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Location choices within global innovation networks: the case of Europe

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Abstract Rapid growth in internationalization of corporate R&D has spurred considerable interest since the 1990s. Foreign R&D is still mainly driven by the expansion of international production, but technology sourcing has become an increasingly important driver of dispersion. Actually, differences across sectors and companies tend to obscure the mix of motivations behind the development of global innovation networks. This paper distinguishes the various drivers of the international dispersion of corporate R&D in order to elaborate a typology of foreign R&D units, including in emerging countries. This typology is used to discuss the emergence of differentiated global innovation networks and the location choices by type of R&D unit. It is applied to foreign R&D projects in Europe in high and low cost countries between 2002 and 2005. It is then used to discuss the weakening attractiveness of the European Union for R&D activities and the relevant policies that countries can design to attract different types of units.

Keywords Globalization of R&D · Location of R&D · Multinationals · Europe

JEL Classification F23 · O32

1 Introduction

Rapid growth in internationalization of corporate R&D since the 1990s has resulted both from the continuation of previous tendencies related to the expansion of international production, including through transnational M&A, and from the more systematic building up of global innovation networks by multinational firms. This trend and the greater

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mobility of R&D units have raised fears that they could relocate abroad and, conversely, countries have sought to attract scientific and technological activities. These concerns are particularly acute in Europe, where authorities fear the transatlantic brain drain and seek to stimulate innovation. Since 2000, the growing scientific prowess of some emerging countries and their attractiveness for foreign R&D have raised fears that high tech activities could massively relocate away from high cost countries. If emerging countries rapidly climb the value chain and become innovators, the argument goes, advanced countries could lose their last source of comparative advantage.

In this context, it is important to identify more precisely the determinants of the geographical distribution of R&D activities. This paper argues that firms develop differentiated global innovation networks, where three types of R&D unit play complementary roles. Based on a review of the literature on the evolution of foreign R&D, part 1 elaborates a framework to analyze the relationship between the three types of R&D units and their location. Part 2 uses this typology to explain the choice of location by foreign R&D units in Europe between 2002 and 2005. It then discusses the decreasing attractiveness of European countries and transatlantic technology sourcing. It finally draws policy implications for Europe.

2 A typology of foreign R&D units

Empirical studies have established that internationalization of R&D has been largely driven by internationalization of production.[1] However, this relationship varies among the multinationals of different countries. For example, Japanese multinationals continue to centralize the bulk of their R&D in Japan, whereas the European companies that internationalized rapidly during the 1990s have substantially increased their share of R&D conducted abroad. This is particularly true for German and French companies (Cantwell and Harding 1998; Cantwell and Janne 2000; Larédo and Mustar 2001; Sachwald 2003; Ambos 2005; Belitz et al. 2006).

A number of studies have emphasized the increasing importance of access to local scientific and technological resources as a motivation for R&D location (Florida 1997; Kuemmerle 1999; Serapio and Dalton 1999; Sachwald 2003; Ambos 2005). Over the past two decades, multinationals have been selectively tapping into foreign technological resources to augment their innovation capabilities. Empirical studies have shown that both European and Japanese firms have tended to use their American affiliates to successfully source technology (Almeida 1996; Frost 2001; Chung and Alcacer 2002; Iwasa and Odagiri 2004). Relatedly, foreign units have become more integrated into global R&D strategies (Doz et al. 2001; Zedtwitz and Gassmann 2002).

These trends are not equally developed across sectors, countries and companies, which confuses the overall picture and calls for a finer identification of the drivers of internationalization of R&D. This first part discusses the different drivers of internationalization of R&D and establishes a related typology of foreign R&D units.

2.1 New factors of internationalization of R&D activities

The literature has traditionally contrasted centripetal forces, which justify the centralization of R&D activities in the country of origin, with centrifugal forces, which explain that

[1] Recent surveys include Criscuolo (2004), Narula and Zanfei (2005), UNCTAD (2005), and Veugelers (2005).

multinationals progressively develop R&D units abroad (Pearce and Singh 1992; Cantwell 1997). Globalization has changed the balance between these two forces and, since 2000, the tighter integration of some emerging countries into the global economy has also triggered new centripetal forces.

