion, may be expressed as a sum of pairwise measures of country inventive collaboration ($InvInv_{ij}$).

The measure of applicant internationalisation is constructed along the same lines, and the following formulae hold:

(2') $App_{ijp} = App_{ip} \cdot App_{jp}$

(3') $App_{ij} = \sum_{p=1}^{P} App_{ijp}$

(4') $\sum_{j=1}^{N} App_{ij} = App_i$ and $\sum_{i=1}^{N} App_{ij} = App_j$

All computations for this case are shown in the middle part of Table 0-2. Note that $App_{ij} = App_{ji}$ (again, the order of the countries is irrelevant). Equation (4') allows us to express a country patent portfolio, according to the applicant criterion, as a sum of interactions between applicants in different countries. The values reported in the last column and row of the middle part of Table 0-2 correspond to those of Table 0-1.

A measure of Inventor-Applicant internationalisation is constructed similarly. The strength of the collaboration between inventors in country *i* and applicants in country *j*, for a single patent *p*, is defined as:

(5) $Invapp_{ijp} = Inv_{ijp} \cdot App_{ijp}$

Summing over patents provides a measure of the strength of the overall collaboration between country *i* inventors and country *j* applicants:

(6) $Invapp_{ij} = \sum_{p=1}^{P} Inv_{ijp} \cdot App_{ijp}$

These measures aggregate to the patent attributed to a country either according to the inventor, or to the applicant criterion, depending on whether the summation is over *i*, or over *j*:

(7) $\sum_{j=1}^{N} Invapp_{ij} = Inv_i$

(7') $\sum_{i=1}^{N} Invapp_{ij} = App_j$

The bottom part of Table 0-2 indicates all computations for our fictitious example. Note that $InvApp_{ij}$ generally differs from $InvApp_{ji}$.

The quantities defined in (3), (3') and (6) are the three measures of internationalisation of innovative activities. In order to provide a first description of the degree of internationalisation, *relative* measures of internationalisation are used which are expressed as a share of the total number of patents. It is straightforward to construct relative measures of (3) and (3'):

(8) $Inv_{ij|i} = Inv_{ij} / Inv_i$

and

(8') $App_{ij|i} = App_{ij} / App_i$

where $\sum_{j=1}^{N} Inv_{ij|i} = 1$ and $\sum_{j=1}^{N} App_{ij|i} = 1$.

There are in fact two conditional measures of inventor-applicant internationalisation, depending on whether the normalization is carried out with respect to the inventors of country *i*, or to the applicants of country *j*:

(9) $Invapp_{ij|i} = Invapp_{ij} / Inv_i$

(9') $Invapp_{ij|j} = Invapp_{ij} / App_j$

where $\sum_{j=1}^{N} Invapp_{ij|i} = 1$ and $\sum_{i=1}^{N} Invapp_{ij|j} = 1$.

The relative measures of internationalisation defined by Equations 8, 8', 9 and 9' are computed by using including all priority applications filed at all European national patent offices, at the EPO, and at the USPTO between 1990 and 2006. As we discussed in that report, our approach effectively corrects for the 'home bias' with respect to inventive activities taking place in the European Union and in the United States. Consequently, it is suitable to consider inventive collaborations between actors residing within this broad area. On the other hand, any consideration regarding inventive collaborations among actors that at least in part are from outside the European Union or the United States will be possible only with great care and with a good understanding of the consequences of the presence of a form of home bias.

These metrics of relative internationalisation have similarities with those of Guellec and van Pottelsberghe de la Potterie (2001), who adopt three measures that they call SHAI, SHIA, and SHII. The first one is similar to our $Invapp_{ij|i} = Invapp_{ij} / Inv_i$, the second to $Invapp_{ij|j} = Invapp_{ij} / App_j$, and the third to $Inv_{ij|i} = Inv_{ij} / Inv_i$. Our $App_{ij|i} = App_{ij} / App_i$ has no analogue in their paper. There are, however, several differences in the way that the measures are constructed, perhaps the main one being that, here, fractional counts of patents lead to counting as 'more international' those patents where international collaboration is more pronounced. One advantage of our measures is that they are coherent with the concept of fractional counting, in that they allow us to express country patent counts as sums of pairwise internationalisation linkages (equations 4, 4', 7 and 7'). The measures adopted by Guellec and van Pottelsberghe de la Potterie (2001), on the other hand, do not make this distinction, and consider alike all patents where there is at least some international collaboration of a given type. Similar considerations hold for the patent statistics of internationalisation presented in OECD (2008a).

An analysis of any shortcomings of our concepts of internationalisation should be carried out with an eye to the alternatives available. As we mentioned in the introduction, there are two competing approaches to analyzing internationalisation of R&D activities using patents data. One is by assembling a firm's portfolio: Firms are typically selected (also) according to their size, and this leads to problems of sample selection. This method, on the other hand, looks at patents regardless of the size or type of the applicant(s), and resort to an 'automatized' criterion to select international patents. The limits each approach may have ultimately derive from the fact that patent applications are so numerous and are not amenable to a case-by-case examination.

