Working Paper – IFRIS 15-11-2013

Internationalisation of Large Firms R&D: is the increase trend levelling off?

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Abstract

The aim of the paper is to contribute to the literature dealing with firm R&D internationalization by tracking two critical patterns: the evolution of the share of firm R&D carried out abroad and the changes in firm locational strategies related to R&D. We have built up a large data set covering patenting efforts of worldwide large firms for many countries over a large time period. We study a sample of 946 large firms for two time periods (1994-96, 2003-05). Our results tend to strongly nuance the dominant view in the literature. The rate of internationalisation remains very low at world level; over the decade under inquiry after withdrawing Japanese and Korean firms it does not increase. This trend is the result of two opposite movements: European firms that were by far the most internationalised at the beginning of the period enter a movement of rationalisation that drive to refocus on their home base and on Europe, while US firms witness a continuous increase even if they still stand below their European counterparts at the end of period. Asian firms, which were completely absent from this movement, have started an internationalisation movement that remains limited and focused on other Asian markets. This is why we propose to decompose between continental and intercontinental movements in internationalisation. Motives for such movements clearly highlight the lasting prevalence of the home base, but contrary to what was expected by previous studies, we do not find a continuous move towards home base augmenting assets, but rather a rebalancing between home base augmenting and home base exploiting strategic motives. Again these global dynamics widely differ according to continents.

Keywords: MNC R&D; innovation; internationalization; patents

1- Introduction: setting the scene and research questions

The continuing internationalisation of the R&D activities of firms is a subject of considerable interest to policymakers (UNCTAD, 2005; OECD, 2005). As there is a strong link between innovation and corporate R&D, policy concerns in developed countries focus on the potential loss of jobs and economic benefits as well as on the potential impoverishment of the local knowledge base due to the internationalisation of R&D (Dunning and Lundan, 2009, Moncado-Paternò-Castello, 2011). The increasing attraction of Asian countries (in particular China and India) as R&D locations, the so-called "R&D offshoring" (see for instance d'Agostino and al. 2013) lead to a growing concern among policy makers for hollowing out the national innovation system (Narula and Zanfei, 2005). These concerns have stimulated empirical research into the drivers and the consequences of the internationalisation of corporate invention in recent years (see among others Florida and Kenney, 1994; Frost, 2001; Ambos, 2005; Abramovsky and al. 2008; Sachwald, 2008). In this paper we address two topics related to the process of corporate technological (or R&D) activity internationalisation. Is this process really increasing in the last period of time? Is this process still under the dominant influence of strategic asset-seeking motives as shown by previous studies?

R&D MNCs activity is very important as the main source of technological knowledge creation, transfer and diffusion. Today the dominant view is that this activity is *increasingly internationalised* (see for instance Cantwel, 1995; Narula and Zanfei, 2005). In other words the share of new technologies produced globally by MNCs is increasing (Iammarino and McCann, 2013). This view is confirmed by the special issue of ICC dedicated to the internationalisation of R&D. In opening it, Moncada-Paternò-Castello et al. (2011) noted: "The globalisation of R&D activities has continued its *growth path* as companies are *increasingly* trying to capture knowledge and market opportunities internationally." This very

first body of evidence is different from the basic idea developed by Patel and Pavitt (1991), who considered at the time technological activity as "an important case of non-globalization". This drove to a series of attempts for finer measures at the turn of the century (Patel and Vega 1999, Roberts 2001, Le Bas and Sierra 2002, UNCTAD 2005 and Doz 2006) that all conclude to an increasing internationalisation movement, while underlining the rather limited levels of internationalisation still e.g. from 15.8% in 1988-1990 to 19.5% in 1994-96 in Le Bas and Sierra 2002). In section 2, we shall review the arguments that have driven towards this dual consensus between analysts of inventive activities of MNC: a growing but still weak internationalisation. This drove Dunning and Lundan (2009) and Patel (2011) to note *the continuing reliance of firms on the* home *country as a base for innovation.* The first objective of this paper is thus to look at more recent data to see if the supposedly fast globalisation movement of large firms has changed the picture. To avoid mixing multiple effects, we have chosen to look at dynamics until the beginning of the financial crisis. Our hypothesis is that the assertion of Pavitt and Patel of a large gap between the internationalisation of activities and of R&D still holds but needs to be nuanced depending upon the regional origin of firms.

The motives for investing abroad set up the second topic dealt with in this paper. Multiple arguments have been put forward (from Bartlett and Ghoshal, 1989 to Piscitello, 2011, just to name a few). A quite elegant framework was put forward considering the type of knowledge looked for (for increasing firm capabilities versus for exploiting further existing capabilities, Kuemmerle 1997) and the type of location selected (being specialised or not in the core competences of the firm, Patel and Vega 1999, Le Bas and Sierra 2002). Its interest is that it can be measured looking at inventive activities of firms. Empirical studies already cited have all convincingly shown that the dominant strategy as far as location abroad is concerned was of the Home Base Augmenting (HBA) type and not the Home Base Exploiting (HBE) type. In these two dominant options MNCs have relative advantages at home. HBA strategies

characterize locations that have complementary strengths of those created at home. HBE strategies consist in exploiting abroad the advantage created at home in a particular technology field. In the former there are stronger interaction processes between MNCs and local actors aiming to increase (augment) the stock of knowledge for some technologies (Piscitello, 2011). Furthermore the studies underlined the increasing importance over time of HBA strategies. What is the situation 10 years later, when firms can be considered as global in their range of activities and when knowledge producing capabilities have spread in a larger number of countries as witnessed by the evolution of country shares in publications (in particular BRIC countries)? Might there be a reverse trend, where firms, as anecdotal evidence seems to tell (EIRMA, 2013), have entered a rationalisation movement of their R&D activities?

Thus the two questions this paper addresses are quite simple: 1. Can we confirm the general dominant view assuming a growing trend of technology internationalisation? 2. Does the dominant strategy observed in the 1990s ("home base augmenting") still hold? The first might be also expressed as: Can a general trend characterised by an *increase* hide *decreases* for some countries or technology fields? Are there national specific patterns in R&D MNCs internationalisation that sometimes involve a decrease? To address both questions, we follow the strategy developed by previous studies. As it is still difficult (if not impossible) today to access the spatial partition of R&D efforts of firms in a systematic way, we have selected to work on patents. Of course we are aware of limitations of patents in certain industries. Still the largest firms investing in R&D (as delineated by the "Industrial R&D Investment Scoreboard") are all present in our dataset. Furthermore, it will enable comparisons with previous studies, both to test the results found in similar periods of time, and to discuss more in depth dynamics. Compared to previous studies we benefit from the development of a wider dataset that section 3 will present.

The paper is organised as follows. The next section presents the contrasting results proposed by the literature dealing with *Firm R&D internationalisation*. Section 3 presents our data set and the methodology used. In Section 4 the level of MNC R&D internationalisation is calculated for many countries and its evolution is delineated. Section 5 addresses the issue of the *locational strategies* of MNCs and their evolutions. The final section will reflect about our main results: we are still facing an overall case of weak internationalisation, but both levels and trajectories differ widely between continents, with Europe as a very special case of internal diverging dynamics. Secondly there is a clear evolution towards motives that are more articulated to market penetration even if the search for new capabilities remains prevalent. Once more these results witness a strong spatial differentiation.

2. Framing Firms R&D internationalisation: a review of the literature

Before tracking and explaining the recent trends of large firms R&D internationalisation we need to bear in mind the main factors put forth in the literature pulling this process. We review two aspects: the degree (the volume) of firm R&D internationalisation and the choice of the R&D location abroad.

2.1- The decision to invest abroad

First we examine the main driving forces explaining the degree of internationalisation. The motivations for locating R&D activities abroad have fed a significant literature (the important contributors are: Cantwell, 1997; Cantwell and Piscitello, 1999; Dunning, 1997; Kuemmerle 1997 and 1999; Lall, 1979; Ronstadt, 1978; Rugman, 1981). The two main reasons why firms tend to internationalize their technological activities are: 1) the necessary adaptation of

products and processes to foreign conditions, a compulsory rule for penetrating markets abroad; and 2) the acquisition of knowledge and expertise from foreign R&D centers and universities (Belitz, 2010)[1]. There is a long tradition underlining that firms invest abroad in R&D activity (often more in development than in research) mainly for organizing the adaptation of their products to the local markets. In this tradition, the main driver of R&D internationalisation is technology adaptation. This corresponds to Vernon (1966) hypothesis related to the international product life cycle. Now, the dominant view states that the international localisation of innovation activities responds mainly to the need to gain access to local competencies and knowledge (Narula and Zanfei, 2005) in order to produce innovations on an international basis. This aspect is related to the "knowledge seeking" motivation of MNCs foreign direct investment (FDI) pictured in particular by Cantwell (1989) and Dunning (1981)[2]. It implies that firms must be embedded in local research networks and/or searching for a close geographic proximity with foreign knowledge producers in order to acquire new knowledge (including tacit knowledge according to Jacquier-Roux and Paraponaris, 2011).

In the last two decades the increasing importance of the globalisation of R&D by MNCs is contemporaneous with the decline of the Chandlerian megacorporation and the growing importance of the network firm. We follow here the very stimulating analysis provided by Iammarino and McCann (2013). The reduction of transaction costs has made the outsourcing of multiple enterprise functions possible. The diminishing costs of communication (linked to ICT diffusion) and costs of transportation (linked to the development of container-based shipping) enabled to invest abroad and to offshore numerous activities (including knowledge production). These perspectives have given rise to the "end of distance conjecture" and the

[1] For studies pointing out the importance of knowledge bases see also Almeida (1996), Daniels and Lever (1996), Florida (1997; Cantwell and Iammarino, (2000), Kumar, (2001), von Zedtwitz and Gassmann (2002), Dicken (2004), Iwasa and Odagiri (2004), Ambos (2005), Ito and Wakasugi (2007), Jacquier-Roux and Paraponaris (2011).
[2] See the contribution by Chen et al. (2013) for other references.