Historically, the centralization of research activities in the country of origin resulted from both the supply and demand factors that influence the location of R&D (Vernon 1966). Figure 1 indicates that in the face of this set of centralization forces, the need to adapt to local demand was the main incentive for the decentralization of development activities. The largest foreign markets would attract such activities, provided adequate local technological capabilities were available.

As multinationals matured, the traditional factors of dispersion have become more influential. Adaptation to local markets has become relatively more important as foreign subsidiaries have expanded and multinationals have created R&D units in an increasing number of countries. Foreign acquisitions have also played an important role in the sharp increase in the number of foreign R&D units since the late 1980s.

Figure 1 indicates in bold characters the new factors of dispersion that have appeared since the late 1980s. These new factors result from both changes in innovation processes and the gradual adoption of global strategies by companies. On the demand side, in the context of innovation-driven competition, companies have located technological outposts, design centers or technical centers in lead markets, where new practices are emerging (Beise 2004; Gerybadze and Reger 1999; Doz et al. 2001). On the supply side, strong technological resources and centers of scientific excellence attract R&D units (Davis and Meyer 2004). Initially, the analysis of technology sourcing was stimulated by the observation of R&D investments in the U.S. by Japanese multinationals in the 1980s. Early studies that used R&D intensity of firms and sectors to identify technology sourcing partially confirmed this hypothesis (Kogut and Chang 1991; Hennart and Park 1994). Studies based on patent data, specific surveys and case studies have found stronger evidence of technology sourcing by Japanese and European R&D units in the United States (Almeida 1996; Florida 1997; Weil 2000; Sachwald 2003; Iwasa and Odagiri 2004). The survey of German multinationals conducted by Björn Ambos (2005) clearly shows that the number of their capability augmenting foreign R&D units sharply increased in the 1990s.

The division of labor between small and large companies constitutes a particularly important evolution of innovation processes. In the context of globalization, the division of labor between start-ups and incumbents, or between suppliers and customers, has taken on a global dimension. The establishment of relations with foreign start-ups, which have developed within clusters, is one of the best means of accessing new technological

Factor of:	Characteristics of science and technology supply	Characteristics of demand
Centralization in the country of origin	• Strong S&T capabilities of the country of origin • Economies of scale in R&D	• Country of origin is a lead market
International dispersion	• **Attractive centers of excellence abroad** • **Low cost talent pool; increasing supply of scientists and engineers in emerging countries**	• Adaptation to foreign markets and local production conditions • **New lead markets abroad**

Fig. 1 The new internationalization forces of R&D depending on the characteristics of home and foreign countries. The factors of dispersion that appeared in the context of globalization are in bold

resources. Agglomeration economies have been considered in the early analyses as centripetal forces. But, as more destinations with attractive science and technology bases have developed, agglomeration economies in the country of origin may be superseded by agglomeration economies in foreign countries. Similarly, foreign centers of excellence may attract large R&D units, which are able to exploit economies of scale.

More recently, low cost locations have also attracted R&D activities. Since the 1990s, the combination of globalization and the growing role of innovation as a factor of competitiveness have led to major changes in R&D management. Innovation has absorbed more resources in most sectors and escalating costs have elicited a growing interest in streamlining R&D, in particular in some high tech sectors. Simultaneously, the pool of viable locations for R&D has expanded hugely in the last decade. China and India have large and increasing outputs of scientific graduates, even though the countries still have weak innovative capabilities. Both countries and an increasing number of smaller emerging countries invest in higher education and R&D facilities. Moreover, access to these new locations has been reinforced after the Internet bubble with plummeting telecommunication costs, which allow easier exchanges with teams in India for example.

Surveys of senior executives of multinational companies and case studies emphasize the increasing attractiveness of emerging countries for the location of R&D (EIU 2004; Koudal 2004; Zedtwitz 2004; UNCTAD 2005; Thursby and Thursby 2006). Companies generally emphasize the availability of skilled technicians and researchers, while they rank low costs as relatively less important. However, it seems difficult to disentangle the argument of access to large pools of skilled engineers or scientists from that of access to low cost R&D. India in particular attracts foreign firms because it offers more intellectual power per dollar spent than industrial countries over a range of R&D activities (Wharton 2005).

