A Case for Non-Globalization?
The Organization of R&D in the Wireless Telecommunications Industry*

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ABSTRACT: The offshoring of manufacturing has been the most visible ingredient of economic globalization in recent years. However, the rapid change in the global division of manufacturing has overshadowed another – and perhaps even more significant phenomena – namely the internationalization of the R&D and inventive activities of firms.
In concrete terms this means that researchers and inventors increasingly tend to be located outside the domestic country of origin of firms, as captured in numerous empirical studies. This paper revisits the "case for non-globalization" in the context of strategically important technologies in a truly global industry, namely the wireless telecommunications industry. It analyses, in comparative set-up, the evolution of the notified essential patent portfolios of four leading incumbents to assess to what degree and how R&D and inventive activity of this technological core of the industry is globalizing. Contrary to expectations the results clearly support the case for non-globalization. They thereby raise a range of important issues and research avenues related to the organization of R&D, location advantages and IPR management of firms.

KEYWORDS: globalization, R&D, wireless telecommunications, essential patents

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1. INTRODUCTION

1.1. Background

Heightened international Schumpeterian competition implies that 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 liberalization of world markets and technological change, especially concerning 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).

From the viewpoint of firms, foreign direct investment (FDI) and the offshoring of manufacturing has been the most visible trend of globalization. However, the rapid change in the global division of manufacturing has hence far overshadowed another, and perhaps even more significant phenomena, namely the rapid internationalization also 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 domestic country of origin of firms. Indeed, several studies have recently documented that a growing share of inventions of multinationals involve foreign inventors. This trend appears to be especially clear in the case of technologically leading multinationals originating from smaller countries (see Patel and Vega (1999); Guellec and van Pottelsberghe de la Potterie (2001); Hayashi (2004) and Cantwell and Kosmopoulou (2004)).

The internationalization of R&D is a multidimensional issue that needs to be analyzed from various viewpoints where the specificities of both the nature of R&D and technologies have to be taken into account. In particular a seminal – and perhaps long-forgotten – paper by Patel and Pavitt (1991) points out that the actual inventive activities of multinational corporations (MNCs) tend to be significantly less internationalized than the global distribution of the R&D expenditures seem to suggest, with considerable variations across technological sectors. 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 the core R&D activities of the MNCs, highlighting such issues as the importance of physical proximity and tacit knowledge, education, training and basic research. Patel and Vega (1999) provide additional evidence regarding the importance of country level effects to explain inventive location decisions.

1.2. Aim and structure

Against this general background this paper analyses the internationalization of R&D of a set of major firms in core technological fields of the wireless telecommunications industry. It aims to assess to what degree there is any room for the 'case of non-globalization' in the Patel and Pavittian sense referred to above. An analysis of the wireless telecommunication industry from this viewpoint is particularly interesting for three reasons.

First, the 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, 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.

The paper should be read as a descriptive and explorative study relating to the collaborative Berkeley University Roundtable of the International Economy (BRIE) - ETLA project, to be both elaborated up and deepened, in subsequent papers to follow. It opens the discussion on the globalization of R&D by looking at patents deemed essential from the viewpoint of standardization in the wireless telecommunications industry in a comparative setting. Its overreaching aim can – more precisely – be broken down into the following two research questions:

1. To what extent are networks of inventors of so-called essential patents of a set of significant MNCs in the wireless telecommunications industry globalized?
2. What does the international composition of inventor networks of essential patents suggest about the organization of R&D and inventive activity in this particular industry?

The paper is structured as follows. The second section provides a brief conceptual discussion of major interpretations of why R&D is internationalizing, combined with some insights into the specificities of the wireless telecommunications industry. The third section discusses the data that we use and provides the empirical analysis based on recently collected data on essential patents notified to the ETSI (European Telecommunications Standards Institute). The fourth section synthesizes and concludes the paper.

2. A Conceptual Framework

2.1. The Internationalization of R&D

The recent UNCTAD (2005) report offers a comprehensive overview of international trade and investment. When we look at overseas investment in R&D, three general observations emerge from the report. First of all, R&D still seems to be the least internationalized of all functions performed by a MNC. Nonetheless, the second observation is that the degree of internationalization of R&D is increasingly rapidly as both the popular press and numerous research papers suggest based on data on R&D expenditures, patenting, strategic alliances etc. (see e.g. Hayashi (2004), Ali-Yrkkö and Palmberg, 2006). The third observation is that FDI related to R&D is relatively concentrated in a few areas of the world, namely in the highly developed incumbent countries such as the US, Japan and European countries, and it mainly occurs across the border of these countries.

As a recent and increasingly significant phenomenon, the internationalization of R&D deserves attention, as the competitiveness of MNCs – as well as the development of regions and countries where these are headquartered and locate their R&D labs – is at stake. In the literature one can find three main explanations for the internationalization of R&D that also shape research agendas and the policy discussion. The first of these explanations relates to the general international expansion of the export activities of MNCs. As MNCs expand their export activities for existing or new 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 markets. In this case R&D activities offer support to export expansion as knowledge generated in the central R&D lab – typically in the home-country – is applied to the foreign market. (Dunning, 1958; Hymer, 1976). As the desire by MNCs to enter new markets is the main driver of this form of internationalization, it is often labelled 'home-based exploiting' as its priorities are to exploit home-based knowledge advantage through foreign activities (Kuemmerle, 1997).

