Laboratorio M&I
Management e Innovazione

Working Paper Series

Alberto DI MININ*
M&I Laboratory - Scuola Superiore Sant'Anna
Pisa, Italy

Christopher PALMBERG
Etlatieto/Research Institute of the Finnish Economy (ETLA)
Helsinki, Finland

Why is strategic R&D (still) homebound in a globalized industry?

The case of leading firms in wireless telecom

*Corresponding author: alberto@sssup.it

M&I Working Paper 02/2007

M &I Laboratory

Piazza Martiri della Libertà,33
56127 Pisa (Italy)
Phone: +39 050 883 805
Fax: +39 050 883 839

Scuola Superiore Sant'Anna

1. INTRODUCTION

1.1. Background

Globalization is a topical issue for policymakers and firms alike. Although individuals, firms and countries always have been connected in various ways throughout history, commentators usually claim that globalization has reached a new phase at the dawn of the 21st century. This is typically considered to be the outcome of the combined effects of regulatory, political and market liberalization combined with technological change, especially related to information and communication technologies (ICT). In short hand globalization might be defined as *"the high and increasing interdependency and interrelatedness among different and geographically dispersed actors"* (Archibugi and Iammarino, 2002, p. 99; for a popularized discussion see also Friedman (2005)).

From the viewpoint of firms, foreign direct investment (FDI), the outsourcing and offshoring of manufacturing has been the most visible trend of globalization. However, the rapid change in the global division of manufacturing has perhaps overshadowed another phenomenon, namely the internationalization of research and development (R&D) (UNCTAD, 2005). Concretely, this means that researchers and inventors generating these inventions increasingly tend to be located outside the home country of companies. A seminal paper by Patel and Pavitt (1991) brings forward the "non-globalization" argument, suggesting that the actual inventive activities of multinational corporations (MNCs) tend to be significantly less globalised than the international distribution of the R&D expenditures seems to indicate. Patel and Pavitt (1991) suggest that this might be due to the fact that country-specific characteristics of national systems of innovation still matter for more strategic R&D activities, highlighting such issues as the importance of physical proximity and tacit knowledge, education, training and basic research. Indeed, still today R&D internationalization is a much debated subject. Several studies, which will be reviewed in later sections, have recently documented that a growing share of R&D of MNCs is offshored, but still evidence is mixed and the "non-globalization" argument also finds echoes in other empirical analyses.

Our focus on the wireless telecommunications industry in this context is particularly interesting for three reasons. *First*, this industry has probably benefited the most from trade liberalization, deregulation, and technological change, as governments across the globe are developing and upgrading their ICT infrastructures (Zysman and Newman, 2006). *Secondly*, the industry is also changing its technological core due to the convergence of data- and telecommunications and the emergence of the Internet, thus providing multiple entry points for firms and inventors, also from new geographical locations outside the US and Europe.

Third, much of the extant research on the internationalization of R&D tends to treat R&D as a `black box´ where the specificities of different types of R&D are not accounted for. This is partly a consequence of the lack or inaccessibility of detailed data on the different types of R&D and inventive activity at the firm level. Due to the significance of standardization, a system of notification of patents deemed essential to specific standards has been set up. This system provides an interesting analytical lens for identifying R&D and inventive activities that lie the closest to the technological core of the industry in a strategic, and perhaps also, in a commercial sense.

1.2. Aim and structure

This paper looks at internationalization of R&D in the wireless telecommunications industry. We compare the international distribution of strategic R&D activities related to the development of wireless standards to other (non standard related) projects. While there is evidence that leading companies in this industry are sourcing globally their know how, still more strategic R&D projects remain homebound. This finding is further elaborated through conversations with R&D and IP managers at Ericsson, Motorola, Nokia, and Qualcomm. These semi-structured interviews suggested that a closer look at the internationalization of R&D investment requires scholars to consider maturation and decentralization of R&D and R&D management.

The paper is structured as follows. The second section provides a brief conceptual discussion of major interpretations of R&D internationalization and a review of the major themes in the empirical literature. We also consider the specificities of the wireless telecommunications industry. The third section discusses the data that we use and provides empirical analysis of essential patents notified to ETSI (European Telecommunications Standards Institute), and less essential ones. In the fourth section we validate our statistical analysis through interviews with managers at the four companies. The fifth section concludes the paper.

2. THE INTERNATIONALIZATION OF R&D

2.1. Three drivers of R&D internationalization

Given the relatively recent nature of a relatively confined, but growing phenomenon[1], there is much attention on causes and consequences of internationalization of R&D. This is particularly true as the competitiveness of firms, and the development of regions where MNC are headquartered, or where labs will be located, are at stake. The literature identifies three main drivers for the internationalization of R&D.

The *first* driver of internationalization is adaptation to foreign demand. As MNCs expand their export activities for new or existing markets, they also need to invest more resources into understanding the specificities of foreign markets in order to adapt their products to the specific needs and demand of these clienteles. R&D efforts in this case, with a big emphasis of the "D" element, offer the logistic support to leverage overseas knowledge generated in the central -and generally domestic- R&D lab. The knowledge flows of these types of investment are therefore one-way only; from the center to the periphery (Dunning, 1958, Hymer, 1976). Scientists and technicians remain homebound and the result of critical R&D activities is combined with know-how of a local market for the local exploitation of a globally homogeneous production. Scholars call this type of investment "adaptive R&D" since it is driven by the desire of MNCs to enter new markets and exploit home-based advantage through foreign activities (Kuemmerle, 1997).

Investing in a firm's "absorptive capacity" is a critical juncture for a *second* driver of R&D internationalization (Cohen and Levinthal, 1990). An R&D presence overseas might be necessary, given (1) raising levels of technological integration and specialization, (2) the need to gain access to and exploit pockets of knowledge located in various countries, as well as (3) the need to integrate "peripheral" forms of knowledge with core technologies. Today, companies don't go abroad merely to exploit home-based knowledge for foreign markets, but also to learn and explore foreign knowledge located in deep pockets overseas (see here: Gerybadze and Reger, 1999; Dunning, 1994; Kuemmerle 1997, 1999). This type of FDI is classified as `home-based augmenting´, in contrast to `home-based exploiting´ (or adaptive R&D), discussed in the previous paragraph.

The *third* driver of internationalization is the access to, and the use of, cheaper factors of production for the more time intensive phases of an R&D project. This form of internationalization shares characteristics similar to the modularization and decentralization of manufacturing activities. Such phenomenon is heavily discussed in the organizational literature[2]. Modularization of an R&D project theoretically renders possible a distribution of labor within a company and, in particular, the delocalization of time intensive R&D phases to peripheral laboratories localized in areas with access to a cheap and qualified labor pool[3].

2.2. Maturation of foreign R&D investment

Adapting to local foreign demand, tapping into deep and distant knowledge pockets, and achieving cost reduction by offshoring advanced service functions lead to a rethinking of the entire R&D workflow and, in particular, a reorganization of both strategic planning, support functions, and time intensive phases of development projects. This process does not happen overnight and there is a vast amount of literature focused on the trial and error process that guides MNCs through the reorganization of their international technological activities. While it is not possible here to review a large and growing literature, it is worth pointing to three dimensions that guide empirical and theoretical discussion[4].

Maturation suggests that as foreign R&D sites grow their local know-how, they are assigned different tasks and responsibilities from the headquarters (Birkinshaw (1996) and Birkinshaw and Hood (1998), Gerybadze and Reger (1999), von Zedwitz and Gassmann (2002), Mendez (2003), Mudambi and Navarra (2004))[5]. The level of *autonomy from the headquarters* sets the conditions for a trade-off between central coordination and local "embeddedness", and exploitation of foreign knowledge pockets (Zander (1997 and 2002), Gerybadze and Reger (1999), Pearch (1999), Rugman and Verbeke (2001), Frost (2001), Mudambi and Navarra (2004)). *Coordination* between local "centers of excellence" and headquarters is one of the dimensions of organizational models for an MNC with distributed R&D investment (Hood et al. (1994), Birkinshaw and Morrison (1995), Birkinshaw (1996), Asakawa (2001), Frost et al. (2002)).

2.3. Evidence of non globalization: Patel and Pavitt (1991) revised

The seminal paper by Patel and Pavitt (1991) is possibly the first comprehensive empirical effort to seek evidence of the internationalization of R&D using patent data, thus sharing some features of the empirical part of this paper. In a series of empirical papers using the affiliation of inventors of patents to identify of the location of inventive activity, they show the overwhelming importance of *home-based* innovative activity for the main MNCs in the period from 1969 to 1986. The conclusions of that exercise were surprising as they clearly highlighted the importance of a `non-globalization´ of the innovative activities of these MNCs. In particular, Patel and Pavitt (1991) suggest that in most cases these companies *"have a long way to go before their technology activities become anywhere nearly as globalized"*. Only tentative explanations of this need for physical proximity are brought forward by the two scholars, relating to market uncertainties and characteristics of the local innovation systems, such as proximity to relevant and tacit sources of knowledge, or to facilities that incorporate and integrate multidisciplinary knowledge.

In 1996, a special issue of the IEEE Transactions on Engineering Management opens with a section dedicated to the observation that "R&D is going global."[6], and the internationalization of R&D is the topic of debate of both managers and policy makers[7]. Patel and Pavitt (1991)'s claim that *"we expect to see greater internationalization of large firms' technological activities in the future"* is echoed throughout the 1990s in subsequent studies. While we will not review here this literature, such analysis provides ambiguous support to the claim that R&D performed at a foreign location is proving to be increasingly important for the development of core technologies. A large body of literature points to the resilience of the non-globalization argument[8], and find little to now new evidence. On the contrary, other scholars[9] point to different sources to suggest that indeed a growing decentralization of R&D is taking place. While there is no doubt that companies assign their foreign subsidiaries development responsibilities to adapt production to the local needs, still

Kuemmerle (1999)'s argument about the coexistence of both "adaptive" and "augmentive" R&D activities is validated by subsequent empirical analysis. Home-based knowledge exploitation and augmentation do coexist and no clear trend can be isolated and generalized. Our study contributes to this debate and differentiates R&D projects according to the strategic relevance of their results.