Recent data thus confirm the strengthening of the factors of dispersion indicated in Fig. 1. Accumulated scientific and technological capabitilites in the country of origin and economies of scale in R&D continue to weigh in favor of centralization, but innovation networks processes become increasingly polycentric as the potential locations for R&D activities diversify and technology increases the capacity to divide and distribute innovation processes. The above discussion also suggests that foreign R&D activities have become more heterogeneous, which may explain the uncertainty of the overall impact of some country variables on the decision to invest. Costs seem to be more important than tax breaks in deciding to locate in an emerging country, while public support seems more important in advanced countries (Thursby and Thursby 2006; EC 2006).

2.2 Three types of foreign R&D units

Based on the analysis of the main drivers of international dispersion of R&D, three types of R&D units may be identified: the local development center, the global laboratory and the global rationalization center.

2.2.1 The local development center (LDC)

Local development centers correspond to the traditional motive of support to production for locating R&D activities abroad, as discussed above (Fig. 1). These home-base exploiting R&D units are more numerous and dispersed than research facilities and constitute the majority of R&D units abroad (Gerybadze and Reger 1999; Madeuf et al. 2000; Zedtwitz and Gassmann 2002; Ambos 2005). Their location is driven by the geographical distribution of production sites, which is itself influenced by the relative importance and dynamism of local demand.

2.2.2 *The global research laboratory (GRL)*

Foreign research laboratories contribute to the global innovation process of multinationals. These laboratories are home-base augmenting R&D units and their output generates applications for different countries. They may be organized as part of a global network of laboratories, in which the historical core R&D unit in the country of origin has a less central role. As part of the innovation network of the multinational firms, global laboratories may partly draw on the home R&D resources when they conduct projects with home-based research teams. They may also source technology and monitor scientific developments in the host country. Finally, some foreign laboratories may be of small size and specialized on a very specific research area in relation with a local university.

In the 1990s, the increasing number of global foreign laboratories has been driven by the wave of transnational M&A. After a series of acquisitions a multinational typically restructures its R&D operations, but some R&D centers may then become global laboratories for the group. This has been the case for example of some US R&D facilities after their acquisitions by European companies in the 1990s. In a number of cases firms have nevertheless invested in greenfield global laboratories to reach out for foreign centers of excellence. Numerous European and Asian R&D laboratories have thus been located in American high tech clusters and high R&D intensity states (Florida 1997; Miotti and Sachwald 2001; Chung and Alcacer 2002; Sachwald 2003; Iwasa and Odagiri 2004; Kaiser and Prange 2004). Lead customers, major companies and frontier research are concentrated in these locations. As a manager from SAP's R&D laboratory in Palo Alto puts it: "We have our major competitors here...and we have Silicon valley as a fountain for ideas and talent" (EIU 2004). GRLs are attracted by world class scientific and technological resources. Demand characteristics nevertheless play a complementary role as global laboratories benefit from on-the-spot learning in lead markets and adaptation to sophisticated customer needs (Meyer-Krahmer and Reger 1999; Doz et al. 2001; Beise 2004).

GRLs conducting applied research should be much fewer than LDCs. Data from studies on home-based augmenting R&D units can give an indication in this respect. According to a survey on 700 Japanese affiliates in the United-States, in 1998, 137 of them conducted R&D activities (Iwasa and Odagiri 2004). Among those, 77% had support laboratories and 23% research laboratories. In the sample of 130 German R&D foreign R&D units surveyed by Ambos (2005) in 2000, a slightly higher proportion of capability augmenting facilities (30%) has been identified. The number of GRLs has probably recently increased with the development and diversification of global innovation networks, but they should remain a minority among foreign R&D units.