In his survey of FDI in the US, Kuemmerle (1999) suggests that during a more recent wave of globalization, a substantive change in the form of R&D internationalization took place. Today, companies don't go abroad merely to exploit home-based knowledge for foreign markets, but also to learn and explore foreign knowledge which is located in deep pockets overseas. Even though demand is still today recognized as the main driver for FDI, Dunning (1994) recognizes that host countries might also be *"sources of new knowledge and not only new markets"* as the second explanation for the internationalization of R&D. Dunning (1998) uses the OLI framework (Ownership, Localization, Internalisation as the three main sources of advantages and motivation of a firm's FDI activities) to justify the existence of an 'asset seeking FDI' which is driven by access to 'knowledge intensive factors of production' that are embedded in the locations where the MNC invests. Kuemmerle (1997, 1999) distinguishes this type of FDI into R&D as 'home-based augmenting' to contrast it with 'home-based exploiting'.

The access and use of cheaper factors of productions for the more labour intensive phases of an R&D project has become a progressively more important third explanation for the internationalization of R&D. This explanation finds some parallels with internationalization of manufacturing due to increasing modularization of products and systems (Brusoni et al., 2001). In this context the regional economics literature is relevant to refer to. This literature suggests that as the marginal costs of critical factors of production – such as human labour – become more expensive in core regions of the highly industrialised countries, low value added production activities are increasingly transferred to peripheral locations (Vernon, 1960). This phenomenon is self-enforcing as both core and peripheral regions build up a specialized labour force, intermediaries and supporting industries, as well as tacit know-how related to their specific activities (Krugman, 1991).

Even though our empirical analysis does not directly address the cost advantage explanation for the internationalization of R&D, it is important to acknowledge its possible presence. Global players might decide to relocate the most labour-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 very likely that firms that did already go through a delocalization of back-office operations will now look at the same locations as possible areas where to move some parts of their R&D operations.

The seminal paper by Patel and Pavitt (1991) is possibly the first comprehensive empirical effort to show 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.

Inspired by one of the last remarks in Patel and Pavitt (1991) – stating that *"we expect to see greater internationalization of large firms' technological activities in the future"* – this paper partly replicates the empirical approach by these two scholars. It contributes by reassessing the case for non-globalization in the wireless telecommunication industry, an industry that shows all the signs of internationalization for demand, production and R&D. We will do this by also incorporating the specificities of both the nature of R&D and technologies.

2.2. Globalization, technological change and standardization in telecommunications

A priori, by the face of it, there seems to be very little to support the case for 'non globalization' of R&D and inventive activity in the wireless telecommunications industry. For various reasons not dwelled into here trade liberalization has been particularly rapid in many high-technology industries, and particularly so in the case of ICT (see here Zysman and Newmann (2006) for one of the most recent overview of the development of this industry). Apart from trade tariffs of the general kind, regulatory liberalization has been particularly noteworthy and rapid in the last couple of decades.

Prior to the 1980s most national telecommunications markets – even in the highly industrialized countries – were characterized by vertically integrated national monopolies where telecommunications equipment production and demand largely was in the hands of the PTTs. The wave of regulatory liberalization was set in motion in the early 1980s by the privatization of the British Telecom, NTT in Japan and the break-up of AT&T in the US, although it should be noted that decentralized markets already had been in existence especially in Sweden and Finland where wireless telecommunications took of earlier (Davies, 1994).

By the 1990s the vertically integrated monopolies of PTTs had dissolved, while R&D and innovation increasingly shifted 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, and leading firms makes their largest share of revenues, by far, outside their home base (Steinbock, 2003).

While trade and regulatory liberalization foremost has 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 is that it opens up multiple entry-points also for new firms and other players.

With ICT convergence we refer to the merging of data- and telecommunications technologies which previously, until around the 1980s, rightfully could be characterized as two separate fields. 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 many important implications for telecommunications incumbents. The increasing popularity of the Internet means that mobile telecommunications applications and services also have to 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; Tan et al., 2004).

Standards define the interfaces of technologies to which firms in the industry have to comply to and thus create new markets. Standards are typically created throughout different types of consortia, "clubs" or industry groups consisting of carriers, manufacturing firms, standardization bodies and other stakeholders (Leiponen, 2005). The technologies that the standards define become quite essential for firms to master. As a consequence standardization bodies have set-up various schemes to support the notification and crosslicensing of the intellectual property rights (IPRs) over such essential 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 put much effort on managing their IPRs with respect to these various notification schemes (Bekker, 2001; Bekkers and West, 2006).

Despite heterogeneity in the degree to which firms approach these issues notification schemes add one important aspect to the globalization of the telecommunications industry that we capitalize on in this paper. Specifically, these schemes delimit a subset of technologies 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. In the case of the European standardization body ETSI, Bekkers (2001) suggests that IPR holders indeed do have strong incentives to lobby for their patents to be notified as essential. The inclusion into a standard opens up for the company various strategy avenues, and licensing revenue opportunities, the success of which ultimately is tied to the success of the standard itself.

