Multinational Enterprises and the Internationalization of R&D: Are There Intra-Firm R&D Networks?[+]

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Abstract

Using patent data, this paper attempts to add empirical evidence to the study of the internationalization of R&D by understanding the types of knowledge developed abroad by MNE and associating them to firm characteristics. The gathering of the results seems to put in doubt the existence of a intra-firm network stricto sensu. Foreign technological efforts seem to be associated with three very important features: internationalization of productive activity, technological diversification and duplication of competencies (that is, non-specialization). It seems therefore that the internationalization of R&D activities is a consequence of the globalization of production and the need to adapt production to clients in a scenario where home markets lose relative importance.

1 Introduction

The study of the process of internationalization of R&D activities by multinational enterprises (MNE) may be divided into two main approaches. The first approach attempts to explain the reasons why MNE decide to develop part of their technological activities abroad. Most empirical and theoretical studies work on arguments originated from the eclectic theory that justify the phenomenon combined with some macroeconomic elements related to the characteristics of the home and host countries of the MNE. According to this interpretation, MNE internationalize their R&D in response to three sets of factors: (i) MNE may have technological advantages or property advantages acquired in their home country; (ii) the host country may offer technological advantages that may be enjoyed by MNE; or (iii) there are advantages from the internalization of these activities over subcontracting or cooperation (Dunning, 1979).

1.1 Host Country Advantages

Reasons in favor of the identification of technological advantage associated with host country characteristics vary across different technological trajectories and may be divided into two main sets. Whenever the performance of R&D abroad is related to supply of technology related factors such as the technological excellency of host country’s R&D labs, qualification of scientists and engineers, access to financing of R&D, advantages of host country are associated with technology push factors (Wortmann 1990). If the advantages from executing R&D abroad are associated with the specification of demand characteristics that help the establishment of technological imperatives, host country advantages are related to demand pull factors (see the case of LCD products in Gerybadse and Reger 1999).

The explanation of advantages of internationalization of R&D acquired in their home countries emerge from Penrosian approaches to the theory of the firm. They may be associated with either the exploitation of firm specific competencies created from home country R&D in foreign markets (home base exploiting) or the pursue of additional knowledge in foreign countries in order to strengthen their technological base and secure long period survival. Therefore, two types of R&D efforts abroad may be sought: (i) exploitation of technical base developed in the home country with adaptation efforts, usually duplicating competencies (Zander 1998); or (ii) the search for complementary assets in order to identify possible future growth trajectories, extending product lines in cases where it is called specialized or diversified. The duplicative R&D is more likely to have adaptive character while the specialization in certain competencies should be associated with the search for more generic (basic) knowledge.

Summing up, depending on the main cause for internationalization of R&D efforts, the thematic may be centered on geographical patterns of diversification or duplication of technological efforts, whenever firms are exploiting host country’s technological advantages (Cantwell and Janne 1999, Gerybadse and Reger 1999); technological patterns of diversification or duplication of competencies, if the firm is attempting to exploit their own technological advantages accumulated at home country (Zander 1999); or both whenever both effects are present (Patel and Vega 1999).

1.2 Home Based Advantages

On the aspects related to technological advantages of firms, the literature aims at identifying different organizational modes, according to certain criteria relative to the technological competencies of MNE, the characteristics of the host country and the characteristics that technical progress may present in the main sector of the firm's activities. Effort is therefore directed to relating different modes of organization of R&D to the type of knowledge base developed by the firm, that is to the firm's technological competencies, to the characteristics of the product lines developed by the firm (for instance, the level of product diversification and differentiation), and to the type of R&D to be developed, that is, if efforts are directed to development, applied or basic R&D, or if it pursues foreign produced knowledge in order to adapt products and processes or to accumulation of new knowledge or tap into new technologies, or to the market where the firm intends to apply the knowledge gained from their foreign R&D efforts.