2.4. The wireless industry and the importance of standards

A priori, there seems to be little evidence to support the case for 'non globalization' of R&D and inventive activity in the wireless telecommunications industry. For various reasons not explored here, trade liberalization has been particularly rapid in many high-technology industries, and particularly so in the case of ICT (see Zysman and Newmann (2006) for one of the most recent overviews of the development of this industry).

Prior to the 1980s, most national telecommunications markets – even in highly industrialized countries – were characterized by vertically integrated national monopolies where telecommunications equipment production and demand were largely in the hands of the Public Telecom Operators (PTTs). By the 1990s, the vertically integrated monopolies of PTTs had dissolved, while R&D and innovation were shifting increasingly towards the producers of telecommunications equipment. Regulatory liberalization and the emergence and diffusion of the GSM also gave rise to the entry of many new producers and operators. Since the rise of GSM, this trend has strengthened further, especially through the opening of fast-growing markets in Eastern Europe and Asia (China being the most obvious example). Meanwhile, the structure of demand has also widened significantly. Today, any equipment producer that hopes to join the top-tier players must have a presence in hundreds of markets, especially outside their homebase, where leading firms make, by far, their largest share of revenues (Steinbock, 2003).

While trade and regulatory liberalization have globalized the demand for telecommunications equipment, technological change in the industry has had pervasive effects on R&D further upstream. One aspect of this is ongoing convergence – or fusion – between various technology subfields of ICT (Information and Communication Technologies). This fusion opens up multiple entry-points for new firms and other players.

The term ICT convergence is commonly used to indicate the merging of data and telecommunications technologies, which were characterized as two separate fields until the 1980s. As a consequence, a range of new products, services, applications, markets, policy and regulatory domains are also merging (Bohlin et al., 2000). Above all, the Internet has had many important implications for telecommunications incumbents. The increasing popularity of the Internet means that mobile telecommunications applications and services must also become compatible with the so-called TCP/IP-standards. This is also evident in a range of standardization efforts around the fringes of the core next generation standards (such as the 3G standard UMTS in Europe), examples of which include the WAP forum, GPRS and EDGE standards. (Kogut, 2004).

Standards define the interfaces of technologies that firms in the industry have to comply with in order to create new markets. Standards are typically created through different types of consortia, "clubs" or industry groups consisting of carriers, manufacturing firms, standardization bodies and other stakeholders (Leiponen, 2005). As a consequence, standardization bodies have set-up various methods to support the notification and crosslicensing of the intellectual property rights (IPRs), and in particular patents, over such technologies in order to assure that no single firm or other stakeholder might block the standardization process itself. On the other hand, the existence of multiple and potentially overlapping technologies and IPRs acts as an incentive for firms to make efforts to manage their IPRs with respect to these various notification schemes (Bekkers, 2001; Bekkers and West, 2006).

2.5. "Essential IP" and the system of patents notification

The standardization schemes delimit a subset of technologies and IPRs that are at the core of the industry in a strategic longer-term sense, but that also should have a relatively higher technological and economic value. The European Telecommunications Standards Institute (ETSI) defines a patent to be *essential* when "it is not possible on technical (but not commercial) ground, taking into account normal technical practice and the state of art generally available at the time of standardisation, to make, sell lease, otherwise dispose of, repair, use, or operate equipment or methods which comply with a standard without infringing that [intellectual property]" (ETSI, 1998). An early disclosure and licensing agreements of "essential patents" are important ingredients for the smooth application of the work of the technical committee. Disclosure and licensing should eliminate roadblocks to technological development that might jeopardize the efforts of standardization partners. Most of the modern commercially successful standard had carefully managed the IPR implications of their work, setting ground rules in scouting, disclosure, and licensing of essential IP. Indeed, a number of standardization efforts failed over IPR related disputes.[10] One of the pivotal ideas behind standard setting is the network externalities of adoption of a particular technology (Katz and Shapiro, 1985; 1986). By avoiding a deadlock and pursuing development and adoption of a particular standard, everybody will benefit, especially companies that will have been able to lobby for inclusion of their IPR in the standard.

In the case of the European standardization body ETSI, Bekkers (2001) suggests that IPR holders indeed do have strong incentives to notify their patents as essential[11], as this is the first necessary step to lobby for single patents into the technical specifications coming out of the standardization working group. ETSI's regulations have been very often cited as good practice for standardization bodies.[12] Specifically, the early and strong endorsement of the European Community Commission, the semi-public nature of ETSI's mission to create a pan-European wireless telecommunication infrastructure, and the transparency of the disclosure and listing of essential patents, made ETSI quite a unique and influential standardization body. ETSI does not require members to perform routine patent searches, nevertheless, failure to disclose potentially essential patents is sanctioned as a breach of the ETSI IPR Policy agreement between standardization partners.[13] As of yet, no cases of malicious delay or failure to notify ETSI have been notified to the General Assembly.[14]

The inclusion of essential patents into an ETSI technical specification opens up various strategy avenues for the company, as well as significant licensing revenue opportunities, even under the fair and non-discriminatory agreement. The complexities of patent searches and the uncertainties related to the technological developments of the standard might suggest that ETSI members are more likely to notify and lobby for inclusion of IPR that they know extremely well and which they are convinced can be enforced and controlled further downstream in product development projects. During pre-standardization, each assignee will have to lobby and convince partners that a license to its IPRs is the most efficient way to solve a technological need, while designing around these might either be impossible or only a second-best solution. During this complex negotiation phase, it is not only the successful market adoption of a standard that is on the line, but also the reputation of the IPR assignee. Thus, it seems safe to assume that these IPRs protect proprietary technologies that influence the trend of their technological activities and strategic choices in terms of commercialization. Framed in this way, it is therefore interesting to ask the question: to what extent are the R&D activities which lead to essential IPR homebound?

Apart from the strategic importance of essential patents, there is a debate about whether or not these types of patents might also be more significant in terms of their technological and economic value. A recent paper by Rysman and Simcoe (2006), which analyzes the notifications schemes of four major international standard setting bodies, finds that notified IPRs (patents) have a higher technological, and potentially also economic, significance than non-notified ones. The paper by Rysman and Simcoe (2006) also suggests that the data used here captures technologically and economically "more significant R&D" of the firms included.

3. A NOTE ON THE METHODOLOGY

This section moves on to the empirical analysis with the purpose of exploring to what degree, and how, the technological core of the wireless telecommunications industry is globalizing, and the degree to which the case for non-globalization might still have some relevance in the context of Patel and Pavitt (1991). In order to do so, the analysis presented in this paper rests on the comparative analysis of inventive location activity validated through in person interviews with the VP for R&D and standards at the most representative companies in the industry. The comparison is here performed using patent data for the development of telecommunications standards, with a control group of similar, but ultimately less strategic, patents.

With reference to the earlier discussion, the European Telecommunications Standards Institute (ETSI) represents an important standard-setting body in the European context and thus functions as a natural point of departure for data gathering. ETSI has set up a notification scheme where both members and non-members are requested to provide a written statement if their technologies and IPRs (patents) can be deemed essential to the development and inauguration of particular standards (see http://www.etsi.org/).

This empirical analysis uses patent data that were originally identified in the ETSI database on essential patents. These data can be accessed through online documentation containing lists of "essential patents" under various standards commissioned by ETSI (see Appendix 2 for the complete list of ETSI standards per April 2005). In particular, this paper considers the four largest assignees of essential ETSI patents, Ericsson, Motorola, Nokia, and Qualcomm, filed at the patent office in the U.S. (USPTO) during the period 1985 - 2001, and subsequently published before May 2006 (see Table 1). For these patents, information about technology classes, date of filing and publication, affiliation of inventors, scope of international protection and forward citations are also gathered. Given the arguments brought forward in the previous section, it seems safe to assume that the disclosed essential ETSI patents provide a complete coverage over the enabling technologies discussed by the standardization committee, and that in particular, standardization partners are not concealing, or failing to disclose, patents that are essential.

TABLE 1: Patents Notified as Essential at ETSI by Companies

Company	Patents	Company	Patents	Company	Patents
Ericsson	241	Digital Theater Systems	6	Marconi Communications	2
Qualcomm Inc.	143	Nexus Telocation Systems	6	3COM Corporation	1
Motorola	91	Samsung	6	Ensemble	1
Nokia Corporation	78	British Telecom	5	Entrust Ltd.	1
InterDigital Technology	66	Digital Voice Systems	5	France Telecom	1
Philips Electronics	29	Mitsubishi Electric	5	Innovatron	1
Hughes Network Systems	27	Sun Microsystems	5	Intel	1
SIEMENS	19	KPN	3	IPR Licensing	1
Alcatel	18	NEC Corporation	3	Microsoft Corp.	1
AirTouch Communications	15	NTT	3	Tantivy Communications	1
TOSHIBA Corp	14	OKI Electric Industry	3	Vimatix	1
Nortel Networks Ltd.	11	Ascom Management	2	Wi-Lan	1
Lockheed Martin	7	ETRI	2		
AT&T	6	Inmarsat Ltd.	2	Total	834

In order to assess the case for non-globalization in the context of strategically important patents at the technological core of this industry, a control group of non-notified patents is defined, according to the following steps:

1. In order to define this set of patents, all the technology classes assigned to the essential patents are considered.
2. The complete portfolio of non-notified patents belonging to the same technology classes assigned during the same period of time to the same four companies and their subsidiaries is gathered.[15]

With reference to the discussion above, this control group of patents can be considered as being less strategic, on average, from the viewpoint of the activities of these firms in European and global markets. This assumption requires some clarification.

Patents are not commodities, and their value distribution is often skewed as a large majority of patents assigned to companies have little to no intrinsic economic significance. By definition, control group patents have not been notified as essential to ETSI. This does not, however, exclude the possibility that at least some of them are extremely important for the company. No information has been gathered about the current use of these patents, and it is not possible to convincingly predict their future use. Even if we are assuming that these patents will not be deemed as essential for ETSI standards, some of them might indeed protect critical aspects of a commercialized product, be relevant for other standards, or become the objects of profitable licensing contracts. The main assumption here is merely that, on average, the strategic relevance of patents is lower in the control group. Moreover, it can be argued with some confidence that the technological and economic value of patents in the control group is, at the very least, more heterogeneous. In other words, the notification with ETSI makes a patent strategically more relevant for the company, even though it might not always be so in technological or economic terms.