"flat world vision" (Friedman, 2005). It postulates that two barriers have been removed: operating at a distance and across borders on the one hand, and transaction costs between firms on the other. The idea that offshoring of R&D activity might have no limits stems from this approach of globalisation. By contrast another perspective considers that the world is not becoming flatter but more curved (McCann, 2008), spiky (Florida, 2005), lumpy or uneven (Iammarino and McCann, 2013). The trend of decreasing communication / transportation / transaction costs does not apply everywhere at the same rate and does not affect the organisations with the same force. The large concentrated corporation has not disappeared; on the contrary its role has increased. It shapes and manages important internal and external networks. Its role is to link local clusters and networks to the economic world.

Another important reason that could explain the trend toward internationalisation would be that MNCs internalize less their R&D and technology activity abroad and prefer to be a buyer on the international technology markets. Such an approach is coherent with the "open innovation strategy" considered as affective in the new context of innovation (Chesbrough, 2003). In the eclectic paradigm formulated by Dunning (1988), internationalisation of R&D activities can be seen as the internalisation of cross-border activities: instead of acting on the market, the firm places operations under its direct control in order to gain one advantage over its competitors. However this decision to internalise activities is a trade-off associated with the level of transaction costs. It may be that vertical integration is no longer the most effective way for accessing knowledge. MNCs as domestic firms can decide to use other means between markets and hierarchy for absorbing knowledge: networks, joint ventures or strategic alliances.

Recently Narula and Zanfei (2005) proposed to analyse the diverse forces supporting the concentration at home and the dispersion of R&D abroad as two opposed forces, centripetal and centrifugal. In effect the R&D investment abroad can be interpreted as a dispersion of

resources pulled by the search for technological opportunities that match the firm benefits. But such a conduct implies costs of searching, networking, absorbing and integrating knowledge created in foreign locations. This costly strategy is constrained by resource limitations. As a consequence it is tempting to represent this process through a trade-off home/abroad picturing the R&D investment location model (see Table 1). The important message delivered by the two authors is that R&D investment abroad must not be considered as always effective. The decision requests a type of cost/benefit analysis. This point seems useful to recall because most studies only focus on the factors pushing toward internationalisation.

Table 1 -What do recent theoretical and empirical studies tell us on the factors affecting firm positions on the home/abroad trade-off for R&D

Factors in favour of home country centralisation	**Factors in favour of foreign country dissipation**
Risk of dissipation of knowledge towards local firms (Almeida, 1996) In particular when there is weak regime of IPR in foreign countries (Branstetter, 2006; The Economist Intelligent Unit Report, 2007)	Firms can increase their foreign market share thanks to the development abroad of more locally adapted products ("old" but always relevant view formulated by Rugman, 1981)
Less efficient (or weak volume of) intra MNCs knowledge transfer (Sanna-Randaccio and Veugelers, 2001)	Foreign national stock of private R&D capital (Erken and Klein, 2010) conditional to the complementarity between firm domestic R&D and the stock of foreign knowledge (Frank and Owen, 2003)
A leading firm decides to invest first in the market of the follower firm in order to deter the knowledge absorption through FDI by the follower firm of the other country (Bjorvatn and Eckel, 2006)	Access to qualified staff and talent (most cited reason in the survey by Doz, 2006; The Economist Intelligent Unit Report, 2007)
Importance of transaction costs (Iammarino and McCann, 2013)	Searching skilled people abroad with low labour costs (UNCTAD, 2005; Erken et Kleijn, 2010; Doz, 2006)
	R&D agglomeration (or clustering) abroad can facilitate knowledge spillovers and the reversed transfer to the home country (Gersbach and Schmutzler, 2006)

This theoretical analysis shows that we cannot take for granted an ever-increasing growth of the internationalisation of R&D activities of MNCs, but rather that there is a trade-off

between home and abroad location of R&D activities. The model developed by Berbedos et al. (2008) further shows that there could be different trade-offs for firms in similar markets. The authors develop a model of strategic interaction in R&D internationalisation decisions between two multinational firms, competing both in their home markets and abroad. One firm is a technology leader and the other a follower. The model hypothesizes the existence of local inter-firm R&D spillovers and fluid international intra-firm transfer of knowledge (i.e. realized at no cost). Each firm has incentives for allocating part of its R&D abroad in order to absorb R&D spillovers coming from the rival. But it is risky in the sense that the firm can dissipate its tacit knowledge from its foreign affiliates towards the rival firm. The authors suggest that greater efficiency of intra-firm transfers and greater R&D spillovers increase the attractiveness of domestic R&D for the technology leader if the technology gap with the follower is large. They show that R&D investment abroad is not always profitable. For instance when the competition on the product market is strong the leader firm invests more in foreign R&D to capture a larger share of the foreign market, by contrast the follower firm concentrates more R&D at home. The reverse situation is predicted when the gap between the two firms is large. Finally the model tells us that the two firms have not a systematic behaviour of foreign investor in R&D activity.

This explains why a number of empirical studies have tried to measure the de-facto trade-off and its evolution over time. They converge towards a dual conclusion: this trade-off shows a weak but growing level of internationalisation of R&D. For instance the UNCTAD survey (2005) points out that a growing share of MNC R&D is performed abroad at least for the time period 1994 to 2002. But such a trend encompasses large variations across countries. Nevertheless the weak response rate (22%) and finally the low number of MNCs (66 among the largest private R&D spenders) limit the interest of the study for comparative approaches. Roberts (2001) with a panel of the largest R&D-performing companies in North America,

western Europe and Japan found a significant increase of R&D spending abroad as a proportion of their total R&D expenditures from 15% in 1995 to 22% in 2001. The survey conducted by Booz Allen Hamilton and INSEAD (Doz, 2006) pointed out that the number of R&D sites in the home country has decreased regularly since 1975 (until 32% in 2000), however it also recorded a small increase from 2000 to 2004 at 34%. Similarly Le Bas and Sierra (2002) remark that the average degree of internationalisation of technology creation in their large sample of 350 MNCs is around 19.5% of their total patenting over the period 1994-1996. That proportion has been increasing over time as it amounted to 15.8% over the period 1988-1990. Similar results are found by Patel and Vega (1999). More recently Patel (2011) considered a sample made of the 963 most technologically active MNC (they accounted for more than 85% of all corporate R&D in 2006). The measure of R&D internationalisation is made through patents registered at the European Patent Office between 1991 and 2006. He confirms the small but increasing trend (+2.5% for the total sample) but shows that we should be attentive to regional differences: the growth is higher for the US (4.7%), average for Japan (2.5%) and lower for Europe. The latter is the result of diverging trends: the share of patenting outside the home country *decreased* for Austria, Denmark or Italy; it has increased *but very weakly* for France (0.9%), Sweden (1.5%) or Switzerland (1.5%) and is near to average for Germany (2.3%)[3]. So it is relevant to observe that from the mid 1980s to the end of the 1990s *large firm R&D internationalisation increased while it stayed weak in general*. Some empirical facts from the same studies even drive to consider whether there would be a threshold beyond which the trade-off stabilizes. For instance the UNCTAD report (2005) interestingly quotes that the international share of R&D expenditures of the largest Swedish MNCs *stagnates* at 43% after a regular period of growth. The Pro Inno survey (2007)[4] studying offshoring of R&D developed a measure based on the share of new product

[3] Personal communication from the author

[4] It is based on the results from a survey carried out in 2006 by TNS Gallup among EU companies engaged in R&D offshoring. The final number of respondents is 158.

originated from R&D offshore. It arrives to similar orders of magnitude than studies based on patents (the figure is less than 20% for 80% of firms surveyed) but, *more important for us, R&D offshoring is expected to increase less than total R&D spending.* Gammeltoft (2006) further hypothesizes that the growth in R&D internationalisation may have come to an end. His own interpretation of this quantitative stagnation is that managerial focus is shifting towards organizational consolidation of the existing complex international R&D structures[5].

Looking at this empirical evidence, which is mostly based upon trends witnessed in the early and mid 1990s, this drives to our first question: what is the situation 10 years later, and can it help verify the limited elements we have about a stabilization in the internationalisation of R&D activities, and if we follow Patel, of very different regional levels and dynamics?

2.2- The location decision

Dunning (2009) in his latest contributions noted that the location has become an increasingly important determinant of the scope, pattern, form and growth of MNCs. In his perspective, specific characteristics of local environments matter for expanding MNCs knowledge resources. The recent paper by Siedschlag et al. (2013) analyzing 446 location decisions of R&D activities by multinational firms incorporated in the European Union over the period 1999-2006 confirms this view. It suggests that on average, the probability of developing a R&D foreign affiliate increases with agglomeration economies from foreign R&D activities, with the importance of human capital, with proximity to centres of research excellence and with the research and innovation capacity of the region. In the same vein, Erken and Kleijn (2010) consider that the private stock of R&D capital is an important location factor.

[5] The international organizational aspects of the MNC R&D have been recently addressed by Chen and al. (2012).