The traditional model stressed that the organization of R&D efforts should not be different from the organization of any other function executed by the MNE. The main proposition would then be that the dominant mode of organization would follow a center-periphery organization whereas the decision center would be located in the home country that would radiate instructions and coordinate activities taking place in business units abroad. Furthermore, the decision center would be in charge of selecting lines of investigation relevant to the firm's core-business and would usually be the unit that would carry out basic R&D and would transfer generic knowledge to periphery R&D units. Periphery R&D units in this model would be restricted to the performance of adaptive and applied R&D and the development of products. Results from the decision center may be transferred towards the other R&D centers, however periphery R&D should be directed totally or mostly to marketplaces where they are located. Knowledge flows should therefore be unidirectional from the parent to affiliates and technological efforts developed abroad should mainly duplicate competencies.

Nonetheless it seems to be enough evidence to speculate that this model has been through some changes. According to Gerybadze and Reger (1999), a new technological scenario has emerged redirecting the old center-periphery model into more decentralized modes of organization. Their arguments are based in:

(i) the appearance of new centers of excellency outside the USA, producing relevant knowledge;
(ii) the need for increasing interaction across productive, innovative and marketing activities carried out by the firm. This new developed has weakened the role of basic R&D that are not directed related to other activities performed by business enterprises;
(iii) the obstacles for financing basic R&D projects, increasing the interest for more applied R&D efforts outside the parent R&D center, due to the easiness to profit from their results;
(iv) the advantages from intervening in markets where the technologies follow different rates and directions (technological trajectories) when compared to home country's markets;
(v) the possibility to define technological imperatives and standards in those markets where there is lack of regulation;
(vi) the need to know rivals' strategies; and
(vii) the reduction in the costs of transference of knowledge due to new developments in the frontiers of information and telecommunication technologies.

These elements have lead scholars to attempt to identify different modes of organization of decentralized R&D. Most authors relate the idea of decentralization to networks, though the relation most times is not always clear. Networks are mostly regarded as:

(i) the presence of multiple units executing R&D with some degree of independence from the parent firm in respect to the definition of their own lines of research;
(ii) R&D is increasingly directed to applied knowledge;
(iii) the results may be directed to local users (local for local) but are mostly shared by the whole corporation (local for global). This characteristic demands a management system able to capture innovations produced by affiliates and to overcome communication, cultural and geographical obstacles (Zander 1998).

Not necessarily the presence of greater independence levels from the parent implies the total loss of previous hierarchical structure, but it should require a redefinition of function across subsidiaries and parent labs. The decision center should maintain the coordination of innovative activity performed by foreign units and may still be responsible for the flow of information across affiliates' boundaries at low costs. The type of competence developed outside the home country may vary according to the leadership of the MNE in its sector of activity, the level of technological opportunity in the sector of activity and the leadership of the host country in the technology being exploited abroad.

However, the arguments in favor of new modes of organization of international R&D are not exempt of criticisms. There are limits to intra-firm transfer of knowledge across decentralized units because:

(i) the easiness of transference will depend on the level of codification (or should be negatively related to the tacit character of knowledge). Due to the fact that most types of knowledge are costly to transfer, that innovative efforts require information from different stages of the productive process, and that investigation should be directed to the solution of operational problems inside a firm's general strategy, there should be a tendency for most departments to be closely in touch with the decision centers in the home country. This may explain the great level of centrality of R&D expenditures until our days (Caves 1996:164);

(ii) business units should have capacity to absorb externally produced knowledge, that is, they should be able to understand problems posed by other R&D labs and to apply the solutions proposed. In order to do that, they should have developed some knowledge associated with the problems being developed by foreign or other units' R&D labs;

(iii) furthermore, knowledge may be specific to the problems of the unit where it is developed. Therefore, even in the cases where there is absorptive capacity and knowledge transferability, there should be common use of the knowledge, that is, the transference of knowledge across units requires the possession of complementary assets (Coombs 1996);

(iv) the closer the knowledge produced is to application, the greater the level of specificity of the search process, and therefore the harder it should be to transfer. Thus there should be a trade-off in the organization model, since the phenomena that have caused the shift towards independence form decision centers have created further obstacles for the transference of the knowledge produced as well;

(v) even when there are complementary assets some failures in the channels of transmission of information may cause problems in the management of networks.