Furthermore, a comparison of inventive activities of U.S. and non-U.S. companies based on patents filed and issued by the U.S. patent office (USPTO) is biased. As American companies use the USPTO as the first and main source of protection for their IP, while foreign companies might decide to file a patent in the U.S. only for a subset of their patents. The core of this analysis encompasses a comparison of patenting behavior of U.S. and European companies. It is necessary, therefore, to adopt a correction to this bias: all USPTO patents assigned to the two U.S. companies are excluded from the analysis when, within each patent family, there is no equivalent patent or application filed with at least one European patent office. The Delphion Patent Family database is used for this procedure.

For the sake of clarity, throughout the rest of the paper the two sets of patents are going to be referred to as the "essential patents" and the "control group patents," stressing again that all the ensuing tables and figures contain data collected at the level of patent families and that "non internationally protected" patents assigned to U.S. companies are excluded. The distribution across companies is shown in Table 2. The descriptive analysis and the Chi-Square tests described later refer to this data.

TABLE 2: Distribution of Essential and Control Groups Patents Across Companies

	Total Patents (assigned 1985-2005)	**Ericsson**	**Nokia**	**Motorola**	**Qualcomm**
Essential Patents	537	241	72	85	139
Control Group	4,358	1,752	1,012	1,160	434

In the ETSI database, 1113 USPTO patent notifications were counted. Since each patent can be notified for more than one standard commissioned by ETSI, ultimately the database contains a total of 834 unique granted USPTO patents[16]. 64.4%, or 537, of these patents are assigned to the four largest assignees. As this analysis is a comparison of the inventive activities of MNCs, the choice for these four companies was quite natural. Ericsson, Nokia, Motorola and Qualcomm are the largest assignees of ETSI essential patents. They are also the four most significant players in the wireless telecommunications industry in Europe and the U.S.[17]

Findings presented in the previous paragraphs require a more detailed discussion and a better understanding of the causes of the relative "homeboundness" for essential inventive activities. The approach chosen to cater to this need was to present these research findings to top managers at the companies included in this study. During the period of August and September 2006, interviews were conducted with VP for research, standardization, and IP management at the companies considered for this study.[18] Semi-structured discussions were started by presenting the results of the inventive location analysis. Subsequently managers were presented a set of open questions regarding the methodology, findings, relative positioning of competitors, and perspective on the industry.

3.1. Location of inventive activity across all companies

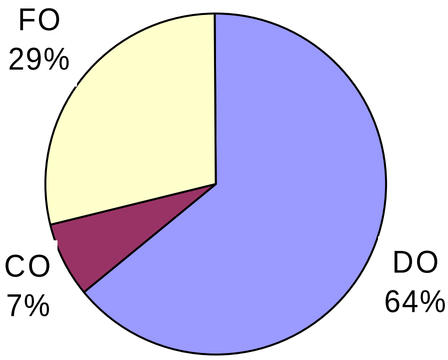
Information about the affiliation of inventors on the patent title is here used as a proxy for the location where the inventive activity leading to the filing of the patent was performed. The analysis assigns patents to the three exclusive categories.

1. Domestic Patents (DO): patents whose inventors are all located in the HQ country of the controlling company: the U.S. for Motorola and Qualcomm, Sweden for Ericsson, and Finland for Nokia.
2. Foreign Patents (FO): patents whose inventors are all located in countries other than the HQ country of the controlling company.
3. International Collaboration Patents (CO): patents which have at least one inventor located in the HQ country and at least one inventor located in another country.

This primary analysis considers data at the country level: U.S. and single EU countries, instead of the European Union or the U.S. at a state level. Besides the obvious cultural and linguistic differences, Europe is not yet a unique market as some factors of production, such as skilled labor, are not as mobile as in the U.S.. Moreover, in spite of the growing integration between different IPR and legal systems, enforcement of IPR rights and settlement of disputes happens at a country level, with scarce margins to select a particular jurisdiction. In spite of this argument, however, subsequent location analyses will consider state-level data for U.S. companies and EU level data for European companies.

Figure 1 shows the distribution of *control group patents*. The majority of the patents are domestic. 36% of control group patents have at least one inventor located outside the HQ country of the four companies.

FIGURE 1: Distribution of Control Group Patents by Location of Inventive Activities



The changing distribution of these patents over time (Figure 2) shows that these four companies substantially increased the numbers of foreign and collaboration patents during the late 1990s. The data indeed show evidence four of an international expansion of inventive activities. While in the period 1985-94, 82% of patents were domestic (DO), for the period 1995-99, this percentage dropped to 60%. At the same time the average number of patents applied per year drastically increased. Hence foreign (FO) and collaboration (CO) patents increased both in absolute and relative numbers. Somewhat of a reverted trend can be detected for the last two years under consideration. The year 2000 marked the beginning of a sharp decline in the number of patents, and this decline was even sharper for FO and CO patents as their share decreased as well.

The sharp decline in the last two years might have been biased by a database tailing effect. Patents are grouped by application date, and for some of the latest years patents might still be under review at the USPTO[19]. In spite of this bias, it is well known that after the euphoria of the late 1990s and the strong emphasis on patenting, some rationalization of R&D budgets took place in the industry, and this is likely to have impacted domestic and foreign R&D activities differently[20].

FIGURE 2: Distribution Over Time of Control Group Patents by Location of Inventive Activity

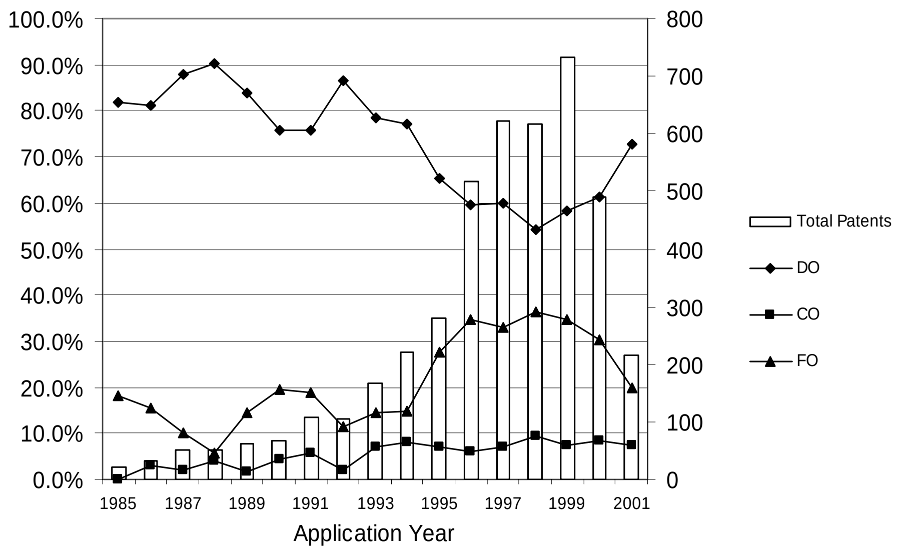


FIGURE 3: Distribution of Forward Cited Control Group Patents by Location of Inventive Activity

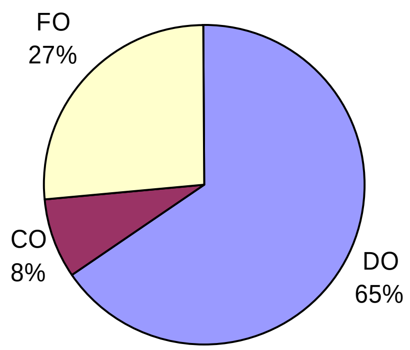


Figure 3 shows the same data weighted by the number of forward citations received by each patent for the two years following publication. The average distribution and trends of DO, FO and CO does not change significantly (Figure 3).

The same DO, FO, CO distribution for *essential patents* appears to be significantly different (Figure 4). As is noticeable from the following pie chart, the concentration of DO essential patents is much higher than the share of DO patents in the control group. The Pearson Chi-Square values for both DO and FO confirm that it is possible to reject (with 0.01% significance level) the null hypothesis that the international distribution of inventive activity locations is similar for essential and control group patents. 78% of essential patents filed in the period between 1985 and 2001 are the result of inventive activities performed in the HQ countries of the four largest assignees. While the share of CO patents is higher than the share in the control group, the share of FO patents drops to 11%.

FIGURE 4: Distribution of Essential/Cited Essential Patents by Location of Inventive Activity