2.2.3 *The global development center (GDC)*

Global development centers are in charge of R&D tasks that can be separated and plugged back into the innovation process of the multinational. They are typically in charge of back-office tasks[2], such as specific studies, tests or software writing. These new foreign units correspond to the increasing pressure on the cost of R&D and the cost-efficiency ratio is thus the main determinant of their location. India may be the country where this type of R&D centers is the most developed and some consider that the country could become a global R&D hub (EIU 2004; Wharton 2005). Some new EU member states and Russia may also develop as R&D platforms (Kalotay 2005). New R&D activities are rapidly expanding in China, but the main drivers here seem to be foreign production and expanding local markets rather than access to low cost knowledge workers (Zedtwitz 2004). Some units may nevertheless combine global and local development activities.

Initially, GDCs correspond to the relocation of a subset of R&D activities from the home country to a lower cost country. They may however progressively upgrade from subcontracting to more autonomous and sophisticated tasks. Their contribution may also not be limited to reducing costs, but can also allow the company to speed up development by involving more human resources or work around the clock. GDCs are difficult to classify as either home-based exploiting or home-based augmenting R&D units. At first they tend to focus on subcontracting type of tasks and have no specific contribution to the home-based capabilities. More complex arrangements are nevertheless developing, which include cooperation of foreign firms with local academic institutes.

2.2.4 Global differentiated innovation networks

Multinationals tend to integrate the three types of R&D units within global networks. As mentioned above, one general feature of these networks is that LDCs are the most numerous and geographically dispersed. Moreover, as emerging countries mostly attract development units (LDCs and GDCs), they focus on activities with which the parent company are quite familiar. A recent survey on multinationals confirms that R&D employees in foreign locations focus on familiar types of research in emerging countries, while they tend to work much more on new research areas in advanced countries (Thursby and Thursby 2006). Apart from that, the existence of several GRLs and the exact role of GDCs will vary greatly. First, technology sourcing will depend on the technology intensity of the sector; low- and mid-technology sectors tend to keep a relatively more centralized and production-driven R&D organization than high-tech sectors. Second the location of GRLs depends on the world distribution of frontier research in each sector or scientific field. Third, the specific organization of multinationals may also differ within sectors, depending on their country of origin, strategy and international experience (Bartlett and Ghoshal 1989; Reger 2001; Zedtwitz and Gassmann 2002).

Finally, the overall extent and organization of global innovation networks also depend on the two complementary channels of internationalization: outsourcing and R&D partnerships. The rationale for outsourcing of R&D may be compared to that of GDCs. R&D partnerships are more diverse and can be used for various purposes from economies of scale to technology sourcing or standardization. Moreover, they take place both between foreign partners and the affiliates in the host country, and directly between the foreign partners and the parent company.

[2] Valeo, the automobile supplier, distinguishes among its R&D activities, *front-office*, in contact with customers, *back office* and *core activities* (Devauchelle 2006). Front-office activities correspond to the *LDCs* and *core activities* to GRLs.

		Attractive local characteristics	
		of scientific and technological supply	of demand
Type of R&D units	Local development centre	Quality of training (engineers, technicians...) and local technological infrastructure	**Large local market (size, purchasing power)**
	Global research laboratory	**Excellence centers, good relationships between research and industry**	Lead market
	Global development centre	**Good cost/efficiency ratio for some R&D activities** Protection of intellectual property	-

Fig. 2 Determinants of the location of foreign R&D units, by type. The main determinants of location for each type of R&D unit are in bold characters

Our typology and the discussion of global innovation networks show that the distinction between home-based exploiting and home-based augmenting foreign R&D units can not account for the diversity of the drivers of internationalization. The global organization of R&D becomes more comparable to that of production, with various types of foreign units aimed at both penetrating markets and fine tuning the value added chain.

3 The attractiveness of local economies for R&D activities

This second part uses our typology to analyze the recent evolution of the location of R&D. It shows that countries are unequally attractive for R&D and draws policy implications.

3.1 Site selection by type of R&D unit

Figure 2 shows the determinants of location for each type of R&D activity. For each type of R&D unit, it indicates the major determinant of location (in bold characters), as well as other attractive features of the host country. The quality of the scientific and technological environment always has a positive influence on the location of foreign R&D. The specific contribution of the typology is to be more precise about which characteristics may be more important for each type of activity. Figure 2 stresses the paramount role of demand for LDCs, and its complementary role for GRLs. For GRLs, the quality of the scientific environment has to be combined with an easy access to local innovation resources.[3]

Based on Fig. 2, we can make a number of hypotheses with respect to the main location of each type of R&D center. Being attracted by the development of production, new LDCs will be located in dynamic markets. As emerging markets are driving global demand, new production sites and LDCs are increasingly located in emerging countries, in particular in

[3] Based on patent data between 1969 and 1995 Cantwell and Kosmopolou (2002) suggest that technologically strong local companies can inhibit foreign R&D investment in their industry. This result may depend on the characteristics of the national system of innovation and the degree of competition on the local market.