These arguments show that if, on the one hand, the transformations in technology lead to greater decentralization of R&D that may assume network modes of organization, on the other hand, they may end up in a model of total decentralization, with no coordination across business or R&D units. This work attempts to add empirical evidence to the study of this trade-off by understanding the types of knowledge developed abroad and associating them to firm characteristics by analyzing two subjects: (i) the type of R&D developed abroad in relation to the R&D undertaken by MNE in their home countries, emphasizing the level of specialization of foreign R&D and the location of the R&D efforts undertaken abroad in the firm's technology base; and (ii) the assessment of the importance of the main characteristics of MNE according to the type of their internationalization of R&D.

On the Concept of Networks and Other Modes of Organization

According to the above arguments, one may characterize the new organization modes of R&D by three main features: (i) the level of internationalization of technological activity; and (ii) the degree to which knowledge developed elsewhere may be transferred and absorbed, which depends on the degree of complementarity and dissimilarity of the technological activities taking place in different units. Each of these features should be detailed in order to have a precise idea of their meaning and their role in the establishment of distinguished organizational modes.

The level of internationalization of technological activity

High levels of geographical dispersion of technological activity should first characterize the international decentralization of R&D. It is here hypothesized that big corporations that execute little R&D efforts abroad have centralized types of R&D, responding to the traditional center-periphery model. It is worth to highlight that empirical evidence has shown that, though the level of internationalization of R&D activities has increased recently, it is still quite inferior to the level of productive internationalization. Dunning (1994) has proved from a sample of 792 corporations that, in 1982, the rate of internationalization of R&D was around 12%, against 30% of productive internationalization. The rate for R&D internationalization showed a greater level for European based multinationals (23%) than for US (9%) and Japanese firms. Sectors with higher rate of internationalization of R&D were mechanical engineering, computers, motor vehicles, food and other manufacturing. The sample of 113 US corporations used in this paper, using patents filed in the US, shows an internationalization level of R&D around 21% and a level of international employment around 41%. Patel (1995) shows furthermore that only 43 out of 569 MNE in his sample had over 50% of their technological activity located abroad. Furthermore, only small countries had firms executing a large proportion of their R&D efforts abroad (Belgium and the Netherlands). Firms with greater level of internationalization of R&D belonged to food, drink & tobacco, building materials, other transports, pharmaceutical and mineral industries. With the exception of pharmaceuticals, those are sectors that are not characterized by high level of R&D expenditures. Patel (1995) concludes that mostly firms that have directed great technological efforts outside their home countries are usually performing adaptive R&D to local tastes and needs, adapting products to regulation requirements or (in the case of minerals) to exploit local natural resources. On the other hand, in high technology industries, such as computers, aircraft, instruments and electrical equipment the role played by R&D, on one side, and design, on the other side, are associated to the creation of new products and geographical closeness seems to play a more important role.

The internationalization of R&D seems to have more importance in leading companies in each sector of activity (Dunning 1994, Cantwell 1995 and Cantwell and Janne 1999). The theoretical arguments that sustain this fact seem to state that leading firms are more likely to have greater absorptive capacity, greater level of productive and technological diversification and a greater capability to manage resources, being more capable to identify new advances and applications, to extend their core businesses and to find use for the results of their research. Leading firms should then be more likely to work in network modes of organization of R&D.

Transference of knowledge and organizational modes of international R&D

The elements that characterize the new organizational network paradigm are the decentralization and specialization of R&D units, allowing the performance of R&D outside home country's boundaries and acting as an antithesis to the traditional model characterized by the centralization of R&D activities. Following Zander (1998, 1999), the duplication of competencies would be associated with more centralized modes of organizational of the multinational's R&D activities. This would be a consequence of the presence of one sole unit responsible for the production of basic knowledge. Therefore, the transference of knowledge across intra-firm R&D units could only occur in the cases where the periphery units are using knowledge produced by the center or when they are using the basic knowledge produced by the center to produce innovations in more concrete problems. In both cases, it is likely that technological efforts of the R&D units maintain great similarity to the center's efforts.

On the contrary, network modes of organization are associated with specialization of competencies. Networks are associated with complementarity of the efforts of the member units, that is, if the production of one asset of a member of the network is incremented, the production of other members' assets should also be incremented (Foray 1991). However, in order to secure information flows, apart from being complementary, assets produced by different members should not be the same, that is, some degree of dissimilarity should be expect to hold (Richardson 1972). This should be explained because if assets produced by different members are the same, there should be an apparent reason for not producing it in one sole unit, since transference costs of knowledge should be quite high due to the specific character of knowledge. From this, if a network mode of organization should hold, some level of specialization across R&D units should be expected to arise.