To follow strategic choices made by firms, Patel and Vega (1999) have proposed an approach based upon the Revealed Technological Advantage (RTA) index (Soete, 1987; Patel and Pavitt, 1987; Cantwell, 1989). We present it below since it has been used in all empirical studies developed since.

For a particular technology j, and the agent (firm, country) i, we define:

$RTA_{ij} = (P_{ij} / \Sigma_i P_{ij}) / (\Sigma_j P_{ij} / \Sigma_{ij} P_{ij})$

with P_{ij}, the number of patents applied for in technology field j by firm (or country) i.

For each firm compiling an overall RTA index for all inventions produced in its headquarters country (HomeRTA) and an overall RTA index for inventions produced in host countries (HostRTA) allows to assess on the one hand the firm relative strength in a given technology in its home country and on the other hand, the relative strength of host countries in the same technology[6]. Combining the two indexes allows to classify the internationalisation strategy of firm inventions according to four types (Patel and Vega, 1999; Le Bas and Sierra, 2002).

- HomeRTA >1 and HostRTA >1 indicate a Home-base Augmenting (HBA) FDI in R&D (Kuemmerle, 1997) or "strategic asset-seeking R&D" (Dunning and Narula, 1995). This strategy consists to target technologies in which the firm has a relative advantage at home and in which the host country is also relatively specialised. Such R&D activities are aimed at monitoring or acquiring competitive advantages, which are complementary to those already possessed by the firm so as to augment a firm's existing stock of knowledge. This perspective is consistent with the view developed by many scholars (de Meyer, 1993, Dunning, 1997). This search of complementary assets is a supply-driven (knowledge sourcing) approach. This

[6] HomeRTA and HostRTA indexes are zcompiled for each firm patent. Then data are aggregated at the firm level according to firm patent tehnology fields, inventor countries and firm country using a fractionnal counting. This allows to get for each firm a distribution of its patents according to the four type of strategies.

type of conduct corresponds to 'dynamic learning' (along the taxonomy of Patel and Pavitt, 1990).

- HomeRTA >1 and HostRTA <1 indicate a Home-base Exploiting (HBE) internationalisation strategy where a firm uses its national comparative technological advantage to export or adapt its core technology in host countries not specialized in that technology. HBE internationalisation strategy seeks to find new markets for products in the firm technologies of competence. The rationale for the investment here is to exploit the existing corporate-specific capabilities in foreign environments. A firm possessing a competitive advantage in a technology field in its home market seeks to exploit it abroad, particularly in regions, which are weak in the technology field considered[7]. Hewitt (1980) has labelled this strategy as 'product adaptive R&D', i.e., R&D related to adapting parent technology to the host country market[8]. Finally this type of investment corresponds to what Patel and Pavitt (1990) refer to as "short-sighted learning" (or "myopic learning"): firms exploit their knowledge base to make their technological capital profitable in the short-term, without trying to improve it through external investment operations.

- HomeRTA <1 and HostRTA >1 indicate a Technology Seeking (TS). In this case, a firm compensates its national under-specialization in a given technology by seeking for foreign skills in host countries specialized in the same technology. This type of strategy has been labelled as 'technology-seeking FDI' in R&D (Shan and Song, 1997). Patel and Vega (1999) interestingly suggested to qualify such a strategy as "host country-exploiting FDI" in R&D as it refers to situations where a firm is exploiting host country technological advantages in areas of domestic weakness. In this respect there are two options. The first option consists in setting

[7] In some sense this strategy is very close to that described in the product cycle model initially proposed by Vernon (1966).

[8] See also Rugman (1981)

up local R&D units in a host country with proven technological superiority in order to upgrade a firm's technological capabilities in fields in which it appears as relatively weak in its home country (Almeida, 1996, Chiesa, 1996). The second option is linked to foreign technology acquisitions (Granstrand, 1999). Recently Lehrer and al. (2011) named this conduct: Home-base compensating R&D.

- HomeRTA <1 and HostRTA <1 indicate that moves observed are not driven by a technological strategy (Dunning, 1998). It corresponds to situations where a firm invests abroad in technological activities in which it is relatively weak in its home country and the host country is also relatively weak. In other words, there is neither a home technological advantage nor a host technological advantage. The motivation for this fourth type of strategy seems to be not technology-oriented. Many authors have stressed that this case is probably the result of mergers and acquisition activities (Håkanson, 1992, Patel and Vega 1999). As a consequence we consider this situation pictures a Market Seeking (MS) internationalisation strategy driven by market considerations, not taking into account the technological environment.

The works by Patel and Vega (1999) and Le Bas and Sierra (2002) unambiguously show that the most important strategies are the two first, with HBA strategy outclassing HBE. Le Bas (2006) with the same data set that Le Bas and Sierra (2002) undertook to perform logistic regressions in order to seize the determinants of the two main strategies. He showed that there is no effect of the *level* of technological internationalisation on the choice of the strategy. Its findings concerning the factors increasing the probability to choose a HBA strategy are: an increasing technological diversification, the size of technological activity (but its effect is very weak), the firm nationality (US, Europe) and the specialization in some technology fields

(instrumentation, industrial processes)[9]. These studies indicate also clearly that there is a growing trend over time in favour of HBA. The relevance of home-base augmenting motivations for internationalisation has not changed in time according to the recent documented study by Picci and Savorelli (2012)[10]. But the two authors do not find evidence that home-base augmenting motives have become more important in recent years (their study covers the period 1990-2006). Other recent studies (e.g. Nachum and Song, 2011) argue that firms take advantage of the location-specific assets driving them to build synergistic portfolios of knowledge. This means that we might find not one overall trend, but specific combinations of different options, and in particular a mix of HBA and HBE options. Such findings set up an argument for tracking the recent evolution of motivations for R&D internationalisation. Do we witness an evolving balance? And are there different mixes associated with different levels of internationalisation?

3. The data set

Our study on MNC R&D internationalisation relies on patent data. The natural way would be to use R&D statistics. There are only few data sets accounting for R&D internationalisation through R&D expenditures. Even when countries publish data on the share of R&D undertaken by foreign firms, this does not enable to track individual firms (Patel, 2011). Financial data also prohibit tracking the scope of R&D internationalisation. This explains why, besides one-off surveys, all studies on the internationalisation of R&D activities of large firms have been based on patents. By tracking the addresses of inventors, patents enable to

[9] See also Le Bas and Patel (2007) and Jacquier-Roux and Le Bas (2008).

[10] The two authors suggest that in explaining the internationalisation of inventive activities we should distinguish between system (national)-specific and sector-specific motives.

map knowledge activities at the international level. As we have seen in the previous section, they also enable to map motives for internationalisation.

Patenting is an indicator of inventive activities. It however imperfectly reflects the innovation activities we are trying to address. Limitations are well known. Patents only account for the codified dimensions of knowledge creation, leaving out all kinds of tacit forms of knowledge. Comparing technological activities in different sectors and different regions of the world using patent indicators is questionable since the propensity to patent to protect technological inventions differs according to industrial sectors and national patent offices. It is acknowledged that industries where innovation requires long and costly R&D or generates substantial income (pharmaceuticals, medical devices and some specialty chemicals) are more prone to patent than other sectors where secrecy still dominates (Nikzad, 2013). Furthermore, certain inventions are not patentable or their patentability differs according to national patent offices, for instance in software industry (the so-called institutional bias). Despite these shortcomings, patenting remains one of the most prevalent measures to account for technological activity and several studies have shown that patents properly reflect the technological performance of firms, sectors or countries. Studying 1 200 companies in high-technology industries, Hagedoorn and Clood (2003) concluded that the number of patents filed by a company is a very good reflection of its technological performance. At the country level, de Rassenfosse and van Pottelsberghe (2008 a) have found a high correlation between patent numbers and R&D performance. Finally Patel (2011) has shown that the patterns revealed by patenting are consistent with those pictured by R&D statistics.

Furthermore patents display numerous advantages compared to other measures (as R&D inputs). Patents are very directly linked to inventiveness. They are easy to access, often available in long time series, display rich information (place and date of applications, inventor and applicant affiliations, knowledge bases) and are classified in categories according to field

of application and technology. Detailed information on individuals and organizations (names and affiliations) make them well suited to investigate internationalisation patterns of technology activities. Besides, they can be easily matched with information from other databases in order to recover missing data or add supplementary information.

However choices on how to proceed have to be carefully defined. The methodology to compile patent based indicators has to be wisely chosen since it can influence the results to a large extend (de Rassenfosse, 2014). There are four critical dimensions to consider: the choice of the patent data source, the type of considered patents, the computational methods and the definition of the sample of MNC. We consider them in turn.

The choice of the patent data source: the first works on MNC internationalisation used patents applied for in a single patent office: Patel and Vega (1999) used patents granted by the US patent office (USPTO) while Le Bas and Sierra (2002) used patents applied for at the European patent office (EPO). Despite some discrepancies in the quantitative results, both studies revealed quite similar firm R&D internationalisation trends. Guellec and Pottelberghe de la Potterie (2001) analyzing internationalisation aggregated patent data at the country level compared results using patents from EPO or from USPTO: this showed similar patterns at country level, but not at the firm level, stressing that the internationalisation level depends on the proximity between the country and the patent office. Since 2006, counting patents from a large set of patent offices has been facilitated. The European Patent Office (EPO) has started to deliver the Patstat database gathering standardized data of patents applied for in 170 national, regional and worldwide patent offices in one single database. This makes possible to incorporate patents applied for in different patent offices. It allows avoiding geographical bias (single office bias discussed above) and prevents a too restrictive selection of patents as obtained when using either PCT patents (i.e. patents that have been extended internationally) or triadic patents (that is patents taken simultaneously in the US, Europe and Japan). De

Rassenfosse (2013) has thus proposed to select a large number of patent offices (40 patent offices were selected in his study). We have chosen to consider all patent offices included in the Patstat database.