One possible implication of this is that companies disclose only those patent-based IPRs that they know extremely well, that they are convinced they can enforce and control 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, not only the successful market adoption of a standard 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, the question of the degree to which this part of the R&D activities of companies is globalized or not is an important one in the current debate about the internationalization of R&D and the interpretations thereof.

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. In a recent paper by Rysman and Simcoe (2006), that analyses the notifications schemes of four major international standard setting bodies through looking at the degree to which notified IPRs (patents) score higher in terms of technological content than non-notified ones, some evidence is provided that such essential patents indeed also have a higher technological, and potentially also economic, significance. The paper by Rysman and Simcoe (2006) thus also suggests that the data that we explore captures technologically and economically 'more significant R&D' of the firms included although we do not wish to push this assumption too far at this stage.

3. Empirical Analysis

3.1. Methodological considerations

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 this context in the vain of Patel and Pavitt (1991). In order to do so we here compare patent data for the development of telecommunication standards, with a control group of similar – but ultimately less strategic – patents.

With reference to the earlier discussion, the European Telecommunication 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/).

We here use patent data that originally was identified in the ETSI database on essential patents. This data can be accessed through online documentation containing lists of 'essential patents' under various standards commissioned by ETSI (see Appendix 1 for the complete list of ETSI standards per April 2005). In particular, in this paper we consider the four largest assignees of essential ETSI patents, filed at the patent office in the US (USPTO) during the period 1985 - 2001, and subsequently published before May 2006 (see Table 1). For these patents we gather information about their technology classes, date of filing and publication, affiliation of inventors, scope of international protection and forward citations.

Table 1. Patents notified as essential at ETSI by companies (our own calculations)

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 we constructed a control group of non-notified patents. In order to define this set of patents we considered all the technology classes assigned to the essential patents. We then collected 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.[4] With reference to the discussion above, we thus consider this control group of patents as being on average less strategic from the viewpoint of the activities of these firms on European and global markets. This assumption requires some clarification.

Patents are not commodities, and their value distribution is often very 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, however, does not exclude that at least some of them are extremely important for the company. We do not gather information about the current use of these patents, and we have no way of predicting their future use. Some of them might indeed protect critical aspects of a commercialized product, or they could be the object of profitable licensing contracts. Our assumption here is merely that on average the strategic relevance of patents is lower in the control group. Moreover, we are confident in claiming that the technological and economic value of patents in the control group is more

[4] In order to gather the most complete set of patents filed by the company and its controlled subsidiaries, we built search strings that combined 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.

heterogeneous at the very least. In other words, the event of having been notified 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 US and non-US companies based on patents filed and issued by the US patent office (USPTO) suffers from a significant bias. Usually, when a company files for a patent, initially it seeks protection in its own country, filing a priority application. Subsequently, and only for a subset of patents, the company decides to file for equivalent patents to protect the same invention in each of the countries where the company is seeking to commercialize the related product. A patent assignee has a grace period (one year after filing in the US) to extend the international reach of its patents. However, since filing for international patents is significantly more expensive, the company has to carefully screen its patents to select which ones deserve international protection. Even though IPR strategies vary across firms, it is thus possible to assume that companies are likely to expand the international protection of patents for those inventions that have a higher chance of commercialization.

While it is reasonable to assume that European companies file a US patent only for inventions that did already go through this screening process, for US companies a patent at the USPTO represents the easiest and possibly also the cheapest form of protection. Assuming this is true, when we consider USPTO patents assigned to European companies, we consider only a subset of the entire company portfolio. On the contrary, when we look at USPTO patents assigned to US companies we look at patents before a similar filtering was applied by IPR managers. Hence, in order to make patents filed by European companies comparable with those filed by US companies we look at the composition of the "international patent families" of each single USPTO patent.

A patent family is the collection of all international patents, filed with different national authorities, to extend the reach of protection of the same invention in different countries. We filter out from our analysis all USPTO patents assigned to the two US companies when – within each patent family – we find no equivalent patent or application filed with at least one European patent office. We use the Delphion Patent Family database for this procedure. For the sake of clarity, we will from now on refer to these two sets of patents as the 'essential patents' and the 'control group patents', stressing again that all the ensuing tables and figures contains data collected at the level of patent families subject to the modification concerning the USPTO patents as discussed above. The distribution across companies is shown in Table 2. Our descriptive analysis and the Chi-Square tests described later on in sections 4.2 and 4.3 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 we counted 1 113 USPTO patent notifications. Since each patent can be notified for more than one standard commissioned by ETSI, ultimately we counted a total of 834 unique granted USPTO patents. 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 telecommunication industry in Europe and the US.

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 we consider forward patent citations received in the two years after each patent was granted. Table 3 shows the ratio of two years forward citations for essential and control group patents.

Table 3. Distribution of forward cited essential and control group patents across companies.