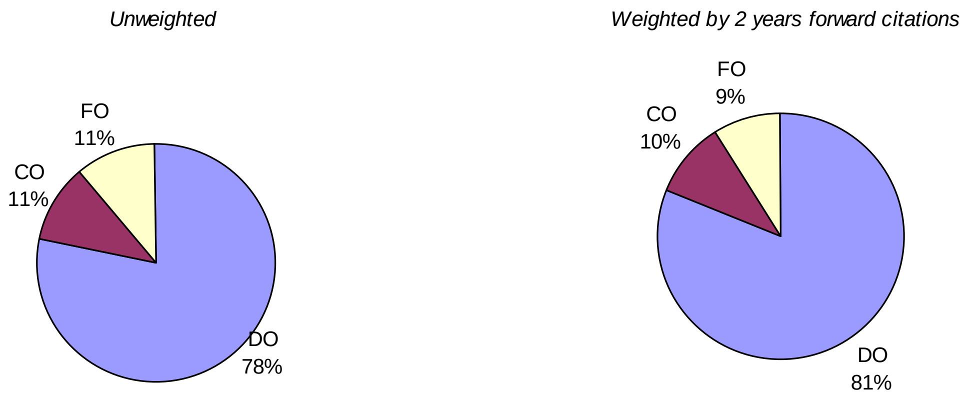
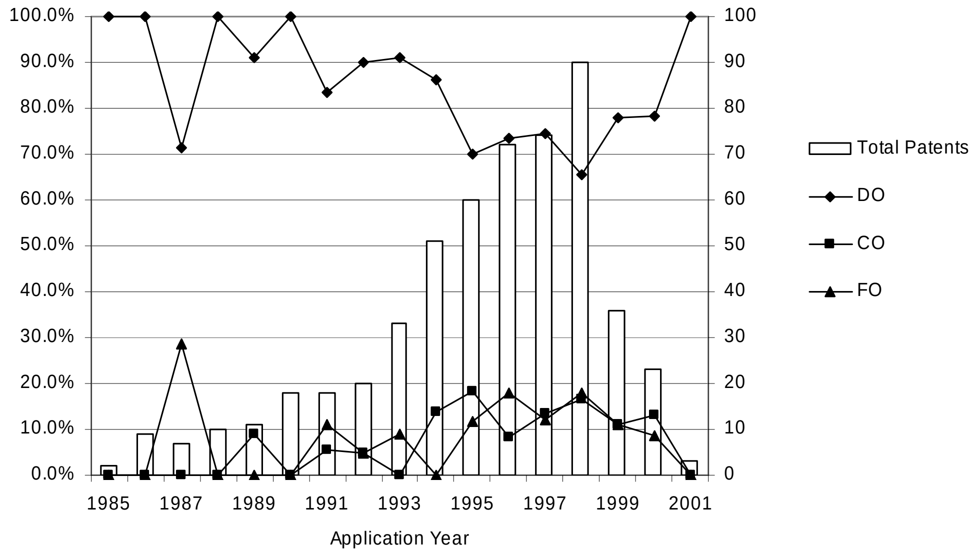


FIGURE 5: Distribution Over Time of Essential Patents by Location of Inventive Activity

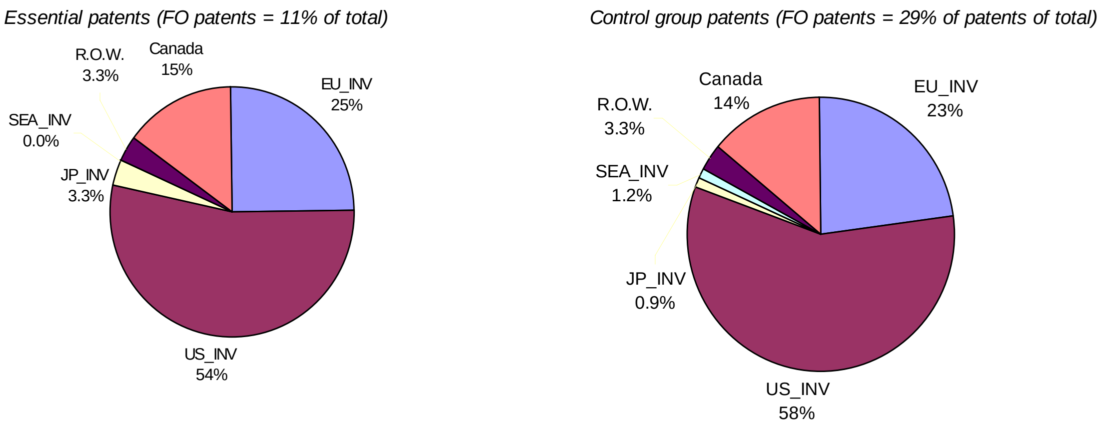


When considering data weighted with two years forward citation, the difference is even more significant (also Figure 4). As for the control group patents, DO patents are slightly more likely to receive citations than FO and CO patents. As a result, the share of DO citations rises to 81% of total forward citations. Therefore, the Pearson Chi-Square values for both DO and FO confirm that it is possible to reject (with 0.01% significance level) the null hypothesis that the international distribution of patent citations is similar for essential and control group patents.

The time trend for essential patents shows a similar, but significantly less pronounced trend, in the course of the late 1990s (Figure 5).

The following analysis refers to the offshore location of these inventors. Figure 6 compares the distribution of offshore sites of the FO patents across the essential and control group. Domestic and collaborative patents are excluded from this analysis, since, by definition, the inventors for these patents are located either in the U.S. or in Europe.

FIGURE 6: Distribution of Inventors of Essential/Control Group Patents by U.S. State-Level Location of Inventive Activity



The first interesting aspect in the data is the dominant position of the United States as an affiliation of inventors, both for essential and control group patents. 58% of offshore inventive activities of control group patents (60% if we weighted by 2 years forward citations) is performed in the U.S., while 54% of the patents indicated as essentials display a

U.S. inventor (the share of 2 years forward citation is 49%). European countries are the second most common affiliation for both essential and control group patents for all companies.

Canada is also another important affiliation of inventors, and the share of Canada across the board is significantly higher than Japan, Asia (SEA) and the Rest of the World (ROW). Somewhat surprisingly, this latter group of countries/regions altogether represents merely 5% - 6% of all control group and essential patents. Hence, such emerging countries and regions are substantially absent as affiliations of inventions for ETSI standards and non essential wireless technologies according to this analysis. Since not many inventive locations are located outside North America and Europe, and since this research looks at European and American companies only, it is possible to say that what the data describes is, for the most part, a flow of R&D related investment from the U.S. to Europe and from Europe to the U.S..

Unfortunately the data lag behind and cannot reach definite conclusions about the R&D and inventive activities performed in the last three or four years, during which time these countries have been identified in the popular press as the largest recipients of foreign R&D investment. Nonetheless, these observations appear in line with the findings of the UNCTAD 2005 report, which describes a distribution of R&D investment that is still highly skewed toward these "old and incumbent" centers of innovation.

3.2. Locations of inventive activity at the company level

As the following figures show, the finding that the share of DO patents is higher for essential patents than for the control group is consistent for all four companies in the sample.

Qualcomm, the second largest assignee and the company with the highest average citations per patent ratio, is also the one with the highest share of DO patents. Less than 4.5% of essential patents have at least one foreign-located inventor on the title (Figure 7). Essential patents are also more homebound than the control group. The Pearson Chi-Square value for DO confirms that it is possible to reject (with 0.01% significance level) the null hypothesis that the international distribution of inventive activity locations for Qualcomm is similar for essential and control group patents.

FIGURE 7: Distribution of Essential/Control Group Patents of Qualcomm by Location of Inventive Activity

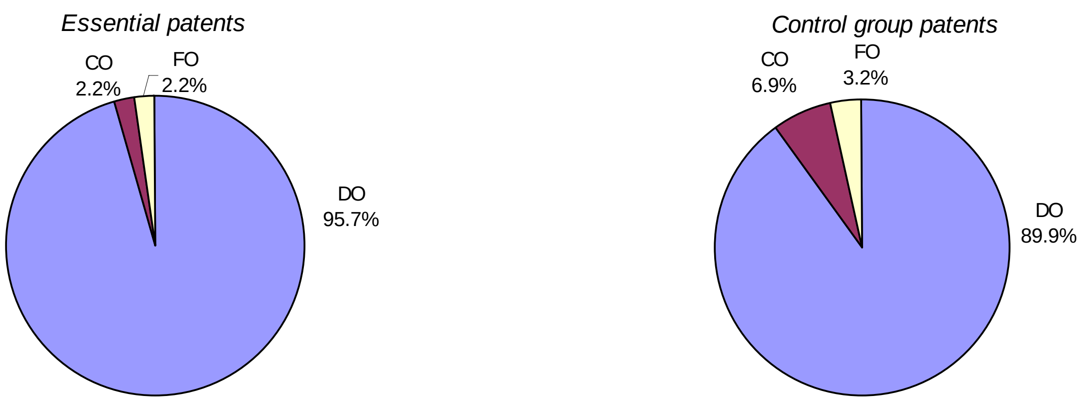
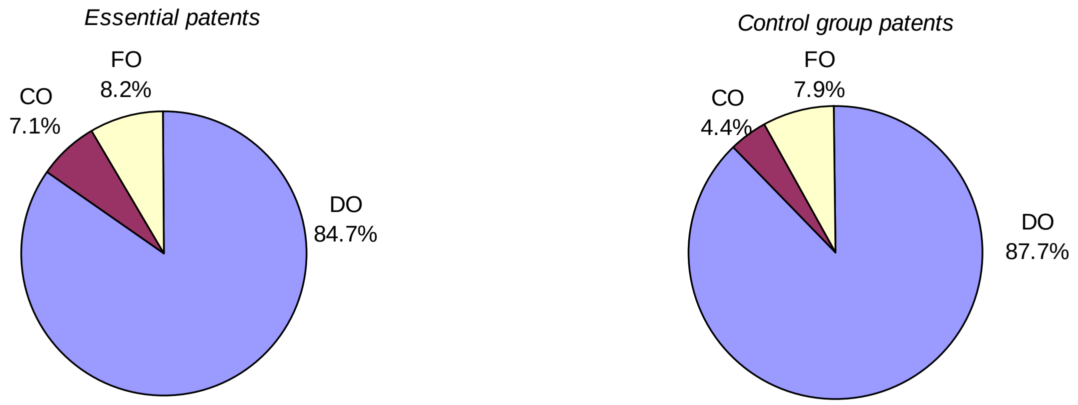