The type of patents considered: de Rassenfosse (2013) has proposed to use priority patents (that is the first to have been applied for and not its further extensions, whether geographical, technical or commercial). This new approach allows benefiting from a large set of inventions, it prevents geographical bias and avoids multiple counting of patents applied for in different patent offices. Comparing the two approaches, de Rassenfosse (2013) evidenced that the former "captures different dimensions of inventive activity" stressing the "local and entrepreneurial natures of inventive activity" and "better reflects the inventive activity of developing countries and countries with a strong entrepreneurial base". However in the absence of any threshold on patent value, it incorporates a consequent share of patents having low value, and suffers from an institutional bias, favoring patents originating from offices where the rules for patenting are smoother (lower cost or lower inventive level). Even when considering this limitation, the choice of priority patents fulfils our need of an exhaustive dataset of patents in order to get a global view of MNC internationalisation, integrating patenting outside OECD countries, and in particular from so-called BRIC countries. Our study has thus adopted de Rassenfosse's approach. It includes priority patent applications from all the patent offices available in Patstat (version autumn 2011).

Computational approach: we use fractional counting. This means that when more than one country address appear on the same patent, we attribute a fraction of the patent to each country (fractional counting). Our approach differs from the methodology implemented by Patel (2011) who used the 'whole' count approach (the patent is attributed to each country). Fractional counting prevents patent double counting. Each patent being counted only once, the number of patents attributed to a country is equal to the sum of the fractional counts for

the firms considered separately and the distribution of patents counted by country reflects the real contribution of each country to the corporate R&D. Fractional counting is thus more accurate than 'whole' counting to measure trends in the shares of credit attributable to different entities, in our case countries. Many recent studies are also using this mode of counting (see Picci 2010, de Rassenfosse 2013). In order to recover missing information on inventor countries, we have developed our own data-recovering algorithm quite similar to de Rassenfosse's algorithm[11]. Information retrieved from the database is: the country of the inventors, the application filing year and IPC categories. Patent technological classification in 35 technology fields is realized according to the WIPO classification.

The selection of firms: Our choice has been to be exhaustive, relying on the most widely known source about R&D in large firms, the "Industrial R&D Investment Scoreboard" produced annually by the Institute for Prospective Technological Studies of the European Commission. In this study we used the 2008 edition that provides economic performance and total R&D corporate spending for the 2000 firms with the largest R&D expenditures (1000 based within Europe, 1000 based outside of it). As firms from BRIC countries were missing, we added 433 Indian and Chinese firms declaring R&D investments in the Computstat database. We also complemented it by analyzing the lists of the most important assignees of

[11] The recovery of missing information of the inventor residence country is carried out following three successive steps: first, by matching the Patstat database with two additional databases from INPI (the French patent office) and from OECD (REGPAT); second, by retrieving country information displayed in other patents from the same Inpadoc family. Finally, when these steps have failed to recover inventor country, we hypothesized that when a patent is applied for in the country of the firm headquarters the residence country of the inventor is this very country (i.e. of the firm headquarters). Matching Patstat with INPI and REGPAT databases increased the share of filled inventor country from 21% (initially in Patstat) to 26%. This share reached 30% after the 2nd step and 97.5% after the third one. The huge recovery in the last step affected almost exclusively inventors in Japan (98%). To test the validity of such a large recovery of country information for Japanese inventors we have also investigated the situation of priority patents of Japanese firms where the inventors were known to be located in Japan. We found that 99,7% of the patents from Japanese firms with inventors located in Japan applied their priority patents for in Japan. Therefore our massive recovery of missing residence country in Japan is consistent with what is found initially in Patstat.

patents produced by WIPO[12], EPO and USPTO. All in all it gave us an extensive list of 2800 firms. A major issue is then to consider the effective perimeter of these firms, since all large firms are made of multiple legal entities. To establish it, we used financial information from the Orbis database edited by the Bureau van Dijk Electronic Publishing. We selected all legal entities linked to "global ultimate owners" (GUO) identified. All legal entities in which a given GUO had more than 50.01% of shares were considered as belonging to the perimeter of this GUO. Following this procedure allowed to identify nearly 170 000 subsidiaries belonging to the 2800 MNCs. One limitation of the approach is that it is static: this delineation was made for year 2008 only. Consequently the perimeter of a firm remains identical over the time period under observation. But it has an important advantage: our focus is about firm internationalisation whatever the means they have used over time for this internationalisation. In using the delineation of the last period of observation, we reconstruct the dynamics over the period of observation of the technological competences that the firm has progressively integrated in its portfolio, whatever means have been chosen: in this way we account for the effective technological dynamics of firms, incorporating in particular the effect of mergers and acquisitions. A final issue is to define the home country of the firm: following the practice of the "Industrial R&D Investment Scoreboard", the home country of the firm was defined according to the location of its headquarters.

In order to identify the patent portfolio of the consolidated MNCs, we matched the 170 000 entity names with the patent applicant name in Patstat. We relied on the methodology developed by Tom Magerman (2006) that includes spelling checks, cleaning and harmonization steps. The final MNC database contains 5 127 129 priority patents applied for between 1986 and 2005. This represents 58% of the total number of priority patents applied for across the world. 99% of the patents of our patent set were applied for in eleven patent

[12] World Intellectual Property Organization, the international organization that deals with all geographical patent extensions.

offices located in Japan (73%), United States (11.7%), Korea (6%), Germany (4.6%), France (1.1%), China (0.8%), European Patent Office (0.7%), United Kingdom (0.4%), Taiwan (0.4%), Finland (0.2%) and Sweden (0.2%). Using priority patents from the original patent office (and not a distant patent office like EPO in Le Bas and Sierra 2002) reinforces strongly the contribution patents applied for in Japan and Korea. This is not specific to this study, de Rassenfosse (2013) or Picci (2012) arrive to similar ratios. This would be a problem if we were considering the weight of countries, but in this case we only consider data at firm level and deal with the relative share of national vs foreign patents. Though there remains a bias linked to the national propensities to patent, we think it enables to consider firm strategies and compare them. We shall see that when aggregated by country, firm behaviours vary strongly between Korea and Japan, reinforcing our views that the approach is robust.

To study dynamics we have chosen to compare two triennial periods: 1994-1996 (which is the last period covered by the main studies we have mentioned) and 2003-2005. In order to have meaningful comparisons of sustained inventive activity, only corporations that have applied for at least 5 patents during both periods were selected (this is made possible by the delineation of firms at end of period, and thus enables to capture emerging entities that were further acquired). Still this drives to a drastic reduction of the sample, which contains 946 firms. But it does not change significantly the coverage of inventive activities: the sample still covers half of word priority patents applied for between 2003-2005 (49.4% exactly), the patenting activity increases between both periods standing at 25% (706 524 priority patents for 1994-1996 and 882 895 priority patents for 2003-2005). Figure 1 presents the distribution according to geographical origin of this set of firms and their share of patents in the total data set[13].

[13] the lecturer will find in annexes more information on the distribution of firms and patents by industrial sector in appendix A and on the distribution of patents according to technology fields in appendix B.

Figure 1 - Distribution of the 946 firms and their patents by firm country, continent or zone

Country of firm	Firm share (%)	Patent share 2003 -2005 (%)
North America	35.2	11.8
United State	34.0	11.5
Europe	35.7	9.8
Germany	9.2	5.9
France	5.3	1.6
United Kingdom	6.2	0.5
Italy	1.2	0.1
Small countries	7.4	1.1
Nordic countries	6.4	1.0
Asia	27.2	78.0
Japan	23.2	62.0
Emerging Asia	3.3	15.9

Country of firm	Firm share (%)	Patent share 2003 -2005 (%)
Switzerland	2.9	0.47
Netherlands	2.5	0.43
Belgium	1.3	0.06
Austria	0.5	0.04

Country of firm	Firm share (%)	Patent share 2003 -2005 (%)
Sweden	2.9	0.51
Finland	1.9	0.41
Denmark	1.2	0.05
Norway	0.5	0.04

Country of firm	Firm share (%)	Patent share 2003 -2005 (%)
Korea	1.5	13.66
Taiwan	1.2	0.98
China	0.4	1.28
Singapour	0.1	0.01
Hong Kong	0.1	0.01

4. MNC level of RD internationalisation: Main empirical trends and tentative interpretations

The internationalisation of corporate inventions is measured by comparing the nationality of the firm (i.e. the country where the MNC headquarter is located) and the residence country of the inventor (given in the inventors' addresses). We use the country address of the inventor as a proxy measure for where the technological activity related to the invention occurred. We must bear in mind it is not necessarily the country where the patent application was filed. We define the R&D internationalisation rate of a firm as the proportion of patents invented by foreign inventors as done by several academics.