Asia and new EU members. As a result, even if the stock of LDCs is high in advanced countries, new centers should be increasingly located in emerging countries.

GRLs should be concentrated in advanced countries. Based on a statistical analysis of the patents delivered to Japanese companies, Iwasa and Odagiri (2004) have shown that the type of R&D activity they conduct in the United States depends on their location: research units that patent tend to be concentrated in dense scientific areas, while units that merely support local production are more scattered. In Europe, GRLs should be concentrated in the countries that exhibit the strongest technological record in each sector.

GDCs should on the contrary be concentrated in the emerging countries where there are large pools of low-cost scientific and technical knowledge workers. GDCs are probably most developed in the electronics and telecommunication sectors and mainly located in Asian countries. In Europe, GDCs should develop mainly in some Central and Eastern European countries. In the future, the development of protection of intellectual property in emerging countries should reinforce their attractiveness as R&D locations, in particular in high tech sectors or upstream activities (Thursby and Thursby 2006).

Table 1 has been calculated from the FDI-RD data base of foreign R&D projects in Europe to check these hypotheses on the location of R&D centers. The data base uses the R&D section of the foreign investment projects database maintained by AFII[4] and adds company information on each case in order to classify them according to our typology.

Table 1 shows that our hypotheses on the location of the three types of R&D units are quite well supported by the data. LDCs are the most numerous in all sectors and represent 59% of the total sample. They are more numerous in high wage countries (and particularly in large markets). Eastern European countries nevertheless also attract some LDCs. It should be noticed that the R&D units located in low wage countries tend to be very recent and more numerous in the last 2 years. GRLs are less numerous and represent 23% of the total. Most of them are located in high wage countries: Eastern Europe only hosts a GRL in pharmaceuticals.

East European countries attract a relatively larger share of the GDCs, which represent 18% of the total number of R&D units. This is the case in particular in automobile equipment, electrical and electronic equipment and software. The GDCs located in high wage countries are concentrated in Spain, Portugal, Ireland or Austria, depending on the sector.

Large European countries tend to attract a relatively high number of GRLs, especially in their sectors of specialization. Germany appears particularly attractive in the automobile industry—for carmakers as well as suppliers. However, the 4-year-period applied in this study is too short to have a large enough sample and compare the attractiveness of large European countries for GRLs in different sectors. Overall, Western Europe has attracted a large majority of the foreign R&D units at the beginning of the 2000s, but there has been an increasing flow of new R&D locations in the new member states, especially GDCs and to a lesser extent LDCs.

3.2 Europe's weakening position in global innovation networks

Figure 2 suggests that countries with low growth will attract less new LDCs than countries with dynamic growth and increasing production. Indeed, low growth European countries

[4] *Agence Française pour les Investissements Internationaux.* Hatem (2006) gives a presentation of the data base, which includes FDI projects located in Europe from all countries of origin. A project may be a new foreign unit or an extension. Sachwald and Chassagneux (2007) further presents the FDI-RD data base.

Table 1 Location of R&D FDI projects in Europe, number of by type of R&D units 2002–2005

Countries of location in Europe	Local Development Center[a]	Global Research Laboratory	Global Development Center	Total
Automobile	35	9	12	56
Car manufacturing	13	6	4	23
High wage[b]	12	6	1	19
Low wage[c]	1	0	3	4
Car components	22	3	8	33
High wage	20	3	0	23
Low wage	2	0	8	10
Pharmaceuticals	31	27	12	71
High wage	28	26	12	66
Low wage	4	1	0	5
Chemicals–Plastics	14	6	3	23
High wage	14	6	2	22
Low wage	0	0	1	1
Electrical, electronic and medical eq.	45	10	10	65
High wage	40	10	8	58
Low wage	5	0	2	7
Electronic components	27	10	8	45
High wage	27	10	4	41
Low wage	0	0	4	4
Software	48	15	17	80
High wage	43	15	5	63
Low wage	5	0	12	17
All industries	200	77	62	339
High wage	184	76	32	292
Low wage	16	1	30	47