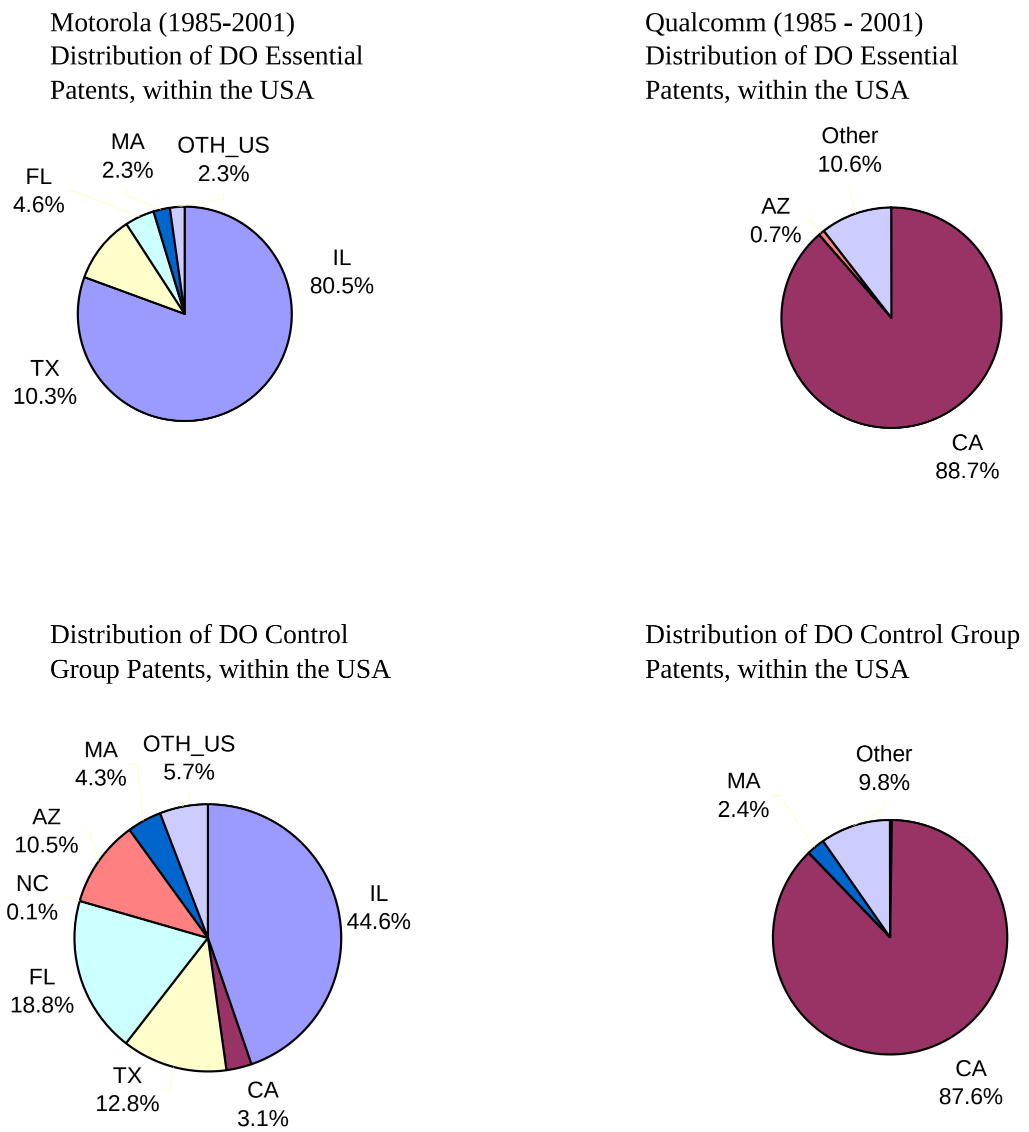
FIGURE 8: Distribution of Essential/Control Group Patents of Motorola by Location of Inventive Activity



Despite the high concentration of DO patents, Motorola has a more similar distribution between essential patents and the control group (Figure 8). The Chi-Square test fails to reject the null hypothesis of a significant difference across the two groups (with 0.01 significance). The FO share of patents is more or less the same, while the CO share varies significantly across the two groups.

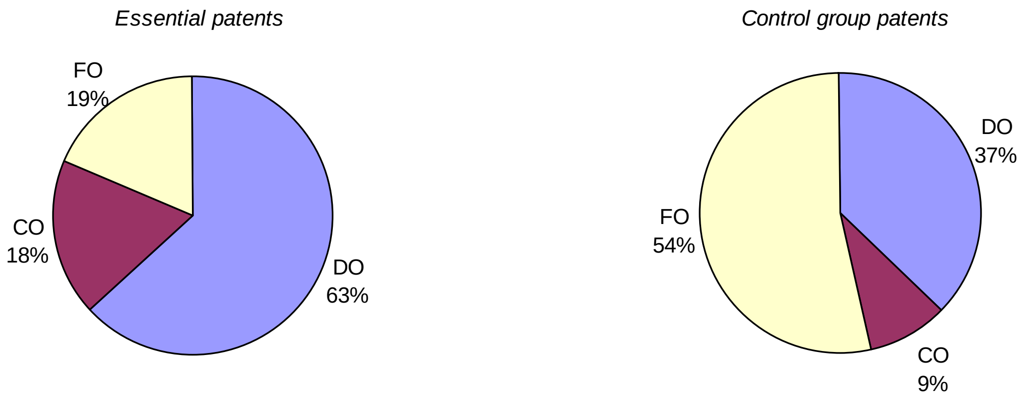
In the course of our discussion over the definition of foreign versus domestic inventive activities, we have suggested that the most appropriate dimension to look at American companies was the U.S. versus non U.S. location of inventors. However, given the non- significance of the difference for Motorola's share of FO patents across the two groups, we will here briefly consider the distribution of inventors within the U.S. for essential and control groups. In the course of the interviews at Motorola (discussed in the next section), managers focused on the relevance and concentration in Illinois of the R&D activities on radio technologies, rather than on the dimension of "homeboundness". Traditionally, we were told, Motorola developed such competence in its main R&D laboratories. While significant investments were performed around the U.S. and in other foreign countries, it was still a natural transition, for the main working group specializing on radio technologies, to take the lead on the development of GSM and other ETSI standards. When only DO patents are considered, the state-by-state distribution of inventors for the two American companies in the sample shows differences between essential and control group patents (Figure 9).

FIGURE 9: Distribution of Essential/Control Group Patents of Motorola and Qualcomm at the U.S. State Level by Location of Inventive Activity



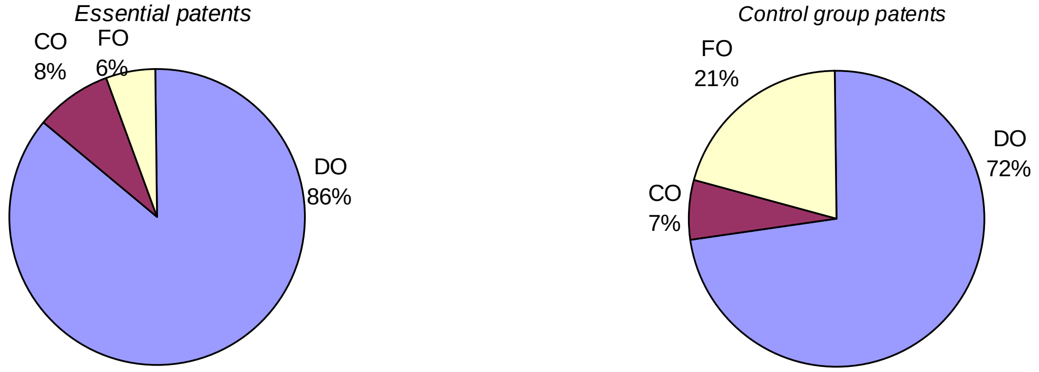
Specifically, the overwhelming majority of Motorola's essential patents originates from the main laboratories located in Illinois (80.5% of all DO essential patents), which are also the inventive site for only 44.6% of the control group DO patents. While such difference is clearly significant for Motorola, in the case of Qualcomm, both the essential and control group patents are largely dominated by California inventive locations. While this finding does not add much to the "non globalization" argument, Motorola's concentration of essential patents in the proximities of the corporate headquarters validates our conversations with the R&D managers; and it also suggests that in order to develop technologies relevant to the ETSI standard, the company heavily relied on the traditional radio and wireless competence and people largely located in its main R&D central labs.

FIGURE 10: Distribution of Essential/Control Group Patents of Ericsson by Location of Inventive Activity



Ericsson, the largest assignee of control group patents in this data, is characterized also by the highest share of FO patents (Figure 10). However, it is important to recall that for both Nokia and Ericsson, patents whose inventors were affiliated with other European countries are categorized as FO or CO. It is interesting to notice that in spite of the fact that for these two companies we are more strict with the identification of DO locations, the difference across the two patent portfolios is still even more pronounced than for the two U.S. companies[21]. For instance, in the case of Ericsson, 63% of all control group patents have at least one inventor located outside Sweden, while only 37% of essential patents are the result of inventive activities performed outside the HQ country.

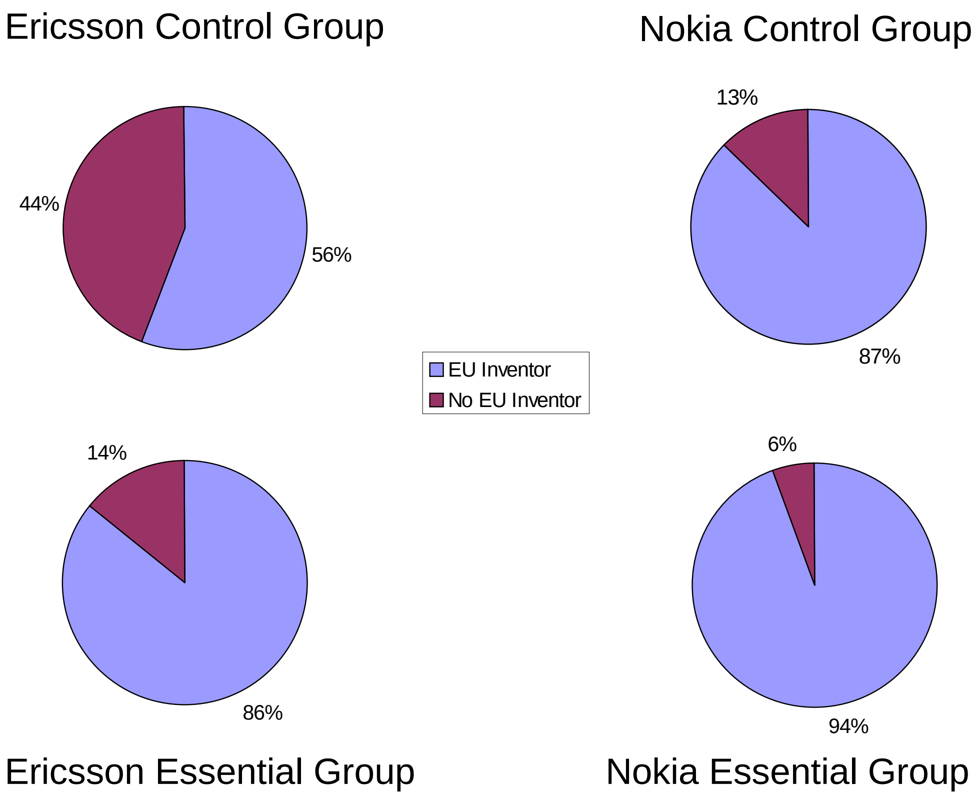
FIGURE 11: Distribution of the Essential/Control Group Patents of Nokia by Location of Inventive Activity



Nokia's inventive activities also vary across the two patent categories (Figure 11). The inventive activities of Nokia are more homebound than those of Ericsson, and the share of patents with at least one foreign inventive location of essential patents is half the share of control group patents.