4.1- Firm rates of R&D internationalisation: still weak internationalisation and slow evolution

The overall rate of internationalisation computed on the total number of patents remains very low, 7.2% for 2003-2005 (see table 2). It has slowly increased over the last decade (37%)[14]. This rate as explained in section 3 is largely dependent upon the two largest patent producers whose firms moreover are the least internationalised in terms of invention activity (Japan and Korean firms represent over 75% of total patents). Excluding them drives the rate of internationalisation to 22.6% in 2003-05. This is not significantly different from the rates found 10 years ago by Patel and Vega (20%) and Sierra and Le Bas (19.5%). Taking into account mergers and acquisitions since their studies, our computed rate for the period 1994-1996 is even higher (23%). Thus we cannot speak, as Pavitt stated in 1990, that R&D is a case of non-globalisation. By contrast, our new data confirms the results of the studies conducted at the turn of the present century. Compared to 10 years ago, the overall situation has not changed. We thus consider this period as a period of stabilisation or, to follow Gammeltoft (see section 2.1) as a period of organisational consolidation. This stabilisation has important implications. It means that the availability of inventive resources at home remains the main source of technological knowledge and that the core strategy of firms is to exploit specialized domestic resources when available. We thus should witness very different levels of internationalisation depending upon the size of domestic resources.

[14] Globally the evolution between the two periods is not very sharp. When we compute the correlation between firms rates for each of two time periods we get a Rsquare of 0.92 with a slope coefficient of 0.82 and a large t of 19.8 (obs = 946).

Table 2 - Evolution of internationalisation rates in firm inventions by firm country, continent or zone over 10 years

Country of firm	Internationalisation rate 1994 - 1996 (%)	Internationalisation rate 2003 - 2005 (%)	Evolution 1994 - 1996 to 2003 - 2005 (%)
North America	10.3	17.7	71.9
United States	9.8	17.3	76.7
Europe	40.7	30.4	-25.3
Germany	15.8	13.8	-12.8
France*	48.0	34.1	-29.0
United Kingdom**	88.1	79.9	-9.3
Italy	45.1	36.8	-18.4
Nordic countries	39.6	45.8	15.5
Small countries	76.2	79.2	3.9
Asia	0.7	2.5	260.8
Japan	0.6	1.3	123.1
Emerging countries	2.4	7.3	210.5
Total	5.2	7.2	37.1
Total without Japan	18.8	16.8	-10.6
Total without Japan & Korea	23.0	22.6	-1.7

* Without Alcatel-Lucent and Sanofi-Aventis, the internationalisation rate of France increases from 20.2% to 23.6% between the two periods of time

** Without Vodafone, the internationalisation rate of United Kingdom decreases from82.3% to 79.8% between the two periods of time

4.2- Very contrasted continental developments

This global analysis however covers both different levels of internationalisation and different dynamics depending upon continents (see Table 2). The level of Asian countries remains very low (2,5%) even if it has increased very rapidly (260% between the 2 periods of observation). This is driven by the very low internationalisation of Japanese firms (from 0.6% in 1994-1996 to 1.3% in 2003-2005), while “emerging” countries have seen their internationalisation rate more than doubled, standing now at the world average (7.3% in 2003-2005 from 2.4% in 1994-1996). Within these, the move is concentrated on Korean and Taiwanese firms; Chinese firms remaining still marginal players at the end of the period of analysis.

The rate of internationalisation of non-Asian firms is a combination of two diverging trends: we witness a regular and sustained increase of US firms (77%) even if their combined internationalisation rate remains below average: from 9.7% in 1994-1996 to 17.3% in 2003-2005). This is in clear contrast with the European overall situation where firm internationalisation stands at 30.4% in 2003-2005, with an important decrease from the previous period (40,7% in 1994-1996, -25%). Even if we take into account the effects of the 3 major firms, which have radically changed of configuration during the period through mergers and acquisitions (2 French firms, Alcatel Lucent and Sanofi, and one British firm, Vodafone), the overall decrease remains (from 35.5% in 1994-1996 to 28.8% in 2003-2005).

Europe remains however a puzzle of different levels of firm internationalisation and of different dynamics: German firms, by far the largest patent producers, exhibit both a lower level of internationalisation (13.8% in 2003-2005) and a decrease over the last decade (-13%). At the other extreme, UK firms (including firms headquartered in fiscally attractive locations[15]) stand at a very high level of internationalisation (around 80% over the decade). Other 'large' European countries, stand in between, especially France, which trajectory is dominated by two very large R&D players, Alcatel-Lucent and Sanofi. The evolution of these two firms explains the drastic overall reduction in internationalisation observed (from 48 to 34% in one decade). When they are left aside, we witness both a far lower rate of internationalisation (23.6% in 2003-2005) and a modest increase over the two periods (17%). For other European countries, the "law" verified by numerous empirical studies applies quite well: the smaller the country, the higher the level of internationalisation of its large firms. As the number of firms is very low for each country, we have made two subgroups: Nordic countries and small & mid-sized European countries. The former stands at 45.8% in 2003-

[15] In particular firms headquartered in the West Indies such as Seagate Technology, Covidien or Ingersoll Rand. This explains why on average British firms rely more on inventors located in the US than in the UK, a situation, which was already specific to the UK when considering firms such as Shell, BP or QinetiQ.

2005, with a modest increase over the decade (15%). The latter are far more internationalised and stand at the level of the UK (around 80%) reaching a plateau over the last decade. This plateau particularly visible for Swiss firms, while both Belgian firms and Dutch headquartered firms continue increasing the internationalisation of their R&D, but this situation largely results from distortions associated with fiscal policies[16].

The hypothesis that the degree of internationalisation of firms depends on the size of domestic resources has thus some ground but needs to be heavily nuanced. It clearly plays for small European countries. But if this was true we should observe higher rates of internationalisation of German firms compared to US firms, which is not the case. Similarly how can we explain the wide difference observed between France and the UK (25% against 80%), while French large firms are quite strong and internationalised in their markets and production facilities (IPTS, 2012). Similarly it remains very difficult to explain the lasting very low level of internationalisation of Japanese firms, while other large Asian firms are rapidly internationalising their R&D. These elements drive us to extend the hypothesis proposed by Patel in 2011: when speaking of European firms, he hypothesized a shift of European firms towards a more continental (European) technological base, firms from larger countries being less tempted to move outside of their borders (such as German firms). Our data support this hypothesis, once the UK is excluded. Furthermore our results drive to enlarge the hypothesis and speak of a generalised "continentalisation" movement. In Asia the rapid growth of the internationalisation of Korean and Taiwanese firms is mainly due to the development of inventive activities in China. Again here, as for the UK in Europe, it remains difficult to explain the very national behaviour of Japanese firms that contrasts with all other firms from OECD countries. Overall this would thus drive us to consider that overall rates of

[16] Again the Dutch situation combines the very dynamic internationalisation of Dutch based firms and the effects of fiscally attractive policies for locating headquarters that firms like EADS, Schlumberger, Gemalto or ST microelectronics have taken advantage of. Like for the UK they explain why the other Dutch headquartered firms depend more on inventors located in other European countries than in the Netherlands.

internationalisation cover two different movements: one linked to the "continentalisation" of firm R&D activities, and one more classical dimension linked to globalisation (seen as the expansion of firm R&D activities in other continents).

4.3- Are there 'optimal' levels of internationalisation?

In order to see if the trends found between our two periods of time,1994-1996 and 2003-2005, were anecdotal or on the contrary match deeper patterns we have build time series related to firm rate of R&D internationalisation over 20 years (see figure 2).

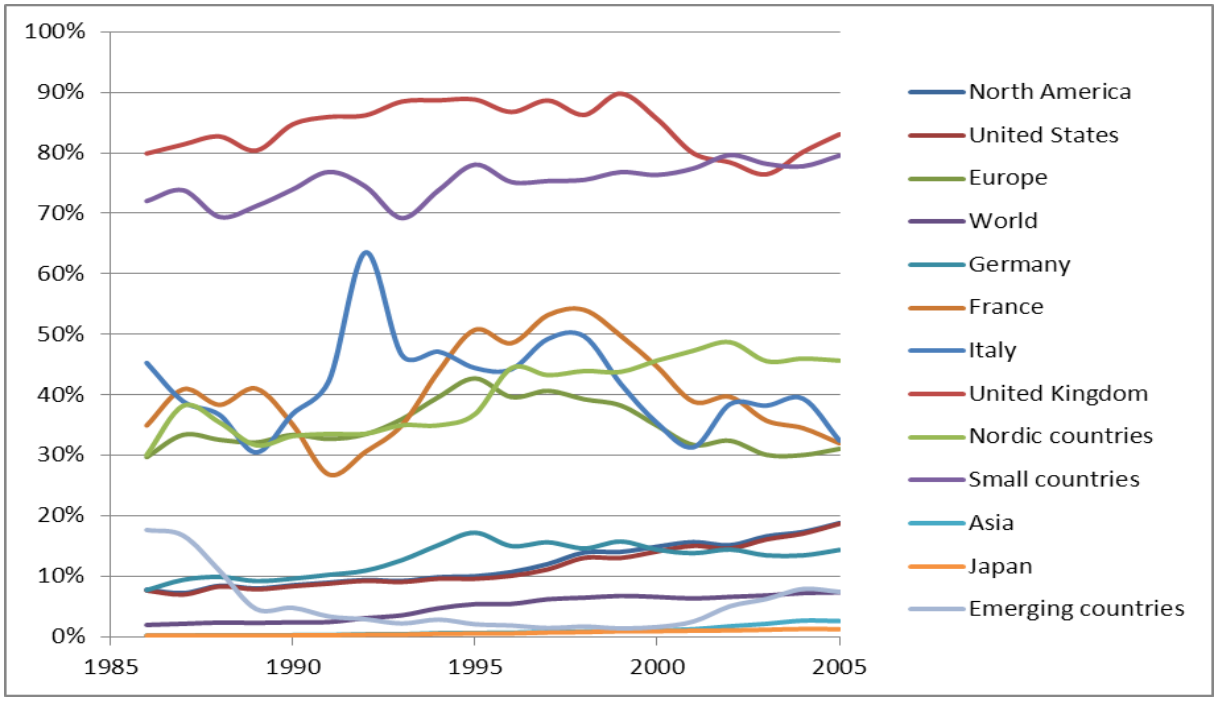


Fig. 2. Evolution of the internationalisation rate over 20 years by continents, countries or zones (1986-2005)

For North America and Asia, figures are steadily increasing. US firms illustrate the fact that "globalisation" taken as developing R&D activities outside of one's continent of origin, is fast rising, while remaining at low levels (less than one invention out of six). The question that it

raises - whether it will go on rising or whether we are entering a plateau - remains open for further studies. Asia still remains a zone of weak R&D internationalisation but growing mostly at the continental level.