2Years Fwd Citations / Patents	Total	Ericsson	Nokia	Motorola	Qualcomm
Essential Patents	4.02	3.31	3.36	3.01	6.21
Control Group	2.31	2.12	2.15	2.47	3.03

Our discussion of a different strategic value of essential and control group patents finds some evidence in the patent citation analysis. Essential patents have an average forward citation rate which is higher than that control group. Essential patents, by definition, are patents whose commercial application and usefulness has 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 higher citation rate of patents by Qualcomm stands out. This holds for both essential and control group patents, even when controlling for the age of patents. Qualitative analysis with industry experts might be necessary to explain this. It seems that Qualcomm is developing technologies of more generic (or enabling) nature, and as a result it plays the double role of competitor and technology providers (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.

3.2. Locations of inventive activity across all companies

Information about the affiliation of inventors on the patent title is here used as a proxy of the location where the inventive activity leading to the filing of the patent was performed (for a critical discussion of this definition of location of inventive activity see e.g. Bergek and Berggren (2004)). The analysis assigns patents to the following three exclusive categories.

1. Domestic Patents (DO): patents whose inventors are all located in the HQ country of the controlling company: the US 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.

We decided to compare the US with single European countries since European countries are rather different types of entities when compared with US states. Besides the obvious cultural and linguistic differences Europe is not yet a unique market as some factors of production, such as skilled labour, are not as mobile as in the US. 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, we will briefly consider state level distribution of patents for the two US companies in the sample.

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.

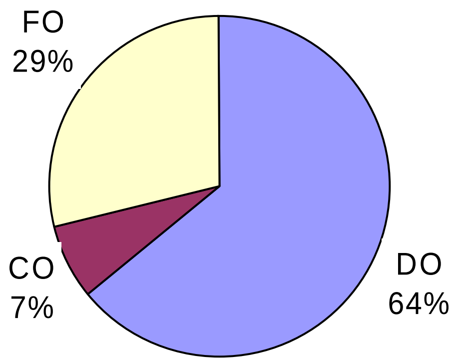

Figure 1. Distribution of control group patents by location of inventive activities.

If we consider the changing distribution of these patents over time (Figure 2), we note that these four companies substantially increased the numbers of foreign and collaboration patents in the course of the late 90's. The data indeed shows evidence of an international expansion of inventive activities. While in the period 1985-94 82% 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. Somehow 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 decreases as well.

The sharp decline in the last two years might have been emphasized by a database 'tailing' effect, since we are here grouping granted patents by application date. For some of the latest years patents might still be under review at the USPTO[5]. In spite of this bias, it is well known that after the euphoria of the late 90's, some rationalization of R&D budgets took place in the industry, and this is likely to have impacted differently domestic and foreign R&D activities.

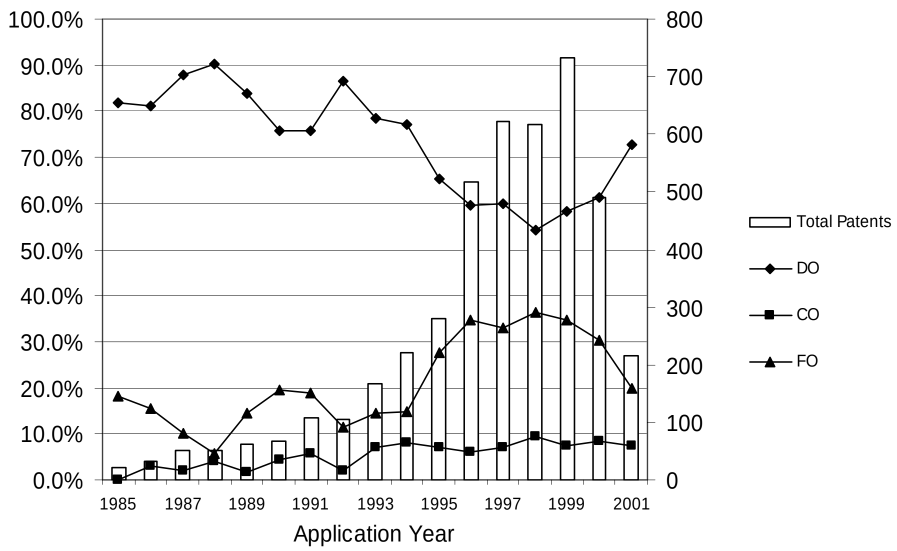

Figure 2. Distribution of control group patents by location of inventive activity: changes over time.

When we weight the number control group patents by the number of forward citations received by each patent for the two years subsequent to publication, the average distribution and trends of DO, FO and CO does not change significantly (Figure 3).

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[5] 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 analyzed and finally published. Pending applications are not considered in this study.

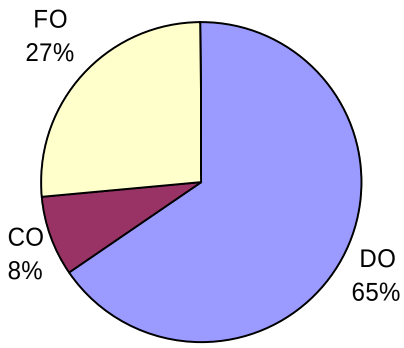

Figure 3. Distribution of forward cited control group patents by location of inventive activity.