Nonetheless, duplication of competencies in different units of the network may still play an important role in the new modes of organization. It should be stressed that some works on the subject point to the importance of duplication of competencies in a network-model. Zander (1998, 1999) emphasize the importance of competence duplication, even in the cases where MNE internationalize most of their R&D. This result was also obtained by Rocha and Urraca (1998). Some arguments may be posed for the duplication of efforts in intra-firm R&D networks:

(i) in order to absorb externally produced knowledge, a unit should be able to understand, implement, use and develop that knowledge. In order to undertake these tasks, the performance of some research in these areas should be necessary (Cohen and Levinthal 1989). It should then be expected to occur some overlapping between technical fields exploited abroad and technical fields exploited at home;

(ii) some R&D may be undertaken abroad in order to tap new developments in the frontiers of technical progress in foreign countries. This line of investigation should be more likely to occur in the technical fields most important for the MNE, that is, in the technical fields where the MNE holds core-distinctive competencies. Duplication of R&D efforts should then arise. In this case, there is still network coordination due to the necessity to transfer technology across firms' boundaries.

These arguments show that in the new model there may exist specialization of R&D units as well as duplication of competencies. Zander (1999:198) states that “internationally duplicated firms include those which have strengthened their technological capabilities in foreign locations, but where foreign units are typically involved in the same kind of technologies which are represented at home. This international duplication of technological capabilities may have resulted from technology transfer to foreign units, which have kept and further developed the received technological knowledge.” At the same time, this may be a result of foreign acquisition of enterprises and therefore may still suffer modifications.

Another element in favor of the duplication of technological efforts in more decentralized modes of organization refers to the capacity of transference of knowledge that will depend on the degree of knowledge codification, that is, on the inverse of its tacit character. Knowledge should be more tacit the greater its proximity to direct application in production processes. The duplication of technology may therefore be a consequence of the inability of MNE to transfer knowledge across subsidiaries due to the high level of applicability of the knowledge produced (Coombs 1996). In this case, the undertaking of foreign R&D will not be related to the transference of knowledge due to the local character of knowledge. This type of R&D would resemble Patel (1995) in that it would be related to adaptive R&D. Therefore, only in those cases where the R&D activity is home-base augmenting, the type of R&D would lose its adaptive character and periphery units may achieve results of generic character that may be used by other units in the corporation. However, including those cases, there should be a reasonable degree of overlapping of technology. Thus, units may transfer and absorb knowledge produced by other members.

The duplicative or specialized character of the competencies developed abroad calls attention to the role played by foreign technological efforts in the firm’s competencies. As has been stated above, the function to develop the core competencies of the firm, in the center-periphery paradigm, was left to the center. R&D units located abroad were expected to develop some minor adaptive innovations, directed to local applications, using mostly core competencies developed in their home base. The role of foreign R&D units in the competence building of multinational corporations in more decentralized modes of organization is however unclear. This is related to the type of network that will be formed. Some corporations may leave their home base as the sole responsible for competence formation, while others may distribute the responsibility for the formation of their core-competencies across R&D units. At the same time, some foreign R&D units may be specialized in niche competencies.

1. Methodology

1.1 The Database

This paper uses patent information to measure the level and direction of internationalization of R&D efforts by multinational enterprises. It uses information from patents filed by 115 US MNE and their subsidiaries at the European Patent Office (EPO) between 1986 and 1999. From the 115 MNE in our sample, 106 are listed among the top 500 R&D performers in the US for the year 1997, according to the US Corporate R&D Survey of the National Science Foundation. Together, these 106 enterprises responded for about US$ 77 billion in R&D expenditures in 1997 (75,5% of total R&D expenditures by the top 500 R&D performers). The 115 firms have filed 57296 patents that were analyzed by EPO from November 1986 to May 1999, that is, around 9% of the total patents filed in the EPO in the period (see table 1). The firm with less overall patents was BW Holdings (46 patents) while the firm with most patents was IBM (4737 patents).