The long trend movement of European firms also shows a fast rising trend from the mid 1980s (where internationalisation stands at 30%) to the mid 1990s where it reaches 43%. This development corresponds to a simultaneous increase of "continentalisation" linked to the common market, and to a fast rising "globalisation", translated in the numerous studies that look at the expansion of European firms in the US (both through the creation of new R&D labs and through the acquisition of labs via mergers and acquisitions). What is however striking in figure 2 is that this corresponds to a peak. Europe at large and most European countries face an inverted U shape relationship, witnessing a strong decrease in the second half of the 1990s and a stabilisation between 2001 and 2005. The analysis of different trends drives to suggest the following hypotheses.

a) At a high level of internationalisation, the dependence of firms towards the wider world is such that it renders difficult any strategy of concentrating on the "home base": rates tend then to stabilize or oscillate around this very high level (between 70% and 90%). As if an "optimal rate" does exist. This is true for the UK, Nordic and "small" countries.

b) Other large European countries – in particular Germany and France – play a large role in the "European decline". They both peak in 1995, and both decline afterwards – very strongly for French firms, rather slowly for German firms. The firms from these large European countries were already strongly internationalized. In the 1990s European MNCs undertook numerous mergers and acquisitions (M&A) in particular in the US. UNCTAD (2007) points out that cross-border M&A increased globally quickly until 2000. This stopped afterwards. This moves match the burst of the so-called "Internet bubble" that affected the IT and

telecommunications sectors. We can hypothesize that, in the following period, they concentrated on rationalizing their R&D activities and on building up a global organisation of their R&D activities. This ended up in stabilising or reducing the overall level of internationalisation. Such an assumption is in line with the view by Gammeltoft (2006) about the end of the growth in R&D internationalisation. Two further factors corroborate this analysis. The creation of euro zone, after 2000, has resulted in greater regional integration within Europe with a sharp increase of intra-European FDI flows (UNCTAD, 2007). The second factor is related to the economic context of globalisation. After observing a selection of main trends through indicators provided by UNCTAD (2007) Report, we found interesting and may be unexpected changes: The upward trend in FDI that began in the 1980s, stopped in year 2000[17]. In this context the decrease in the rate of R&D internationalisation related to European firms is particularly consistent. As a consequence, the basic idea is that new conditions emerged after 2000 that have affected globalisation trends.

c) One logical assumption often discussed in meetings at the European Association of R&D managers (EIRMA), is that European firms, after a rapid expansion in Europe, have started rationalising their European labs, while they pursue their global implantations. This is not what we find. On average large European firms have increased their European investments in R&D (from 15.6% to 17.5% between 1994-1996 and 2003-2005), even if this relative increase has been slow (12% between the two periods), while they have drastically reduced their world level investments. The share of non-European inventions comes back from 25.2% to 12.9%, mostly due to a sharp retraction in the activities in the US. Thus the rationalisation movement we observe is not about European R&D but about intercontinental R&D. This is in

[17] We register a similar trend for the outward direct *investment* at worldwide level: after a persistent growth since 1970, it registered a peak in 2000 followed by a *decrease* during a four years period of time. It started again to increase after (see the data from UNCTAD 2007). By contrast the outward FDI *stock* increased continuously from 1982 to 2006. In the same vein, employment in foreign affiliates decreased in 2000-02 after a long time period of growth. This reflects that important aspects of industrial globalisation can be stopped for given time periods.

line with what we observe for Asian firms which privilege a continental approach[18], but this is in sharp contrast with US firms, which maintain their global R&D investments over the period[19].

These findings raise two central questions about expected dynamics. Firstly, how to explain the very divergent trends between European and US firms in term of intercontinental globalisation? One unconventional analysis would be that European firms went too far and were driven to rationalise, while US firms have 'caught up' meanwhile. This would mean that the intercontinental levels we observe in 2003-2005 – by and large quite similar: 16% for the US and 13% for Europe – would tell about the type of plateau one can expect – around one innovation out of six not coming from its national or 'nearby' environment? Secondly the core of new globalisation of R&D activities should come from Asian firms. But can we really anticipate a 'catch-up' model, when it remains difficult to explain the non-internationalisation of Japanese firms, and when the internationalisation of other Asian firms is mostly explained by a continental enlargement of their 'home base'?

As a first conclusion, we interpret the results of this section as a confirmation of the mainly national dimension of MNC technological bases. This central trait of corporate invention is massively confirmed by the analysis of inventors location which, as a general pattern, coincides mainly with the headquarter country. And only two outliers: United Kingdom (ranked 9th) and Netherlands (ranked 11th), whose internationalisation profiles result from factitious firms nationalities due to fiscal incentives and from the fact that countries internationalisation rates - an aggregate statistics - could stem from a few large firms' behaviours. As a second conclusion it appears that R&D internationalisation is not

[18] In 2003-2005, 88% of the non domestic inventions of Asian firms are realized in another Asian country. It appears difficult to speak about "globalisation".
[19] In 2003-2005 for the US firms the continental R&D internationalisation rate is 1.6 % (1.0 % in 1994-1996) versus 16.0 % for the intercontinental R&D internationalisation rate (17.3 % in 1994-1996).

continuously growing. Countries among the largest in terms of technological activity are experimenting either a stabilisation or a declining trend[20]. The last point concerning the volume of R&D internationalisation links to the old but always relevant taxonomy of technology globalisation produced by Archibugi and Michie (1995). They identified three complementary ways to access technology at the world level: international exploitation of national technology; global technological collaborations involving different types of actors (private/public, domestic/foreign, national/local; and global production of knowledge (the only one we study with our indicators). It may be that, what we observe today, is not a true decline of technology globalisation, but a more balanced distribution between the three ways for organizing the production, the control and the transfer of knowledge.

Section 5. Locational strategies of MNCs: what evolutions in a changing global context?

We now are interested by the type of locational strategy carried out by large firms. We here take over the four types of conduct defined in section 2. As previously said we measure the weight of each strategy by the number of patents matching the four types. The Revealed Technological Advantages (RTA) has been calculated following the approaches developed by Patel and Vega (1999) and Le Bas and Sierra (2002)[21]. The sample has been reduced from 968 firms to 616 firms due to the following reason: in order to characterise strategies, we need

[20] The rate of R&D internationalisation cannot go until 100 % there is necessarily an upper bound given by the cost of knowledge dissipation linked to many foreign locations. To date empirical evidence are missing for rightly interpreting this new trend. The reliability of our data set is not questionable. The decreasing slope is lasting over the last years. As a consequence we cannot interpret it as a shock (still less a random shock). Of course further studies will be necessary for better understanding it.

[21] Laursen (1998) have suggested another algebraic expression for RTA, the symmetric RTA. The first exploration made with our data shows that the use of this different expression does not really change the findings.

that a firm holds two patents in the same technology field with one patent invented in the corporate country and the other in foreign countries. Most firms withdrawn come from the largest countries (US, Japan, Germany, UK and France). Globally they have a marginal impact (6%) and we still cover 43% of total world patents in 2003-2005.

5.1- Internationalisation strategies: overall continuity over the decade

We now look at the relative importance of the four different strategies. The previous studies had shown the importance of the two strategies based upon cases where the firm is more specialised than its home country, whether it uses its base for adapting for other markets the innovations made at home (Home-base Exploiting, HBE) or whether it looks for complementary assets in host countries also specialised in its core technologies (Home-base Augmenting, HBA). These two strategies are also prevalent in our overall sample; they gather 82% of firm inventions in 2003-2005. The home base remains thus critical, which means that our results do not for instance sustain the assertion of Doz et al. (2001)[22] when they suggested that firms were becoming "metanational". Both strategies are quite balanced, even if HBA strategies are slightly more important: 42.5% against 39.4% (table 3). Only one invention in ten (9.8%) corresponds to firms that look for technologies that the home country is not specialised into, while the host country is. Finally 'pure' market seeking strategies (MS), where both the firm and the host country are not specialised, remain quite rare (8.3% in 2003-2005). The latter two strategies have lost ground over the last decade, witnessing an overall decrease of 14%. This decrease explains the major evolution observed during the decade, *that is the slight relative increase of HBE strategies (from 35.7% in 1994-1996 to 39.4% in 2003-2005),* while the weight of HBA strategies remained stable (respectively 43.3 and 42.5% for

[22] Metanational large firms "do not derive their competitive advantage from their home country, or from a set of national subsidiaries" according to Doz et al. (2001).

both periods). These results drive to nuance the results observed by previous studies where HBA strategies were far more prominent and fast rising in relative importance, while on the contrary HBE strategies were loosing ground. Besides the continuing critical role of the home base in the deployment of internationalisation strategies, we face a quite unexpected result: a slight rebalancing of strategies in favour of a more intensive exploitation of the home base.