The same DO, FO, CO distribution for *essential patents* appears to be significantly different (Figure 4). As it is possible to notice 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 we have 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%.

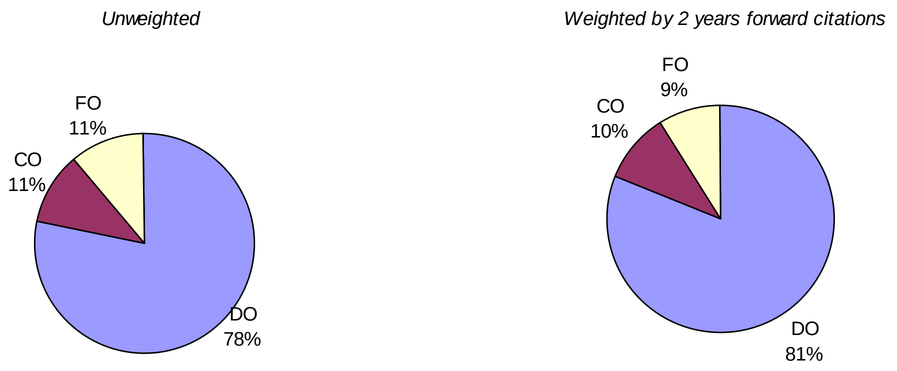

Figure 4. Distribution of essential/cited essential patents by location of inventive activity.

When we weight this data with 2 years forward citation the difference is even more significant (also Figure 4). As for the control group patents, DO patents are slightly more likely do receive citations than FO and CO patents. As a result, the share of DO citations rises to 81% of total forward citations. Therefore, also for patent citations, the Pearson Chi-Square values for both DO and FO confirm that we have 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 90's (Figure 5).

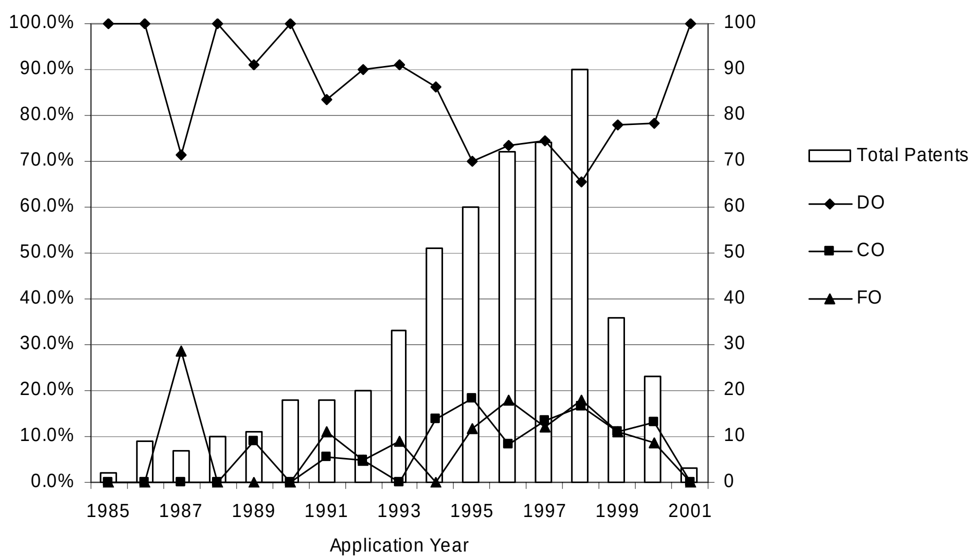

Figure 5. Distribution of essential patents by location of inventive activity: changes over time.

Let us now consider the offshore location for these inventors. In order to do so, Figure 6 compares the distribution of offshore sites of the FO patents across the essential and control group. We are excluding from this analysis domestic and collaborative patents, since, by definition, the inventors for these patents are located either in the US or in Europe.

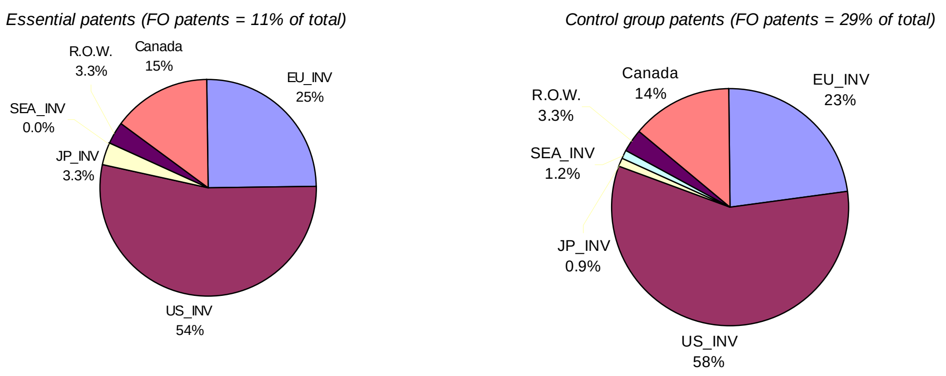

Figure 6. Distribution of inventors of essential/control group patents by US state-level location of inventive activity.