The difference in the international distribution between control and essential groups for both Nokia and Ericsson remains significant, especially when data at the European level is considered. Figure 12 shows the different distribution of inventive sites for patents with at least one inventor located in Western European countries (EU plus Norway and Switzerland), at both companies. Ericsson stands out as being the company with the most offshore R&D activities, whereas Nokia's inventive locations are for the largest part intra European. For both companies Chi Square tests suggest a significant difference in the distribution of European and non-European research activities, when the essential patents group is compared to the control group.

FIGURE 12: Patents with at Least One European Invention Site of Nokia and Ericsson



4. QUALITATIVE INSIGHTS: COMPANY VIEWPOINTS

4.1. Validiation of the patent indicator

An objective of the interviews was to *test the validity of the methodology used* in the patent analysis, and in particular the strength of the distinction between essential and non-essential IP, and the use of patents as a proxy of R&D results. The interviews confirmed both the validity of the empirical approach and the limitations of the inventive location analysis. In general, managers confirmed that the inventors' addresses on the USPTO documents are, in fact, good proxies for the countries where the R&D investments leading to those specific inventions were performed. This is direct support of the methodological discussion of Bergek and Berggren (2004), as well as the approach of Patel and Pavitt (1991), that has been partly replicated throughout this work.

In addition to the common observations above that have also been discussed in the literature, the managers stated that confidence in the accuracy of the inventors' addresses is necessary in particular for USPTO patents, given the fact that the U.S. system grants protection to "the first to invent" and not "the first to file." In litigation, it is often the case that assignees have to trace back laboratory reports to show the original work of inventors. A mismatch between the declared and actual location of invention can be lethal for the validity of a patent.

Nonetheless, as previously acknowledged, the lag between the time of development of inventions underlying these patents and the current events shaping R&D investment of these firms significantly limits the breath of this study. Managers emphasized the importance of recent strategic changes that cannot yet be recorded in the analysis of the location of inventive activity. There was general consensus that the situation in a few years from now might be significantly different, with a lot more inventive activity taking place in peripheral and foreign locations. This was acknowledged as a general trend in the industry, even if the interviewees suggested that the homebound nature of strategic R&D of the type that we identify in this paper may not disappear.

To sum up, discussion regarding the methodology adopted for this study suggested that the inventive location analysis indeed portrays, in a simple yet effective, way the global distribution of R&D locations and the homebound nature of inventive activities related to essential IP. However, managers warned researchers not to draw too many conclusions about the current technology sourcing strategies at their companies.

4.2. Explanations for the homebound nature of strategic R&D

It was also important through the interviews to discuss the *various drivers of R&D internationalization* and to *understand the R&D location history and the global distribution of labor* within corporate R&D labs. Further, we also we asked managers to comment on *the inventive location analysis*. Finally we discussed about the various *drivers of R&D internationalization and "non globalization."* Managers were asked to explain different drivers of R&D internationalization and the relative concentration of IP assets related to the ETSI standards.

All managers interviewed had been with their companies for a significant number of years. They were therefore in the position to discuss the latest developments, as well as provide a perspective on the past geographical distribution of the company's activities, the main motives behind certain investment decisions, and the evolution of foreign R&D labs for both "transatlantic" and decentralization in developing countries.

By and large the interviews did not really highlight the cost explanation for the internationalization R&D. Nonetheless they did confirm the importance of market demand, and the home-based exploitation and augmentation dimensions that are commonly discussed in the literature. Of particular interest here, however, are the reactions of the interviewed managers to the evidence for non-globalization that we find in our patent analysis. In this context they pointed to organizational inertia, rooted in the historical organization of the R&D laboratories of their companies that counterbalance the internationalization of R&D. They also refer to the maturation and learning curve dimensions related to foreign R&D subsidiaries. Further, in-house R&D is till considered important for upstream activities of more strategic nature.

It seems that *organizational inertia* in the organization of R&D is particularly clear for the more strategic R&D that we propose to have highlighted in this paper. The development of the radio technologies – based on which these ETSI wireless telecommunications standards originated – have been at the core of Ericsson and Motorola's activities. These two companies acquired and developed these technologies well before the internationalization of R&D became important, and the related knowledge appears to have accumulated locally in their home countries with a strong element of stickiness and tacitness. Based on previous research we also know that Nokia accumulated knowledge especially for the GSM standard at specific local sites in Finland, for example in the cities of Salo and Oulu (Palmberg and Martikainen, 2005). Qualcomm developed most of its expertise in California, and acquisitions in other areas (mostly in the U.S.) were targeted to expand the technological know-how into new fields.

The case of Motorola is particularly illuminating in this context. The interviewed managers at both companies were not surprised by the homebound nature of their notified essential patents. One of the managers at Motorola suggested that *"We have started to develop these technologies in Illinois and it would not make sense to source them elsewhere"*. The organizational inertia that we discussed above can therefore also be translated into a cumulative advantage for the homebound location of R&D as long as knowledge developed there is relevant for the present technological trajectory of the industry. The greatest threat to homebound R&D of the more strategic type apparently relates to technological discontinuities external to the company. *"As long as radio technologies will be used in a mobile phone, we cannot see how we can divest from our traditional R&D centers* [in Illinois]*."* The interviewees of all companies were convinced about this point, as well as with the assertion that it should not be taken for granted that `the next big technology' will come from the domestic R&D center.

These observations about organizational inertia and accumulated local knowledge are consistent with the vast literature on centers of excellence (see Frost et al. (2002), Birkinshaw et al. (2002)). This literature claims that foreign R&D subsidiaries will develop expertise that is collateral to the core competence of the firm. However, this will not lead to an internationalization of R&D projects directly related to core technologies and strategic R&D (see references discussed in section 2.2).

The interviewees also concurred on the *maturation dimension* of foreign R&D investment as an explanation for the homebound nature of strategic R&D (see references discussed in section 2.2). In particular, foreign R&D subsidiaries have a long *learning curve* and only progressively gain visibility in the overall corporate R&D organization to `earn´ their autonomy also for more strategic types of R&D. Foreign R&D subsidiaries might initially have been set up for home-base exploitation purposes but may subsequently mature into knowledge augmenting centers. While modularity in R&D projects connected to wireless technology allows for a fine-tuned division of labor and collaboration across different teams, the sunk investment required to give a research team the tools necessary for their work is still considerable. Motorola managers talked about "critical mass" that has to be in place at foreign R&D subsidiaries for them to become truly operative also in terms of home-based augmentation.

The two Nordic companies added that one has to become `committed´ to a foreign location before getting anything useful out of it. Becoming committed does not only have to do with the physical investment necessary to get a foreign R&D subsidiary up and running. It also has to do with the accumulation and maturation of `soft´ and more intangible elements. Once a foreign R&D subsidiary gains sufficient credibility in the company organization it becomes a critical asset, and it is unlikely that successful subsidiaries will be divested. Until this occurs homebound R&D will thus play a predominant role for strategic projects.

Interviewees at the four companies were asked to comment about *the importance of partnerships* with universities, key customers and suppliers as issues commonly highlighted in the literature. Here the interviewees provided mixed observations. This kind of collaboration often occurs throughout international alliance networks, and alliances were cited as important in this industry where different competences need to converge (compare with Leiponen (2005); Palmberg and Martikainen (2006)). It seems that alliances become more important further downstream from R&D projects once the related patents have been filed and notified to ETSI. At this phase the notified patents become bargaining chips for cross-licensing activities. Further upstream, however, in-house R&D dominates and the companies `are on their own´ and thus prioritize in-house homebound R&D. This R&D

contributes to strategic components of the final product, and once notified they become bargaining chips in international alliance networks.

4.3. Centralized IP management practices as a selection bias?

So far we have considered whether and why the undertaking of more strategic R&D is homebound. In this final section we consider whether patents, which results from R&D performed at home, have a greater chance to become notified at ETSI. Since we are using patents as indicators for the organization of R&D, it could be the case that patents resulting from homebound R&D activities are also easier “to appropriate” and thus – in this particular context – have a higher probability to turn into notified essential patents in the ETSI system. To what degree does such a possible “selection bias” affect, as well as complement, our discussion in the previous section?

We define appropriability as the ability of companies to take exclusive possession and to extract value from the application of technologies and other intangible assets (for a similar definition see Teece (1986) and Gans and Stern (2002)). This ability is embedded in the IP management activities of companies, on the peculiar linkages that they seek to create between exploration (R&D) activities and its commercial exploitation. It is thereby influenced by headquarters’ guidelines and by the level of sophistication of an IP culture. The disclosure of inventions within the company, and the filing at patent offices around the world, is typically done on a decentralized basis depending on where the inventors are located. However, once patents have been filed at the patent offices the actual strategic management of these IP assets is centralized within the company. In the context of this paper this management concerns issues such as the notification of patents to ETSI, licensing strategies and possible litigation, as well as the ex-ante definition of patenting objectives at the corporate level (see Di Minin (2006)).

The interviews confirmed that more operational IP support services indeed have to follow the internationalization trend of R&D, i.e. inventors dispersed globally need to have sufficient access to IP managers and attorneys when filing for patents. They explained that inventors can get access to local patenting committees in the phase of invention disclosure, and that foreign R&D subsidiaries have to fulfill their own patenting objectives. However, managers at the four companies acknowledged the centralized as well as homebound nature of more strategic management and exploitation of IP assets, in particular related to standardization in telecommunications.