2 Table 1 – Sectoral Distribution of Firms in the Sample

Sector	Total	Patents	International Patents	Number of Firms Among 500 Greatest R&D Performers in the US	R&D Expenditures (US$ Millions
Aircraft	7	1962	211	7	5010
Building Materials	3	320	52	3	351
Chemicals	17	6691	1946	16	4592
Computers	7	7961	1774	7	11706
Drugs	10	8193	2158	10	15053
Electronic and electrical equip.	16	12253	1869	15	12220
Food and kindred products	5	594	177	2	603
Instruments	7	6126	740	6	2951
Lumber and Wood products	1	141	41	1	232

Machinery	9	2277	813	9	2342
Metals	6	612	213	5	535
Paper and Allied products	4	2448	364	4	1355
Petroleum	9	2844	696	8	1661
Rubber and Plastic products	3	454	101	2	413
Transportation Equipment	11	4420	1355	11	18459
Total	115	57296	12510	106	77482

Source: Own elaboration from EPO Espace Bulletin Information CD-ROM, Nov. 1986 to May 1999 and US Corporate R&D

The use of patents as indicators for R&D activities have their virtues and shortcomings and we refer to the literature for any further interest. It is however important to clarify the adequacy of using patent statistics from EPO to measure the level of R&D internationalization of US firms. The first argument against this procedure would be that the data should be biased towards R&D executed in Europe. In fact, when comparing with statistics from previous papers (Patel 1995 and Cantwell 1995), it can be seen that the level of internationalization of R&D activities of US firms is much greater when we use EPO's statistics. Analyzing the patenting activity in the USPTO for about 250 US firms from 1985 to 1990, Patel (1995) finds that 7.8% of total patenting was due to innovative efforts whose inventors reside abroad; Cantwell's (1995) sample for 1969 to 1990 shows a 6.8% of patenting of US firms with inventors residing above. Our sample of 116 US firms shows that 21,8% of total patenting in EPO had inventors residing outside the US. Nevertheless, it should be stressed that EPO may be biased towards European technological efforts as well as USPTO may be biased towards US inventors. Therefore, if, on the one hand, the EPO may overestimate the share of foreign inventors in US MNE, on the other hand, USPTO may underestimate their participation. However, as pointed out by Grupp and Schomach (1999:385), patent applications in EPO are quasi automatically a second application for a patent. Usually, the priority application is done in the home country of the inventor. Furthermore, the filing of a patent at EPO has a quite high cost when compared to other patent offices. In this sense, it is a narrower economic filter for both US and European inventors and therefore should be able to provide more homogeneous statistics.

3 Table 2 – OLS Regressions

	(1)***	(2) ***	(3)***
Constant	1.6721**	2.2074***	2.2588***
	(2.222)	(5.416)	(4.934)
Lnsales	0.88258E-01		
	(0.847)		
ln R&D	0.44943***	0.50414***	0.53079***
	(5.218)	(8.868)	(7.500)
ln % Foreign Employment	0.20394**	0.19244**	0.18844*
	(2.424)	(2.322)	(1.980)
F	30.76	45.92	8.72
Adjusted R-square	0.48446	0.48603	0.51387
N	96	96	96

t-statistics in parenthesis
*Significant at 10%
**Significant at 5%
***Significant at 0,001%

Second, it may be argued that patenting activity in EPO is not representative of US firms' R&D activities. A few arguments may be drawn to support the use of EPO statistics. On the one hand, US residents inventors are the most active in EPO. They account for 28.6% of total patenting in EPO, against 20.6% of German, 8.3% of French and 6.1% of British residents. On the other hand, when we regress EPO'S US firms' patenting activity against R&D efforts by these US firms, the results fit very well. Equations (1), (2) and (3) use ln of total patents as the dependent variable. In equation (3), the results are controlled by sector. As it can be seen, all equations fit very well and ln R&D is positive and significant at 0,001% level. These results suggest that EPO's statistics are a good indicator of R&D activities of US firms.

Patents were selected by the name of the applicant. We used Dun and Bradstreet's paper edition of Who Owns Whom 1996 and CD-ROM edition of Who Owns Whom 2000, version 3, to identify the firms' subsidiaries. Patents were considered as indicators of international R&D efforts whenever there was ***at least*** one inventor resident outside the US. This criterion biases the data towards international efforts since a great deal of patents had inventors resident in more than one country.