Table 3 - Evolution of firm R&D internationalisation strategy by firm country, continent or zone over ten years (%) [23]

Country of firm	HBA 1994 - 1996 (%)	HBA 2003 - 2005 (%)	HBE 1994 - 1996 (%)	HBE 2003 - 2005 (%)	TS 1994 - 1996 (%)	TS 2003 - 2005 (%)	MS 1994 - 1996 (%)	MS 2003 - 2005 (%)
North America	49.6	51.2	32.3	31.0	10.5	9.3	7.6	8.5
United States	49.5	51.1	31.7	30.9	10.9	9.3	7.9	8.6
Europe	44.0	40.9	35.2	37.6	11.4	11.7	8.4	7.8
Germany	37.6	41.2	41.5	36.8	12.0	12.9	8.9	9.1
France	40.8	27.7	34.0	42.7	11.8	17.1	13.3	12.5
United Kingdom	65.2	52.5	29.5	37.5	2.0	2.9	3.3	7.1
Italy	37.2	24.8	27.9	27.2	20.2	16.8	14.8	31.2
Nordic countries	49.5	52.9	38.9	35.2	4.3	8.9	7.2	2.9
Small countries	41.8	42.7	36.2	35.9	16.7	15.9	5.2	5.6
Asia	25.3	35.8	42.7	50.0	14.9	6.4	17.2	7.8
Japan	25.1	31.2	41.8	47.8	15.0	10.6	18.2	10.4
Emerging Asia	26.1	38.4	41.7	51.8	18.6	3.7	13.6	6.1
Total	43.3	42.5	35.7	39.4	11.7	9.8	9.3	8.3
Total without Japan	45.2	44.1	35.1	38.2	11.3	9.7	8.4	8.0
Total without Japan & Korea	45.7	43.8	35.0	36.9	11.1	10.9	8.2	8.4

Notes: for year period the sum is equal to 100

[23] China is missing here because Chinese firms in the first time period do not have patented inventions made by foreign researchers. As a consequence there is no Chinese firm among the 616 setting up our sample.

5.2- important regional differentiations and diverging trends

These overall strategies are in fact the combination of rather opposite strategies between continents. While US firms develop mostly HBA strategies and this is reinforced over time (49.5% in 1994-1996, 51.1% in 2003-2005), Asian firms (at a far lower level of internationalisation though) privilege HBE strategies (their share moves from 42.7% to 50% between the 2 periods). This shows that Asian firms search first for adapting domestic technologies to foreign markets: this is true for all countries including Japan. Interestingly we witness different evolutions for the other major strategy followed in the two continents: in the US the exploitation of home assets abroad remains rather stable (around 31%) while in Asia we witness a clear growth of the search for complementary assets (meaning that this goes along with a parallel reduction of 'technology seeking' strategies). The core effect lies here in the progressive specialisation of emerging Asian countries in the fields where large national companies have developed. Korea is an extreme case of this movement with a doubling of the role of HBA strategies (46% in 2003-2005), HBE strategies having increased by one third and standing at 45%[24].

Europe, once more, has a different profile, close to the world average, and this profile has been rather stable over the decade. The search for complementary assets remains dominant but has slightly diminished (44% to 41%) while the exploitation of home technologies abroad has slightly increased (from 35% to 37.6%). Both technology seeking strategies and market seeking strategies remain stable over the two periods (respectively around 11.5% and 8%).

[24] LG, one of the first and most internationalized Korean conglomerates is an illustration of the massive internationalisation of firms in Korea. Over 10 years LG internationalisation rate has risen from 1% to 13% (its number of patents invented abroad has increased by a factor of 65). With China as a main host country, LG contributes to HBE strategy in several technologies like Audio-visual technology and Electrical machinery.

However, as we have seen before for the rate of internationalisation, this average is the combination of very different national choices, and even diverging trends.

Countries that are heavily internationalised (the UK and Nordic countries) privilege the search for complementary assets (between 52% and 53%), even if quite similar levels in 2003-2005 result from diverging trends in the role of HBA strategies (they stood at 65% in the UK in 1994-1996 and at 49% in Nordic countries). But it is difficult to generalise this trend since 'smaller' European countries that are all very internationalised, witness contradicting evolutions: high level of HBA strategies maintained over time in the Netherlands (also around 52%); and on the contrary a strong decrease for Swiss firms (around 40% in the second period). In all these countries, home-base exploiting strategies gain more prominence, at the expense of previously quite important technology seeking strategies. Can we interpret this through the mould of management studies that are numerous to emphasize the growing concentration of large firms on their core technologies associated with more and more outsourcing (including offshoring)? This may also be a sign of the progressive alignment of specialisations between large firms and their home countries.

HBA strategies are far less important for the two largest patenting countries in Europe. Germany is the last country to follow the pattern highlighted by both Patel and Vega (1999) and Le Bas and Sierra (2002): a growing role of the search for complementary assets over time (from 37.6% to 41.2%) at the expense of the international exploitation of home based inventions (from 41.5% to 36.8%). France was already specific in its profile in the two above-mentioned studies, and this has reinforced over time. Both studies noted that the international exploitation of home based technologies played a higher role than the search for complementary assets, and this trend has heavily increased over time, Home-base Exploiting strategies standing at 43%, while Home-base Augmenting strategies trail at a low 28%, making French firms quite unique in the OECD landscape. It is interesting to note that,

though they are the two European countries with the largest technology base, we find in both countries a significant number of firms that follow 'technology seeking strategies' (13% in Germany and 17% in France in 2003-2005): this manifests the existence in both countries of large firms under-specialised in their home country. These firms have thus internationalised to look for these technologies in specialised countries.

5.3- Evolving host countries as a major source of explanations

A source for a potential explanation about internationalisation strategies lies in the choice of host countries. Which are the key recipient countries and what motives firms privilege to come to these countries? For each patent having inventors from a given country, we can find out the matching strategy developed by the corresponding firm holding the patent (Table 4).

Table 4 - Evolution of firm R&D internationalisation strategy by host country, continent or zone over ten years (%)

Country of inventors	HBA 1994 - 1996 (%)	HBA 2003 - 2005 (%)	HBE 1994 - 1996 (%)	HBE 2003 - 2005 (%)	TS 1994 - 1996 (%)	TS 2003 - 2005 (%)	MS 1994 - 1996 (%)	MS 2003 - 2005 (%)	Total 1994 - 1996 (%)	Total 2003 - 2005 (%)
North America	47.2	18.8	53.5	30.0	40.6	26.4	62.6	32.2	50.1	25.1
United States	44.6	15.1	48.5	27.1	38.5	23.5	56.8	28.3	46.4	21.8
Europe	42.8	51.9	40.2	37.5	53.8	54.1	31.5	42.3	42.1	45.7
Germany	17.8	18.3	12.9	15.0	28.7	17.5	10.3	15.2	16.6	16.7
France	4.9	7.9	5.6	4.5	6.1	9.3	5.8	7.1	5.4	6.6
United Kingdom	6.3	8.7	8.6	5.0	5.7	11.4	5.5	5.9	7.0	7.3
Italy	1.6	2.1	2.0	1.2	1.7	1.4	1.0	1.0	1.7	1.6
Nordic countries	2.5	3.1	3.3	2.8	2.3	3.0	2.2	2.7	2.8	3.0
Small countries	7.7	8.6	5.4	5.3	7.3	8.2	4.5	7.3	6.6	7.2
Asia	9.2	28.2	5.5	31.6	5.1	18.3	5.2	24.5	7.0	28.3
Japan	5.4	4.4	3.1	3.9	3.3	3.5	2.4	4.0	4.1	4.1

Emerging Asia	1.4	18.9	1.7	25.9	0.9	10.6	2.1	17.5	1.5	20.8
Total	100	100	100	100	100	100	100	100	100	100

Clearly in the mid 1990s, the key recipient country was the US with 46% of all activities, and this covers all types of strategies followed by foreign firms investing in the US. As Asian firms are either fully absent or nearly not internationalised, this translated the very fast movement of internationalisation of R&D activities by European firms beyond Europe. Similarly Europe receiving 42% appears as the second central location for other European firms and for US firms: again this covers all 4 types of strategy.

In 2003-2005 we have moved from this transatlantic focus: while Europe remains a central hub (46%), the *US have seen their role reduced by half* (22%) while China (17%) and other emerging countries became as important. What is even more striking is that this decrease is more pronounced for home-base augmenting strategies by investing firms. This is the opposite for Europe that has increased its position significantly, Germany being now the first destination (18%) before the US and China (15% each).

Table 5 - Firm R&D internationalisation strategies in the six largest host countries in 2003-2005 (%)

Country of inventors	HBA 2003 - 2005 (%)	HBE 2003 - 2005 (%)	TS 2003 - 2005 (%)	MS 2003 - 2005 (%)	Total 2003 - 2005 (%)
United States	29.6	49.2	10.4	10.8	100
China	36.6	53.3	3.7	6.5	100
Germany	46.7	35.6	10.1	7.6	100
United Kingdom	51.2	27.0	15.1	6.7	100
France	50.7	26.9	13.5	8.8	100
Japan	45.9	37.8	8.3	8.0	100
Total	43.4	39.3	9.3	8.0	100

If one considers the six largest recipient countries (see Table 5) and the types of strategies developed by foreign firms, the opposition between the US and China on one side and European countries plus Japan on the other is sharp: exploiting home based inventions dominates in the former, while the latter, and especially European countries, attract firms that look for complementary assets, thus in the domains of strengths of the recipient countries. A further observation helps to better understand the on-going movements observed: more than 2/3rds of firm inventive activities encompassing a Chinese inventor are gathered in one Korean firm LG, and a further 7% by the Taiwanese firm, Inventec. This shows the extent of redistribution over one decade: while European firms prevailed in the intercontinental exchanges in 1994-1996, we witness 10 years later a retraction of the US as a destination, and an exponential growth of China as a recipient country, however this is not linked to a reorientation of the internationalisation of R&D activities of European firms, but is focused by the fast rising internationalisation of other firms from emergent Asian countries.