Each of the interviewed managers agreed that not all patents are well written and useful documents. It is quite well known that many patents are practically useless or unenforceable, as they read on claims and technologies which have already been patented, or that have no practical use. One could thus argue that R&D projects that are more closely monitored by IP experts in the home countries also will produce patents that are better written, and easier to appropriate further downstream in the context of notification, licensing and possible litigation. While the interviewee at Ericsson confirmed this idea, the interviewee at Nokia could only acknowledge a possible "IP-bias", but he could not verify this hypothesis as he had not been directly involved in IP management. The interviewees at Motorola and Qualcomm denied the relevance of centralized IP management as a source of selection bias to explain our evidence on the case for non-globalization.

In the case of Ericsson disclosure and patent filing take place at the site of invention. IP management is then centralized at the headquarters in Stockholm, and licensing and possible litigation is also handled at this location. However, this does not necessarily mean that R&D teams around the world are doing less strategic R&D. What this does mean is that results of R&D projects that take place abroad are more difficult to be noticed, understood in a timely fashion, and ultimately appropriated. This is best exemplified with a citation: *"by the time I know that my research team in Australia is working on a project that might have some implications for one of our standards, it is going to be too late to act on that."* While the interviewee at Nokia could not comment on the relevance of IP management centralization, it was suggested that for standardization a close co-operation is necessary between R&D and the teams following standardization, as much support is needed in order to define technically the best solution.

Among the four companies, Ericsson has the most internationalized R&D activities and has the most remarkable difference in the foreign share between essential and control group patents. Views expressed in the course of the discussion at Ericsson did not deny the importance of path dependency in explaining why critical R&D projects are still located in

Sweden. Also, great attention to IP related issues is given to research labs around the world, both in Europe and in other countries. Still, the need for some R&D projects to be closely tied to centralized IP management at the headquarters was singled out as the prevailing factor in guiding decisions to keep some of the most sensitive projects homebound.

To conclude, it seems that the case of Ericsson and partly also Nokia suggest that there might be a certain degree of selection bias in our empirical analysis in so far as centralized homebound IP management provides preferential treatment of inventions with equally home-based inventors. However, this is does not appear to be the case for Qualcomm and Motorola. According to the interviews this was due to a mature and global IP management system in the case of Motorola, and a concentration of most of the R&D activities around San Diego, in the case of Qualcomm.

This paper thus suggests that the discussion and empirical analysis of internationalization of R&D should take more care in considering also how IP management practices of companies affect their global dispersion of R&D. In particular, it might be the case that home-base augmentation strategies abroad requires a clearer decentralization of IP management activities in order to also secure appropriation of foreign R&D. Further research needs to establish the relevancy of this observation also in other industries.

5. CONCLUSIONS

Despite the globalized nature of the wireless telecommunications industry, this paper clearly suggests that the strategic R&D and inventive activity relating to the technological core of this industry is still very homebound. This is taken as support for the ”case of non-globalization”, thus echoing the observations made by Patel and Pavitt (1991) already some twenty years ago, as well as subsequent research along these same lines. The observation is based on an analysis of essential patents of four significant companies (Motorola, Qualcomm, Ericsson and Nokia) in the industry set against a benchmark of non-notified control group patents.

The empirical set-up seeks to control for possible country and firm biases. Nonetheless, it hinges on the assumption that these notified essential patents are strategically, and probably also technologically and economically, more significant than their non-notified counterparts in the control group. Further, observation only concerns the R&D and inventive activity of these firms in relation to standards commissioned by ETSI from where our data has its origin. While these are important standards in the development of the industry towards next generation wireless telecommunications technologies, these firms also hold patents of great importance to a range of other standards outside ETSI that have not been considered here.

Despite these evident limitations, this paper brings forward important questions related to the organization of R&D and inventive activity in this industry worthy of exploration in subsequent research. In particular, the interviews that we undertook with R&D and IP managers of all of the included firms provide complementary and new insights on the homebound nature of strategic R&D and inventive activity in this industry. In particular, once we separate out the more strategic type pf R&D and inventive activity as we proposed to have done in this paper, organizational inertia, maturation and learning curve effects, as well as IP management issue come into play and appear to countervail the drivers for R&D internationalization.

Organizational inertia, maturation and learning curve effects might be considered as company-specific issues and it might be difficult to generalize these in the context of an over-reaching explanation for the homebound nature of strategic R&D and inventive activities. More case studies are needed, drawn from various other industries where a comparative methodology can be used. However, while partly being a selection bias in our empirical analysis, the interviews did also raise the IP management issue as a new and possible quite general issue countervailing the internationalization of R&D. This alternative explanation, which relates more to the specificities of IP management and the interactions between IPR and R&D functions of firms, has not been explored yet by the literature and appears to require further research

In fact, the increased emphasis on knowledge creation in the periphery (alleged or real) regions of the world led theory to focus on various organizational modes for this phenomenon, but none of these discussions points to the international distribution of different phases of IP management. Some directions for further research might be found in Teece (2006) who suggests that not only the sources, but also the appropriability of unique sources of knowledge is the main source of what he calls "special advantage" of MNCs. Coordination between R&D teams and whoever in the company has ultimate responsibility for IP protection and commercialization of results will lead to higher appropriability of R&D investment globally. Thus, for MNCs that attempt to distribute the R&D and innovative activities internationally, this also calls for some level of decentralization of IP planning and management functions. Further research on the international coordination between R&D and IP functions of companies could add new dimensions to the debate on, and management and appropriation of, globally dispersed R&D.

6. REFERENCES

Archibugi, D., and S. Iammarino (1999). "The policy implications of the globalisation of innovation." *Research Policy,* 28(2-3), 317-336.

Asakawa, K. (2001). "Organizational tension in international R&D management: the case of Japanese firms." *Research Policy,* 30(5), 735.

Bekkers, R. (2001). *Mobile telecommunications standards: GSM, UMTS, TETRA, and ERMES*. Norwood, MA: Artech House.

Bekkers, R., and J.W. Paper "The effect of strategic patenting on cumulative innovation in UMTS standardization". Paper presented at *DIME Workshop on Rules, norms and standards.*

Bergek, A., and C. Berggren (2004). "Technological internationalisation in the electro-technical industry: a cross-company comparison of patenting trends 1986-2000." *Research Policy,* 33, 1285-1306.

Birkinshaw, J. (1996). "How multinational subsidiaries are gained and lost." *Journal of International Business Studies,* 27(3), 467-498.

Birkinshaw, J., and N. Hood (1998). "Multinational subsidiary evolution: capability and charter change in foreign-owned subsidiary companies." *Academy of Management Review,* 23(4), 773-795.

Birkinshaw, J., R. Nobel, and J. Ridderstrale (2002). "Knowledge as a contingency variable: Do the characteristics of knowledge predict organization structure?" *Organization Science,* 13(3), 274.

Birkinshaw, J.M., and A.J. Morrison (1995). "Configurations of strategy and structure in subsidiaries of multinational corporations." *Journal of International Business Studies,* 26(4), 729-753.

Cohen, W.M., and D.A. Levinthal (1990). "Absorptive capacity: a new perspective on learning and innovation." *Administrative Sciences Quarterly,* 35, 569-596.

Di Minin, A. (2006). "Internationalization of Research and Development: Evidence from the Semiconductor and Wireless Telecommunications Industries." *U.C. Berkeley Dissertation*.

Dunning, J.H. (1958). *American Investment in British Industry*. London: George Allen & Unwin.

Dunning, J.H. (1994). "Multinational enterprises and the globalization of innovatory capacity." *Research Policy,* 23, 67-89.

ETSI (1998). *Rules of Procedure of the European Telecommunications Standards Institute*. Sofia Antipolis, France: Version adopted by the General Assembly on November 20,1998.

Friedman, T.L. (2005). *The World is Flat. A Brief History of the 21st Century*. New York: Farrar, Straus and Giroux.

Frost, T.S. (2001). "The geographic sources of foreign subsidiaries' innovations." *Strategic Management Journal,* 22(2), 101.

Frost, T.S., J.M. Birkinshaw, and P.C. Ensign (2002). "Centers of excellence in multinational corporations." *Strategic Management Journal,* 23, 997-1018.

Gans, J.S., and S. Stern (2002). "The product market and the market for "ideas": commercialization strategies for technology entrepreneurs." *Research Policy,* 32(2), 333-350.

Gerybadze, A., and G. Reger (1999). "Globalization of R&D: recent changes in the management of innovation in transnational corporations." *Research Policy,* 28(2-3), 251-274.

Hymer, S.H. (1976). *The International Operations of Multinational Firms. A Study of Foreign Direct Investment*. Boston, MA: MIT Press.

Katz, M., and C. Shapiro (1985). "Network externalities, competition and compatibility." *American Economic Review*(3), 424-440.

Katz, M., and C. Shapiro (1986). "Technology adoption in the presence of network externalities." *Journal of Political Economy,* 4(4), 822-841.

Kogut, B. (2004). Conclusion: from regions and firms to multinational highways: knowledge and its diffusion as a factor in the globalization of industries. In *Locating Global Advantage*, edited by M. Kenney and R. Florida. Stanford, CA: Stanford University Press.

Kuemmerle, W. (1997). "Building effective R&D capabilities abroad." *Harvard Business Review,* 75(2), 61-70.

Kuemmerle, W. (1999). "The drivers of foreign direct investment into research and development: An empirical investigation." *Journal of International Business Studies,* 30(1), 1-24.

Leiponen, A. (2005). "Clubs and standards: The role of industry consortia in standarization of wireless telecommunication." *ETLA Working Paper,* no. 997.

Mendez, A. (2003). "The coordination of globalized R&D activities through project teams organization: an exploratory empirical study." *Journal of World Business,* 38(2), 96-109.

Mudambi, R., and P. Navarra (2004). "Is knowledge power? Knowledge flows, subsidiary power and rent-seeking within MNCs." *Journal of International Business Studies,* 35(5), 385.