The first interesting element 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 (and 60% if we weight this data by 2 years forward citations) is performed in the US, while 54% of the patents indicated as essentials display a US 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 Rest of the World (ROW). Somewhat surprisingly, this latter group of countries/regions altogether merely represent somewhere between 5% and 6% of control group and essential patents. Hence, such emerging countries and regions are substantially absent as affiliations of inventions for ETSI standards according to this analysis.

Unfortunately our data lags 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 still is highly skewed towards these 'old and incumbent' centres of innovation.

3.3. 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.

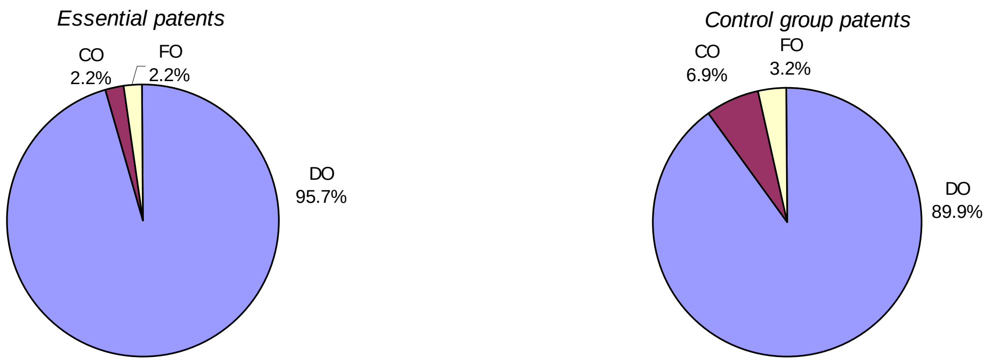

Figure 7. Distribution of essential/control group patents of Qualcomm by location of inventive activity.

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 we have 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.

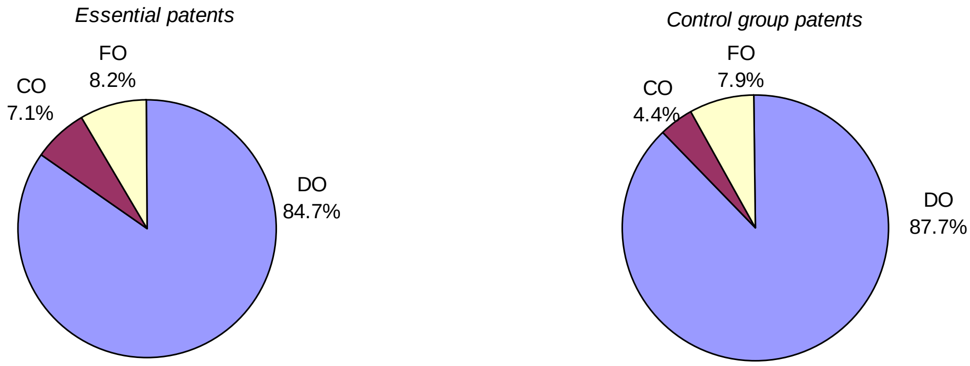

Figure 8. Distribution of essential/control group patents of Motorola by location of inventive activity.

Despite the high concentration of DO patents, Motorola has a more similar distribution between essential patents and the control group (Figure 8). Our 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. For Motorola, however, we are able to find a similar difference in the distribution between essential patents and the control group when we break down the DO patents of these two US firms at the state level (Figure 9). When we move to the state level of analysis the Chi-Square values detect a significant difference.

While this exercise does not make too much difference for Qualcomm (as most of Qualcomm employees are located in San Diego, California), Motorola evidently does R&D in different sites around the US. As a result, inventors of Motorola's control group patents are spread all across the US. However, when considering essential patents only, 80.5% of them are located in Illinois where the company HQ is located.