There are two forms of international inventive effort that our approach may fail to detect. First, imagine that a firm owns an R&D unit in a foreign country, producing an invention with the help of inventors that are all resident in that same location. If, moreover, the applicant of the filing is the foreign subsidiary (instead of the firm's headquarters), or a subsidiary located in the home country, then all the applicants and the inventors would be from the same country and therefore the patent application, according to our taxonomy, would fall into the 'national' category. However, it must be noted that usually multinational firms apply for their patents through their headquarters – thus, the patent in this example would fall into the InvApp type. Another case of internationalisation that would go undetected is when two firms from different countries constitute a joint R&D effort in one of the two countries, or in a third country, and produce an invention where all the inventors are residents of the country where the jointly-owned firm is registered. Arguably, there should not be very many of these cases. Moreover, it is possible that researchers from both countries would team up in the jointly-owned entity, so that their patenting activities would show up as inventor and inventor-applicant internationalisation. Also, there may be patents that we classify as international, which, in fact, are not. For example, a multinational corporation (MNE) could have its legal headquarters in one country, but most of its operations in another. In this case, its patents would automatically display applicant internationalisation. In Picci (2009), a careful analysis of a sample of international patents leads us to conclude that, overall, the number of problematic cases should be quite limited.

Table 0-2: Computation of measures of internationalisation of three fictitious patents

| $InvInv_{ij} = \sum_{p=1}^{P} Inv_{ijp}$ | $j$ = US | $j$ = DE | $j$ = FR | $\sum_{j=1}^{N} InvInv_{ij} = Inv_i$ |
|---|---|---|---|---|
| $i$ = US | 0.5 | 0.125 | 0.375 | **1** |
| $i$ = DE | 0.125 | 0.3125 | 0.3125 | **0.75** |
| $i$ = FR | 0.375 | 0.3125 | 0.5625 | **1.25** |
| $\sum_{i=1}^{N} InvInv_{ij} = Inv_j$ | **1** | **0.75** | **1.25** | |

| $AppApp_{ij} = \sum_{p=1}^{P} App_{ijp}$ | $j$ = US | $j$ = DE | $j$ = FR | $\sum_{j=1}^{N} AppApp_{ij} = App_i$ |
|---|---|---|---|---|
| $i$ = US | 1.5 | 0.25 | 0.25 | **2** |
| $i$ = DE | 0.25 | 0.25 | 0 | **0.5** |
| $i$ = FR | 0.25 | 0 | 0.25 | **0.5** |
| $\sum_{i=1}^{N} AppApp_{ij} = App_j$ | **2** | **0.5** | **0.5** | |

| $InvApp_{ij} = \sum_{p=1}^{P} InvApp_{ijp}$ | $j$ = US | $j$ = DE | $j$ = FR | $\sum_{j=1}^{N} InvApp_{ij} = Inv_i$ |
|---|---|---|---|---|
| $i$ = US | 0.75 | 0.25 | 0 | **1** |
| $i$ = DE | 0.375 | 0.125 | 0.25 | **0.75** |
| $i$ = FR | 0.875 | 0.125 | 0.25 | **1.25** |
| $\sum_{i=1}^{N} InvApp_{ij} = App_j$ | **2** | **0.5** | **0.5** | |

European Commission

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**Abstract**

This report investigates the contrasting views on the process of R&D internationalisation. On the one hand, there is an abundance of anecdotal evidence of companies locating their R&D activities outside of their home countries in order to search for new sources of knowledge and locate themselves close to new markets. On the other hand, however, the levels of international patents lead one to conclude that the level of R&D internationalisation is negligible. Such discrepancies in the views on the new geography of R&D activity, together with the scarcity of data illustrating the developments in R&D activity, pose a challenge for informed policy making.

This apparently contradictory evidence can be explained by the complexity of the inventive process and various motivations behind the decisions to do R&D abroad. To address these complexities related to the internationalisation of R&D, the report uses a methodology that divides the process of R&D into input and output side and, subsequently, analyses separately their levels of internationalisation. The results confirm that there is a discrepancy between them.

The EU and the US have higher levels of internationalisation than Japan and Asia. However, according to which measures are taken into account, there are differences between the levels of internationalisation in the EU and the US. For example, these two regions have similar levels of R&D input internationalisation, but very different levels of R&D output internationalisation. A comparison of Japan and Asia also shows that these two regions follow different R&D internationalisation trajectories. On the one hand, these discrepancies may indicate that all regions follow different R&D internationalisation paths. On the other hand, they may also be a sign of the unequal capabilities of companies from different regions to 'go global'.

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