Patel, P., and K. Pavitt (1991). "Large firms in the production of the world's technology: an important case of 'non-globalisation'." *Journal of International Business Studies,* 22(1), 1-21.

Rugman, A., and A. Verbeke (2001). "Subsidiary-specific advantages in multinational enterprises." *Strategic Management Journal,* 22(5), 237-250.

Rysman, M., and T. Simcoe (2006). "Patents and the performance of voluntary standard setting organizations." *Working Paper, Berkeley Innovation Seminar,* March.

Steinbock, D. (2003). "Globalization of wireless value system: from geographic to strategic advantages." *Telecommunications Policy,* 27(3-4), 207-235.

Teece, D.J. (1986). "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy." *Research Policy,* 15, 285-305.

Teece, D.J. (2006). "Reflections on the Hymer thesis and the multinational enterprise." *International Business Review,* 15(2), 124-139.

UNCTAD (2005). World Investment Report 2005. Transnational Corporations and Internationalization of R&D. New York and Geneva: United Nations.

von Zedtwitz, M., and O. Gassmann (2002). "Market versus technology drive in R D internationalization: four different patterns of managing research and development." *Research policy*, 31(4), 569.

Zander, I. (1997). "Technological diversification in the multinational corporation: historical trends and future prospects." *Research Policy,* 26(2), 209-227.

Zander, I. (2002). "The formation of international innovation networks in the multinational corporation: an evolutionary perspective." *Industrial and Corporate Change,* 11(2), 327-353.

Zysman, J., and A. Newman, eds (2006). *How Revolutionary was the Revolution*. Stanford, CA: Stanford University Press.

[1] The already cited UNCTAD (2005) report offers a comprehensive overview of international trade and investment.

[2] A classic starting point is here Baldwin and Clark (2000) Brusoni et al. (2001) apply the concepts of modularization to the organization and extension of R&D projects.

[3] Even though the empirical analysis presented in the next sections does not directly address the cost advantage explanation for the internationalization of R&D, it is important to acknowledge its relevance. Organizational challenges, related to the offshoring of the most labor-intensive phases of R&D to low-cost countries are not easy to overcome. Expertise of dispersed teams, as well as the architectural complexities of each single product or component will ultimately determine whether or not a project requires geographical proximity For a detailed study of product development and modularization of tasks across dispersed research teams in semiconductors, see Schofield and Gregory (2004). Global players might decide to relocate the most labor-intensive phases of their R&D effort to regions that are desirable, not for the size or growth rate of their market, nor for other cutting edge R&D activities located in the area, but simply because of the availability of qualified and cheap technical expertise. The development of ICT infrastructures is now making available qualified and cheap human capital located in rapidly developing countries (most notably India, South East Asia, China) and transitional economies (Eastern Europe). This has, in turn, already led to the delocalization of low-end support service functions. It is quite likely that firms that have already gone through a delocalization of back-office operations will now look at the same areas as possible locations to move some parts of their R&D operations. Being the first to open up a subsidiary in a foreign country is a risky venture; closures and downsizing of FDIs are a very common phenomenon. When a company gains understanding of local institutions and business climate it is likely to consider "upgrading" its investment on that territory before plunging into a grassroots investment in a new region (examples of upgrading have been studied in particular in the software industry: see O'Riain, 1997 for a study of Ireland and Dossani and Kenney, 2003 for back office operations in India).

[4] For a more complete review of the literature on the organizational dimension of foreign R&D activities, see Werner (2002) and Zanfei and Solvell (2000).

[5] Numerous studies challenge the argument that "maturation" is working only one way, and that R&D centers originally adapting R&D to foreing markets then become centers of excellece and learning centers of new technologies. According to many studies, demand adaptation remains the main driver for FDI in R&D. See here Dunning and Narula (1995); Anand and Kogut (1997); Hakanson and Nobel (1993) Guellec and van Pottelsberghe de la Potterie (2001); Athreye and Keeble (2000); Gertler et al. (2000); Yeung (1999); Le Bas and Sierra (2002); von Zedtwitz and Gassmann, 2002).

[6] IEEE Transactions on Engineering Management (1996), Vol.43, 1

[7] A series of OECD reports (see for example: OECD, 1993) started to infer the policy implication of a global interconnection of technology development activities and the need of countries to create the necessary conditions to attract this form of investment.

[8] See here among others: Patel (1996), Duysters (1996), Kleinknecht and ter Wengel (1998), Patel and Vega (1999), Meyer-Krahmer and Reger (1999), Rama (1999), Asakawa (2001), Belderbos (2001), Kumar, 2001, Mowery (2001), Edler et al. (2002), Mendez, 2002, Bergek and Berggren (2004).

[9]See here: Pearce and Singh (1992), Cantwell (1992 and 1995), Schott (1994), Dunning (1995), Shan and Song (1997), Guellec and van Pottelsberghe de la Potterie (2001), Le Bas and Sierra (2002), Ramirez (2006)

[10] For a series of case studies of standard setting efforts see Grindley (1995). Blind et al. (2002) comment a number of standardization initiatives, focusing in particular on the conflicts between standardization and IP protection and enforcement.

[11] The alternative here is to "act strategically", timing the disclosure of essential IP in order to create "lock-in" situations for the partners. Both partners of the standardization committee and third parties, which hold supposedly essential IPR, might fail or voluntarily conceal the potential infringement by the standards of technologies that they have already patented or that they are currently developing and are going to be covered by patents. This type of behavior attempts to maximize future licensing revenue but threatens the future success of the standard. For a variety of reasons not discussed here (See Bekkers 2002, and Di Minin 2006), in the case of ETSI wireless standards, late disclosure or concealment of potentially essential patent did not constitute a problem for the commercial application of standards and we think that it should not constitute a troublesome bias for the empirical analysis discussed in section 3.

[12] The most complete account of ETSI's work can be found in the already cited Bekkers (2001), and a more detailed study of the GSM case in Bekkers (2002). Readers should refer to Besen (1990) for an analysis of the early negotiation phases that signaled ETSI's uniqueness. Prins (1993) and Blind et al. (2002) point to the transparency of the procedures and management of disclosure and licensing.

[13] Article 4 of ETSI IPR Policy (first adopted in 1994, and last reviewed in November 2005) states that: "each MEMBER shall use its reasonable endeavours, in particular during the development of a STANDARD or TECHNICAL SPECIFICATION where it participates, to inform ETSI of ESSENTIAL IPRs in a timely fashion. In particular, a MEMBER submitting a technical proposal for a STANDARD or TECHNICAL SPECIFICATION shall, on a bona fide basis, draw the attention of ETSI to any of that MEMBER's IPR which might be ESSENTIAL if that proposal is adopted." Failure to give notice of their IPR is considered (Article 14) to be a breach of members' obligations. It is the ETSI General Assembly that has the authority to discuss actions to

be taken on a case by case basis, and member grant the Assembly with exclusive power to make decisions in these circumstances. The concept of "intentional delay" is used in the official ETSI Guide on IPRs: "*Intentional Delay*, where proven, should be treated as a breach of the IPR Policy (clause 14 of the ETSI IPR Policy) and can be sanctioned by the General Assembly." According to the ETSI Statute, breach of members' obligations can lead to expulsion. (the ETSI Guide on IPRs was adopted on November 23rd 1994, and subsequently incorporated in the ETSI Rules of Procedure, both the ETSI IPR Policy and the Guide are available at *http://www.etsi.org/legal/*).

[14] This means that it is not clear what kind of sanctions can be effectively enforced by ETSI (or by the E.U. Commission), but also means that in the history of ETSI, members did not consider such an occurrence a problem. Interviews and email exchanges with ETSI members, officials, and experts confirmed that no official procedure to contest breach of Article 14 was ever brought forward to the Assembly.

[15] In order to gather the most complete set of patents filed by the company and its controlled subsidiaries, original search strings are used combining the parent company with its fully owned subsidiaries (data gathered through Mergent Online and Who Owns Whom). Possible variations of names for the same companies were also considered. Patent data was gathered through Thomson's Dialog search service. Dialog constantly checks patents for misspellings and incorrect information.

[16] All USPTO essential patents assigned to U.S. companies have at least one European equivalent in the patent family. This means, *de facto*, that the "international protection" correction just discussed applies exclusively to the control group. This is not surprising, given the commercial relevance of these patents on the European market.

[17] We also consider forward patent citations to weigth the importance of single patents. Forward patent citations, defined as the number of patents citing a specific patent, are used as a proxy for the usefulness and technological significance of each individual patent. For each patent, all forward patent citations received in the two years after each patent was granted are considered. The discussion of a different strategic value of essential and control group patents finds some evidence in the patent citation analysis. Essential patents have a higher average forward citation rate (4.2 citations per patent) than that of the control group (2.31 citation for patents). Essential patents, by definition, are patents whose commercial application and usefulness have been somehow certified through their notification. They are therefore more likely to get cited as relevant prior art by subsequent and related patents, than patents in the same technological classes that are not identified as essential ones.

The citation rate of patents by Qualcomm is the highest and stands out. Qualcomm essential patents received on average 6.21 citations, and its non essential patents 3.03. This holds for both essential and control group patents, even when controlling for the age of patents. Qualitative investigation with industry experts suggests that Qualcomm is developing technologies of a more generic (or enabling) nature and, as a result, it plays the double role of competitor and technology provider (in particular for the CDMA and 3rd generation networks). Generic technologies are likely to receive more citations than more application-specific patents, since their range of application is much broader.

[18] See Appendix for a complete list of the interviews conducted. Interviews were not recorded, but notes from the interviews were sent back to the interviewees for comments and amendments. Interviews lasted between one and two hours, one was conducted over the phone and the others in person.

[19] The average time for patent examination is 18 months. However, standard deviation is very high and it might take much longer for some patents to be analysed and finally published. Pending applications are not considered in this study.

[20] The report on telecommunications technology patents, edited by the USPTO Patent Technology Monitoring Division, confirms a similar trend.

[21] The Pearson Chi-Square values for DO of both companies confirm that we have to reject (with 0.01% significance level) the null hypotheses that the international distributions of inventive activity locations for Nokia and Ericsson are similar for essential and control group patents.