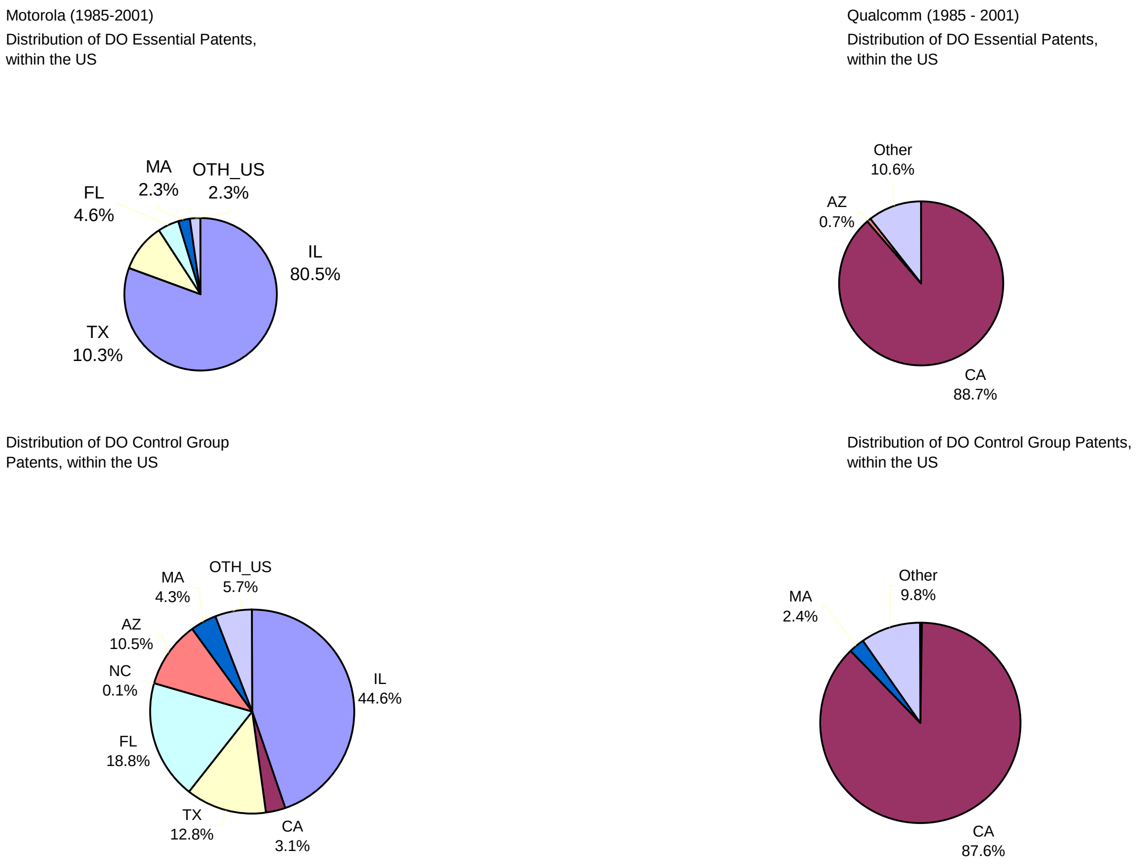

Figure 9. Distribution of essential/control group patents of Motorola and Qualcomm at the US state level by location of inventive activity.

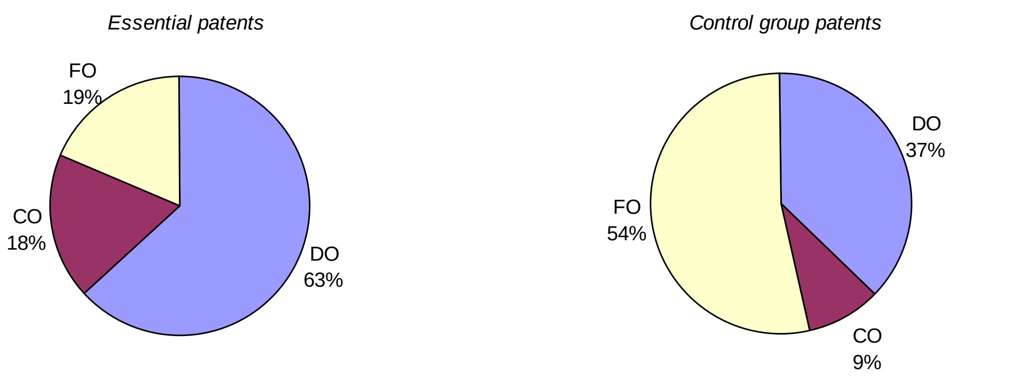

Figure 10. Distribution of essential/control group patents of Ericsson by location of inventive activity.

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 remind that for both Nokia and Ericsson we categorized as foreign locations also patents whose inventors were affiliated to other European countries. 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, still the difference across the two patent portfolios is even more pronounced than for the two US companies[6]. 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.

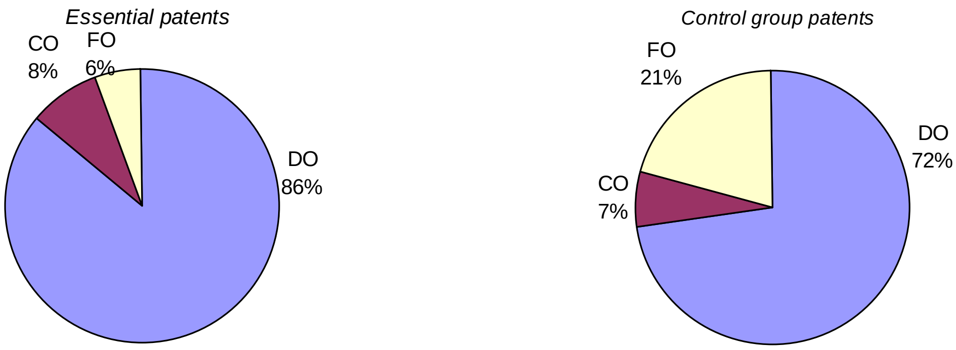

Figure 11. Distribution of the essential/control group patents of Nokia by location of inventive activity.