Patents were classified by the 21 subsection of the International Patent Classification (IPC). Each subsection was defined as a technical field. The distribution across technical fields are understood to define a firm's competencies profile. This kind of work has been used before by Patel and Pavitt (1997), Cantwell (1995), among others.

Data on firm characteristics were obtained from Who Owns Whom 2000 CD-ROM version 3. The ratio of employment in foreign subsidiaries to total employment for the MNE was used as an indicator of the level of internationalization of the MNE. Level of productive diversification was estimated by the inverse of the Herfindhal-Hirschman index for the distribution of employment at US SIC 4-digit level as classified by Who Owns Whom. R&D data were collected from National Science Foundation *US Corporate R&D, volume 2, Company Information on Top 500 Firms on R&D*, for the year 1997.

1.2 Indicators and Taxonomy

From the gathered patent information, some indicators were elaborated. To estimate the firm's rate of internationalization of R&D efforts we defined by $IRD_F = \frac{PN_F}{TP_F}$, where PN_F are patents filed by firm F with at least one non-US resident inventor and TP_F are total patents filed by firm F.

Furthermore, we classified the firms according to the level of specialization of their international technological efforts, vis-a-vis their total technological efforts. This was done by the creation of two indicators. At the level of technical field (IPC subsection), we calculated s_i^F represented by the ratio of patents filed at the subsection i of IPC by firm F to the total patents filed by firm F; $s_i^{I,F}$ represented by the ratio of patents filed at the subsection i of IPC by firm F with at least one inventor non-resident in the US to the total patents filed by firm F with at least one inventor non-resident in the US. From the ratio of $s_i^{I,F}$ to s_i^F we calculated the first indicator, $ISC_i = \frac{s_i^{I,F}}{s_i^F}$ where ISC_i is the international specialization coefficient of technical field "i" at firm F. The second indicator is the weighted international specialization index, represented by $WISI_F = \sum_{i=1}^{n} \left(ISC_i s_i^{I,F}\right)^2$. This indicator will have value 1 if the distribution of technical fields of international research is exactly the same as the distribution of technical fields of total research of the firm, that is, if international R&D perfectly ***duplicates*** home produce R&D, and will be greater, the greater the difference between the two, that is, if there is some ***specialization*** of international R&D.

Firms' technological competencies have been studied by Patel and Pavitt (1997). They have adopted a taxonomy for assessing a firms' competencies in a technical field. Firms' competencies were evaluated according to the level of firm specialization on it, that is, the firm's revealed technological advantage represented by $RTA_i^F = \frac{s_i^F}{s_i^{EPO}}$, where s_i^{EPO} is the ratio of patents filed at EPO at the subsection of IPC to the total patents filed at EPO and the participation of the patents of that technical field in the total patenting activity of the firm s_i^F. If RTA is superior to 2,0 this technical field is considered to be a distinctive competence of the firm; if s_i^F>5%, it is considered a core competence of the firm. Whenever RTA is superior to 2,0 and the share of total patents in that technical field is greater than 5%, the technical field is considered a ***core-distinctive*** competence of the firm; when RTA> 2,0 and s_i^F<5%, it is considered a ***niche-distinctive*** competence, when 0,5<RTA<2,0 and s_i^F> 5%, it is considered a ***core-background*** competence; and when 0,5<RTA<2,0 and s_i^F<5%, it is considered a ***marginal*** competence.

2. Results

3.1. Sectoral Level Analysis

Table 3 shows the level of internationalization of R&D efforts (IRD) and the level of its specialization (WISI) across sectors. The arithmetic average IRD_F was 23.0% with a standard deviation of 20.65%. The highest IRD_F was obtained by Sara Lee (90.63%) against 0% in the lower bound for Brunswick and Clorox. The results do not differ much from those previously obtained by

Patel (1995). In general, it can be said that more traditional (low R&D expenditure) sectors, such as food and kindred goods, metalsand rubber and plastics are among the sectors with highest R&D internationalization levels. The only exception of high technology sectors with high level of R&D internationalization is motor vehicles. Furthermore, four of the five top R&D intensive sectors are among the five sectors with lower R&D expenditures. This may be an indication that foreign R&D may still be a consequence of the need for product adaptation due to differences in tastes (food and kinkred goods) and needs (machinery) and the adaptation to the supply characteristics of foreign raw materials (metals). It seems then that in more technology intensive sectors, the greater interaction between R&D and design efforts stress the importance of geographical proximity in R&D performance at the same time that the prevalence of global products where regional tastes play a minor role reduce the relevance of local R&D.