[a] Local in Europe may be regional as the center may aim at Europe rather than at the host country only

[b] EU15, Switzerland

[c] Other EU27 countries, except for Malta and Cyprus

Source: Sachwald and Chassagneux (2007)

attract relatively less new LDCs than high growth emerging countries with dynamic tertiary education like China. Recent surveys suggest that this trend will last for the years to come (EIU 2004; UNCTAD 2005; Thursby and Thursby 2006). Europe is also less attractive than the United States. At the beginning of the 2000s, despite an equivalent stock of transatlantic FDI on both sides, R&D expenses by European multinationals in the U.S. were about a third higher than American expenses in Europe (NSF 2004). Between 1997 and 2002, R&D expenses of European affiliates in the U.S. have increased by 54%, while expenses of American affiliates in the EU increased by 38% (EU 2005). Qualitative data suggest that this unbalance is due to more foreign expenses in LDCs located in the United States because of the growth differential and specialization profiles. The greater presence of GRLs, due to the characteristics of the American innovation system, also contributes to this unbalance.

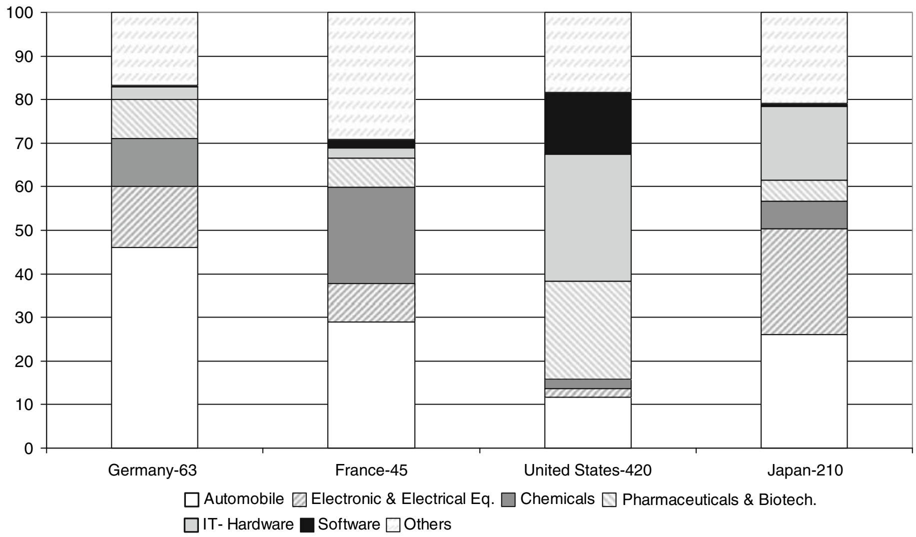

Fig. 3 Distribution of R&D expenses by the 1,000 first R&D corporate budgets, 2005. Note: "Others" include in particular aerospace and defense R&D expenses, 'important in the case of France. The number of companies taken into account is indicated for each country and the proportions are consistent with national data for less disaggregated sectors. Source: Author's calculations from DTI (2005)

As the United States are more specialized in high tech sectors (Miotti and Sachwald 2004), both production and R&D expenses are more concentrated in high tech sectors. This may be illustrated by Fig. 3, which shows the distribution of corporate R&D expenses for the largest firms. It clearly shows the concentration of R&D in mid-high tech sectors for France and Germany whereas in the U.S. R&D expenses are concentrated in pharmaceuticals and IT. As a consequence, FDI tends to flow to high tech sectors and be more intensive in R&D than foreign operations in Europe. This bias in favor of high tech sectors in American corporate R&D actually reflects a broader orientation of the U.S. innovation system towards health technologies and information technologies. The U.S. also spends considerably more on service-sector R&D than the European countries, with the exception of Sweden and Denmark (OECD 2004; EU 2005).