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

4. A Synthesizing And Concluding Discussion

Despite the globalized nature of the wireless telecommunications industry by the face of it, this paper clearly suggests that the R&D and inventive activity relating to the technological core of this industry still is very home-bound. We take this as support for

[6] 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.

the 'case of non-globalization' made by Patel and Pavitt (1991) some twenty years ago. 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.

Our empirical set-up seeks to control for possible country and firm biases. Nonetheless, it hinges on the assumption that these notified essential patens are strategically, and probably also technologically and economically more significant than their non-notified counterparts in the control group. Further, our 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 telecommunication technologies, these firms also hold patents of importance to a range of other standards outside ETSI that we have not been able to consider in this paper.

Despite these evident limitations of our analysis, this paper brings forward important questions related to the organisation of R&D and inventive activity in this industry worthy of exploration in subsequent research. A primary question is why non-globalization appears so significant in the case of the technological core of this industry? We here suggests two possible explanations, both of which we will elaborate on in subsequent work in the next phase of our research. The first relates to location advantages while the second relates to specificities of IPR management, and the interactions between IPR and R&D functions of firms.

Raising levels of technological integration and specialization, the need to get access and exploit pockets of knowledge located in various countries, as well as the need to integrate 'peripheral' forms of knowledge with core technologies might suggest that MNCs are acting as connectors of globally dispersed knowledge. Their 'knowledge augmenting' R&D accumulates in the central labs and research centres, often located in their home country where locational advantages relate to accumulated technological capabilities, fluidity of communication and linkages to the innovation systems of the home country, as well as path-dependency in the organisation of the R&D activities of the company (Ali-Yrkkö and Palmberg, 2006). This home-bound R&D is then exploited globally for specific product development projects at foreign locations through closer collaboration with customers (Archibugi and Michie, 1994). Related to this, Cohen and Levinthal (1990) observe that the absorption of new knowledge depends on the degree to which it lies close to the existing knowledge base of firms. This could be the first explanation, an explanation that might hold for many other industries as well.

The second explanation might be more specific as it relates directly to the way in which companies interact with the system of notification of essential patents, such as the one set-up by ETSI, and manage their IPRs. As suggested already, a company might be biased and capable to lobby for the inclusion of their patents in an ETSI standard primarily for technologies for which it has matured a deep understanding and a great level of confidence about its possible protection. Not all patents are well written documents, and it is a quite well known fact that in industries like telecommunication, a lot of patents are practically useless or not enforceable as they read on claims and technologies which have already been patented, or that have no practical use. In other words, one could argue that R&D projects that are closely monitored by IPR experts are more likely to have a greater impact on standards and downstream revenue streams.

If this second explanation is relevant for the technologies under consideration, then it would be necessary in subsequent research to consider IPR management strategies and organisation of companies as an intermediate factor that affects also the location of R&D and inventive activities of more strategic nature in this industry. While various aspects of an MNC have been considered to explain the evolution and learning curve of foreign subsidiaries (see here among many others Birkinshaw et al. (2002); Zander and Solvell (2000), Zanfei (2000)), the importance of international organization of IPR management has still to be explored. For example, might the home-bound nature of essential patents that we observe be an outcome of the fact that these companies also locate their IPR management functions in the home country and hence also produce patents of higher quality with greater probability of notification there?

Finally, some further interpretations might also be gained by the literature on "alliance capitalism" which suggests that firms increasingly internationalize their strategic R&D activities, and that a new division of labour between global competitors is emerging as a result (see e.g. Dunning and Boyd (2003); Palmberg and Pajarinen (2006)). Standardization in the wireless telecommunication industry is the most recent and impressive effort that fits this collaborative capitalism model (Palmberg and Martikainen, 2006). The analysis in this paper also adds some qualifications to this literature on alliance capitalism by suggesting that while the gambling on the development of wireless standards is a "global" game, firms still bring very "local" chips to the table. An important distinctions should probably also be made with respect to the 'upstream' and 'downstream' R&D where the latter type lies closer to the markets and commercialization, and where international collaborative alliances thus might play a much bigger role.

While the paper has brought some new insights it has also highlighted various research paths to take in next versions. Our empirical analysis of ETSI patents needs additional consideration and elaboration. In addition, data on strategic alliances might invite for various interesting hypotheses regarding the relationships between upstream and downstream R&D in the context of globalization and this is an empirical extension that we will undertake in the near future. Finally, as we only scratch the surface in this paper we feel an important need to complement this data with qualitative interviews covering all four companies included here along one, or both, of the lines of enquiry sketched above.

APPENDIX: STANDARDS COMMISSIONED BY ETSI

Situation as of April 2005

3GPP
BRAN
Cable Modem
DAB
DCS 1800
DECT
DECT/GSM
DIIS
DRM
DTM
DTS
DVB
Electronic Signature
ERM
ERMES
GMR
GPRS
GSM
HDSL
Hiperlan
IPCablecom
ISDN
Lawful Interception
LCS-128 pos
M-COMM
MHP-Broadcast
PLT
PSTN
RES
SDH
SDSL
SES
Smart Card
Speech Recognition
STAG
TV systens
TETRA
TFTS
Tiphon
UICC
UMTS
UMTS/CDMA
VDSL

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