Table 4 analyzes the distribution of MNE's international technological efforts according to their location in the main core competencies of the firm. A technical field was considered to be duplicated whenever ISC_i was inferior to 1,5 and superior to 0,5. If this index was inferior to 0,5, the technical field was considered a home country specialization, if it was superior to 1,5 it was considered international specialization. At the same time, technical fields were classified according to Patel and Pavitt (1997) taxonomy of firms' competencies, with the only exception that marginal competencies and technical fields outside the firm's competencies were counted together.

First, it should be stressed that most international technological efforts are located in those sectors where firms hold core-distinctive competencies (67%) and only a very small proportion of international technological efforts are located outside the firm's competencies and/or in technical fields where the MNE show a home country strong specialization (11%). Second, most international technological efforts of MNE were located in technical fields where the MNE duplicated their technological competencies. The intersection set of core-distinctive and duplicated competencies covers 52% of the total patenting by the MNE in the sample. Most firms that perform international R&D efforts had some of this effort located in the technical fields where they held core-distinctive competencies (97 out of 112).

3.1.1.1.1 Table 3 – Sectoral internationalization rate and weight internationalization specialization index

	N	R&D/ Sales (1997)	IRD Mean	IRD STD	IRD Max	IRD Min	WISI Mean	WISI STD	WISI Max	WISI Min
Metals[1]	7	1.1	33.9	25.3	76.6	0.0	1.3	0.7	2.2	0.0
Machinery	9	3.0	32.8	18.2	62.9	12.9	1.4	0.3	2.0	1.1
Rubber and Plastics	3	1.4	28.9	34.3	67.1	1.0	7.2	10.4	19.2	1.1
Food and Kindred products	5	0.5	31.2	34.6	90.6	1.7	5.2	8.1	19.7	1.0
Drugs	10	10.5	22.7	12.5	41.5	6.7	1.2	0.3	2.0	1.0
Transportation equipment	11	3.8	26.2	25.9	68.8	0.0	3.1	5.7	20.2	0.0
Petroleum	9	0.6	21.5	23.1	60.2	1.7	1.2	0.1	1.4	1.0
Chemicals	17	3.5	22.4	17.3	72.9	0.0	1.4	0.7	3.5	0.0
Paper and Wood[2]	5	1.0	25.1	15.2	46.2	6.8	1.8	0.7	3.0	1.1
Electronic and electrical equipment	15	5.7	25.0	25.7	85.7	2.3	2.5	3.7	14.7	1.0
Building Materials	3	1.8	18.4	8.5	28.3	10.6	1.5	0.1	1.6	1.5
Computers	7	9.2	11.8	9.9	25.5	3.1	1.9	1.1	4.0	1.0
Aircraft	7	3.9	9.6	9.8	23.9	0.3	3.0	1.7	5.8	1.4
Instruments	7	7.7	10.5	7.5	20.7	1.0	2.2	2.2	7.2	1.2
TOTAL	115	2.9	23.0	20.6	90.6	0.0	2.2	3.3	20.2	0.0

Source: Data on International R&D and WISI was obtained from patent statistics by elaboration from EPO Espace Bulletin Information CD-ROM, Nov. 1986 to May 1999. Data on R&D was obtained from National Science Foundation, *Research and Development in Industry: 1998*, NSF, 2000, archive obtained in pdf from www.nsf.gov..
[1] Arithmetic average of Primary and Fabricated Metals R&D/Sales rate.
[2] Arithmetic average of Paper and Allied Products and Lumber, Wood and Furniture R&D/Sales rate.