Transatlantic and intra-European differences in R&D investment are reflected by similar disparities with regard to patent registration. Finland, Sweden and Germany file more international patents per million inhabitants than the US, which in turn outperforms the EU average. European countries file relatively few patents in the fields of the new technologies with the exception, of some Nordic countries (OECD 2004, 2005). Besides, American patents in high tech tend to be more frequently cited in other patents (Albert 1998). An analysis of scientific publications bears out these transatlantic divergences. The U.S. publishes 705 scientific articles per million inhabitants as against 556 for the EU15.[5] And the U.S. publications are of higher quality: they are cited more often in other scientific articles and the transatlantic gap is even more pronounced with the authors quoted most frequently (Dosi et al. 2005).[6] American publications have a larger quantitative and

[5] Data for 2001 (OECD 2004).

[6] Top 1% most cited publications.

qualitative edge in dynamic disciplines like computer science, biology or nanotechnologies, while European authors score relatively better in more traditional disciplines like physics, chemistry and astronomy. Overall, European scientific excellence is thus concentrated in fields linked to sectors where European countries have forged their traditional comparative advantages but seem to be lagging behind in newer fields, which correspond to emerging industrial and service activities. As a consequence, Europe is less attractive for R&D in high tech and dynamic sectors.

As mentioned above, both European and Japanese firms have been sourcing technology in the United States. Between the early 1990s and the early 2000s, the share of French patents for which at least one inventor is located in the U.S. has rapidly increased (Sachwald 2003). German firms (Ambos 2005) and European firms more generally (Meyer-Krahmer and Reger 1999) have experienced a similar evolution. This may be explained by the fact that EU firms have invested in high tech sectors that generate relatively more patents, but also by the fact that a proportion of their R&D units in the United States focus on research and technology sourcing rather than development and market adaptation. European firms have not only used greenfield investment and takeovers to source technology in the United States. Empirical studies have underscored the role played by transatlantic cooperation agreements and acquisitions in securing access to frontier research in the United States, especially in high tech sectors (Inkpen et al. 2000; Miotti and Sachwald 2003). Sector analyses have shown how European firms have combined different channels of technology sourcing in semiconductors (Hobday 1993), electronics more generally (Giarratana and Torrisi 2002) and biotechnology (Sharp et al. 1994).

The attractiveness of the United States for European R&D laboratories in the pharmaceutical sector illustrates both the supply and demand factors mentioned in Fig. 2. On the demand side, the size and profitability of the American market is a fundamental factor of attraction. The U.S. is the leading market, owing to high prices and the Americans' capacity to buy innovative drugs featuring high margins. Between 1999 and 2003 its market share for new molecules was 70%, while that of Europe had declined to 19% (Bouvy 2006). On the supply side, high public and private R&D combined with leading scientific resources in biotechnology attract research laboratories. As a result, the United States has become the leader both in terms of R&D input (46% of the world spending in 2004) and in terms of new molecules (43% of the world total in 2000–2004) (Bouvy 2006). European attractiveness for pharmaceutical R&D is also eroded by the growth in emerging countries, some of which attract an increasing share of clinical trials (Masson 2004).

3.3 Policy implications

Figure 4 draws on our framework to discuss the policy implications of global differentiated innovation networks.

Attracting more LDCs depends on the dynamism of the local market and not only on innovation policy. Healthy growth and an evolution of local specialization towards high tech and sophisticated service sectors will attract LDCs. As we saw, in the case of different European countries, this means a substantial evolution of their industrial profile, which is still marked by post-war growth in the mass production industries (Sapir et al. 2003; Miotti and Sachwald 2004). Moreover, higher education systems in several European countries remain better suited to the post-war catching-up phase than to innovation-based growth (Aghion and Cohen 2004; Jacobs and Ploeg 2005). Attracting more LDCs in Europe thus

		Relevant policies	
		Science & Technology Supply	Market characteristics
Type of R&D unit	Local Development Center	Improve the quality of higher education and life long training	**Stimulate growth and the evolution of specialization**
	Global Research Laboratory	**Promote strong high quality academic research, strong universities and centers of excellence**	Promote the development of lead markets (products or services)
	Global Development Center	**Improve the quality of tertiary education and the business environment (infrastructures, IP)**	-

Fig. 4 Policies to attract different types of R&D activities. Policies in bold are the most important for each case

depends on broad policies aiming at strengthening potential growth, rather than on policies that would specifically target foreign R&D.