As a conclusion, the overall slight rise of HBE strategy deserves more explanation. We surely need a longer time period of observation to be sure we face a lasting changing trend. Nevertheless we rather think it is a rebalancing (especially vis-à-vis the two other minor strategies) and that our data supports Dunning and Narula (1995) assertion upon the lasting dynamics in favour of "strategic asset seeking", meaning that MNCs mostly look for foreign locations that have complementary technological strengths in their 'core' technologies. The rebalancing towards HBE locational strategies is in fact very close to the adaptation function described by Vernon (1966) and linked to the increase of market shares in foreign locations. In particular, this sounds a logical behaviour for European firms in a context marked by the enlargement of the European market and the making of the euro zone. It also explains why we find different results than studies made on the mid 1990s: The rising trend of HBA found by Patel and Vega (1999) and Le Bas and Sierra (2002) can be put in relation with the wave of

mergers and acquisitions in the US by the European MNCs. By contrast the early 2000s are marked by the emergence of China (and more generally the group of BRIC countries) as key markets, and this changes significantly the orientation of R&D locational strategies: HBE motives became prevalent.

6- Conclusions

These results on firm R&D internationalisation patterns drive us to highlight the following "stylised facts" that are summed up in table 6 below.

a) Our statistical series stop in 2005 but do not reflect any acceleration of firm R&D internationalisation, which could suggest a burst in the process globalisation of technology often taken for granted by the literature (at least at the level of our three geographical zones).

b) Over the entire time period under observation at the world level the rate of internationalisation stays very low for some countries included economies considered as very competitive in the global market (Japan and Germany for instance).

c) For the firms from large European countries the atypical evolution (inverted U shape), never pointed out before to our knowledge in the literature, deserves particular attention as a new issue to be seriously investigated. Our data related to *patenting* indicates a break in the continuous growth of the share of R&D carried out abroad. This suggests a new direction for research work, considering the factors that push toward home country centralization.

d) Without any visible deepening of overall internationalisation of R&D activities compared to studies carried out 10 years ago, we nevertheless record different levels between continents and different trajectories: European heavy relative internationalisation but retracting from 10

years ago; continuous US growth even if still far below European levels; the *always* limited internationalisation of Asian countries, *but* fast growing, mostly driven by firms from "emerging Asia".

e) Our results drive us to distinguish between "continentalisation" and "globalisation" in overall internationalisation movements. For Asian firms there is a clear dominance of intra-continental flows (China being the core destination of other Asian countries). Even if US firms witness a lower than average internationalisation level, it is only focused on globalisation, and makes of US firms by far the largest players in this globalisation movement.

f) The European puzzle is partly linked to size – the smaller the more internationalised (with the exception of the UK). However more work is needed to understand the contrasting situations and evolutions of the two largest patenting European countries: French high level of internationalisation, but with a strong retraction over the last decade, German lower level but with a slow continuous reduction.

g) With respect to the motives for internationalisation (the second topic dealt with into the paper) the dominance of the national base remains very central with the very important weight of HBA + HBE strategies. The pattern has evolved over the decade but not as predicted by previous studies. The observed movements (even if they are quite weak) do not witness a significant growth of HBA strategies and a concomitant reduction of HBE motives.

h) However this relative stability is arrived at through, again, very different continental dynamics. Our data confirm lasting geographical differences in the ways firms develop strategies: US firms strongly favour HBA strategies and there has been no change in this movement over time, while Asian firms focus on the exploitation overseas of their home inventions (HBE strategies). However the latter have replaced 'technology seeking strategies'

by HBA strategies, showing a dual alignment of firms with national competences both in their country of origin and the countries of destination (mainly China). A central reason lies in the very important changes witnessed in the direction of flows: while the US represented half of the flows in 1994-1996, they make only 22% of the international investments in 2003-2005, with China nearly equal to them as a destination. However it is critical to note that these new flows originate mostly from other Asian countries and not from European ones. Once more, our results highlight the internal diversity in Europe, where clearly very internationalised 'countries' favour HBA motives, while larger countries witness a growing role of HBE motives. Finally, it is important to highlight that Europe as a whole, and Germany in particular, remains very attractive for R&D FDI in-flows over the period (maintaining a relative position around 40% of total international inventive flows, the double of the US in 2003-2005): this tells about the very large technology base of large European firms and countries, and this suggests that studies focusing on attractiveness factors should not restrict themselves on emerging countries.

Table 6 - Continental variation in overall dynamics of firms R&D internationalisation

Firm continent	Rate of R&D internationalisation	Type of (dominant) location strategy	Main geographical zone of abroad R&D location
Asia	Weak but growing fast	HBE, growing	Continental (Asia)
North America	Medium but growing	HBA, growing	Global
Europe	(Very) high in general but decreasing, For some countries inverted U shape relationship	HBA, decreasing	Reverse from global to continental (Europeanisation)

Appendix A: Distribution of the set of firms and their share of patents in the data set according to sectorial belonging (using the Industry Classification Benchmark).

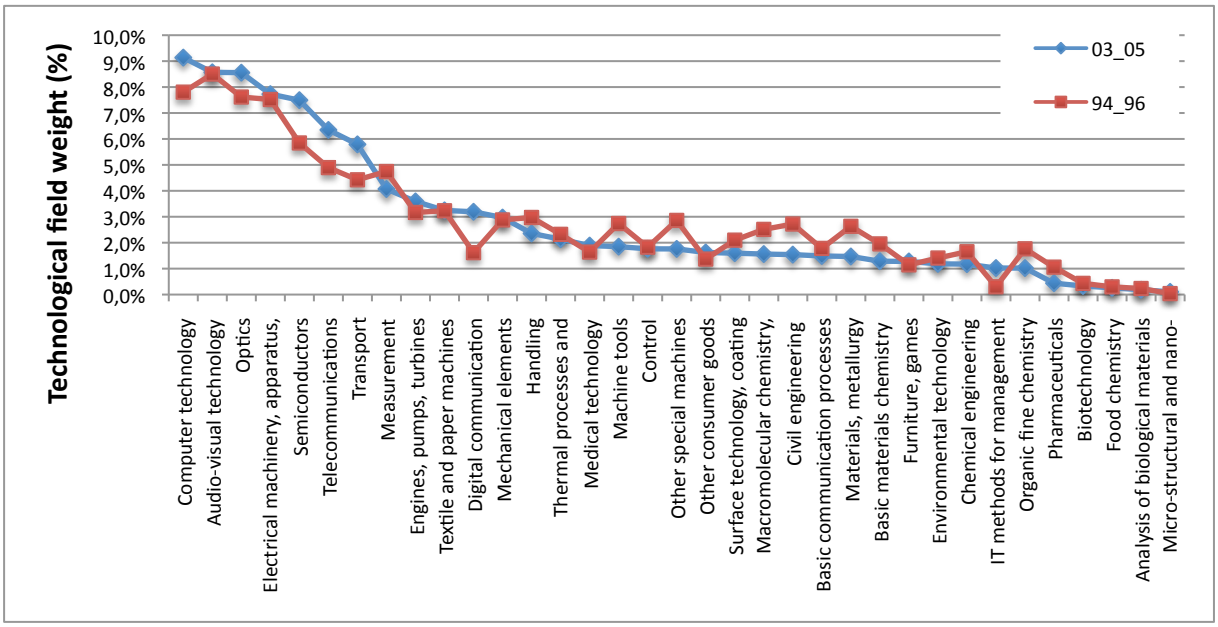
Table A.1: Distribution of large firms and their patent by firm industrial sector

Industrial sector of firms	Number of firms (%)	Patent share 2003-2005 (%)
Industrials	31.90	28.33
Technology	17.80	24.00
Consumer Goods	16.90	29.39
Basic Materials	12.30	12.24
Health Care	11.30	1.28
Oil & Gas	2.70	0.96
Utilities	2.30	0.74
Consumer Services	2.20	1.24
Financials	1.30	0.04
Telecommunications	1.30	1.78
Total	**100.00**	**100.00**

Appendix B. Distribution of patents according to technology fields

Patents are allocated as fractional counts to technology fields according to a classification of technology in 35 fields that has been recently updated by WIPO. The figure shows the breakdown of corporate patents by technology fields for two periods of time, 1994-1996 and 2003-205. A similar distribution is obtained for the two period of time. No technology field exceeds 10% of all fields and only a few fields weigh more than 5%. Most of the heaviest fields are related to ICT and Electrical engineering (computer technology, Audio-visual, Electrical machinery, Semiconductor) or to the domains of Instruments (Optics, Measurements) or Mechanical engineering (Transport, Engines-pumps-turbines). Technology fields related to Chemicals, Pharmaceutics, Foods or Consumer goods exhibit weights that never exceed 3%.

Fig. B.1: Distribution of patents by technology fields in 1994-1996 and 2003-2005



The technology field distribution remains quite stable between the two periods of time (Rsquare = 0.92) but a noticeable reinforcement the weight of ICT related fields and Transport to the expense of Chemistry and Machining related fields is detected.

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