GRLs are more directly attracted by excellent scientific and technological resources. As European R&D investments and outputs have tended to decrease relatively, adequate policy measures may seem straightforward. They have indeed been recommended by many studies and official reports, including the much debated Lisbon/Barcelona process launched in 2000. The above discussion nevertheless suggests that more focus should be put on two issues that are not always emphasized enough. Firstly, the quality of academic research, which is often considered world class despite indications that the European record has been slipping, especially in dynamic scientific areas. This should be related to the broader issue of the quality of universities and the promotion of centers of excellence. Secondly, the role of demand in stimulating innovation needs to be stressed. In a recent paper, Bhidé (2006) argues that "venturesome consumers" play a crucial role in the process of innovation and in the diffusion of new products and services. Rapid adoption of new products, processes and services is certainly a characteristic of the American economy. It has been extensively discussed in the case of information technologies in relation with the strong productivity growth since the mid-1990s. Corporate investment in ICT fell slightly when the dotcom bubble burst, but has risen again to substantially higher levels than in Europe (OECD 2004; Artus 2005). The role of early adoption and rapid diffusion is less often emphasized in the case of pharmaceuticals, but we have seen above that it plays an important role in the attractiveness of the United States for foreign R&D.

The attraction of GDCs depends both on the strengthening of technological and scientific capabilities in emerging countries, but also on the broader business environment, as in the case of FDI in general. GDCs rarely locate in EU countries (Sect. 2 mentioned a couple of cases). EU countries could nevertheless promote the development of more interactions with emerging countries in Europe and Asia to take advantage of their growing scientific and technological capabilities. As in the case of trade with emerging countries, this could contribute to the evolution of the specialization of European firms.

4 Conclusion

Global innovation networks have not developed as the sole result of the expansion of the multinationals and the need to adapt to foreign markets. Our typology emphasizes the differenciation of global innovation networks and takes into account the development of an international division of innovation processes in which a broader array of countries participate. Global innovation networks tend to become more comparable with production networks. Firms have a much broader capacity to access and combine knowledge from a variety of partners, including in particular universities, which focus on upstream research, and suppliers and customers, which contribute to both market and technical information.

The traditional contrast between the forces of centralization and the forces of dispersion of multinationals' R&D does not account for the changes under way. Companies progressively find ways of combining the need for some centralization of research with access to heterogeneous scientific and technological resources throughout the world.

Our typology was designed to study the interactions between different types of R&D activities and their location. It specifically takes into account the growing role of emerging countries in global R&D and innovation networks. Our discussion of GDCs suggests that these R&D units are evolving. In particular, they may take on more autonomous roles and combine with LDCs. The observation of foreign R&D in emerging countries should be a fertile research ground for the years to come.

Our typology has also been useful to discuss the position of Europe within global innovation networks. Europe loses attractiveness for both LDCs and GRLs. Since the late 1990s, policy discussions have emphasized the insufficient technology transfers between public research and corporate R&D. Hence, the promotion of such transfers and incentives to boost venture capital has become increasingly important. Our discussion is based on the characteristics of the different types of R&D and emphasizes two other issues. The first issue is that of the quality of scientific production, especially in emerging and dynamic disciplines. The European record may not be as strong as it is usually thought to be. This points to the need for stronger universities. The latter is actually also called for to face the needs of the knowledge economy more generally and keep up with the growing talent pool in emerging countries. The second important issue is that of the role of demand in promoting innovation and its diffusion. More dynamic demand for new products and services would be important to attract both LDCs and GRLs. This in turn would require evolutions in a number of regulations and attitudes, as suggested by the examples discussed in the paper and broader comparisons among OECD countries. Overall, our discussion points to broader policies than those usually considered as part of "innovation policies". To put it another way, policies to promote innovation should be better integrated with some other policy areas.

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