These findings confirm Zander (1998) on the prevalence of duplicative efforts in the process of internationalization of R&D. Furthermore, they show that this duplication occurs in the technical fields where firms hold core-distinctive competencies. This distribution of foreign technological efforts seem to be associated with two different types of configuration of intra-firm networks:

(i) to the traditional center-periphery model, where foreign R&D is mainly adaptive;
(ii) to new modes of organization where the production of competencies may be decentralized but due to obstacles in the transference of knowledge, there is an increasing need for developing similar competencies in order to achieve absorptive

capacity.
(i)

Table 4 – Duplicative and Specialization of International R&D According to the Type of Competence Developed, Sectoral Distribution

In almost 27% of the cases, international R&D efforts are specialized. In this case, an important regularity may be obtained from table 4. First, only five sectors have over 20% of their international technological efforts located in internationally specialized core-distinctive competencies – aircraft, building materials, food & kindred goods, metals and paper & lumber – and only one sector had over 20% of its technological internationalized efforts specialized in core-background competencies. With the sole exception of aircraft, these are sectors with very low levels of R&D. Four out of these five sectors with high international specialization in core competencies are among the sectors with higher levels of internationalization and two of them – food and kindred goods and metals – present the highest WISI amongst the sectors in table 3.

3.2 Firm Level Analysis

Table 5 shows two regressions in tobit models that have the rate of internationalization of R&D activities as dependent variable. Equation (1) has total employment (EMP), R&D intensity (RDINT), foreign employment (FOREMP), level of productive diversification at 4-digit US-SIC, level of technological diversification (DIVTEC). In equation (2) the foreign employment to total employment ratio (INTEMP) substitutes for foreign employment. Some important results may be extracted from these two equations. First, it seems that the greater the internationalization of productive activities, the greater the level of internationalization of technological activities. This can be seen by the positive and significant sign of the FOREMP variable in equation (1). The INTEMP variable is positive and just misses the 10% level of significance in equation (2). This result may suggest that foreign R&D should be a consequence of the internationalization of productive activities. This may give support to the idea that foreign R&D assumes an adaptive character, since it may be argued that R&D activities associated with foreign direct investment in productive activities are more likely to nurture the needs of production and therefore be demand related. However, it still may be argued that location of productive facilities abroad may be a necessary condition to identify foreign technological potential. The second interesting finding from equations (1) and (2) is the positive and consistently significant sign of the technological diversification variable. This result seems to agree with Cantwell and Janne (1999) that technological diversified firms are more likely to perform international R&D. One possible explanation for this result is that it is quite difficult for any country to have strong research in every technical field. Therefore, firms that need access to a greater number of technical fields are more likely to exploit technologies in different countries. A second possible explanation is associated with the greater level of internationalization in those sectors of production where interaction with users is necessary. It is then possible that different competencies are developed in each affiliate, according to the need, tastes, institutional framework and type of raw material. As a consequence, competencies may be developed according to the need of the international affiliate. It is important to state that none of these results change when we control the equation by sector.

3.1.1.1.2 Table 4 - Regressions

	(1)	(2)	(3)
Dependent Variable	IRD	IRD	WISI
Constant	11.404*	7.9097	3.7708
	(1.920)	(1.235)	(4.333)
EMP	-0.83097E-04**	-0.18279E-04	-0.25042E-05
	(-2.101)	(0.50121)	(-0.443)
RDINT	0.33946	0.31207	-0.55720E-01
	(0.666)	(0.601)	(-0.782)
IRD			-0.16717***
			(-3.569)
$(IRD)^2$			0.16596E-02***
			(2.827)
FOREMP	0.15039E-03**		0.11580E-05
	(2.311)		(0.119)

INTEMP		0.93069E-01	
		(1.566)	
DIV4	-0.54500E-01	-0.71152E-01	
	(-0.389)	(-0.495)	
DIVTEC	3.2197***	3.1677***	0.26911
	(2.583)	(2.501)	(1.491)
N	92	92	96

z-values in parenthesis
*Significant at 10% level
**Significant at the 5% level
***Significant at the 1% level

Equation (3) refers to a tobit test, censored at 1, with $WISI_F = \sum_{i=1}^{n}\left(\frac{s_i^{I,F}}{s_i^F} s_i^{I,F}\right)^2$ as dependent variable. As stated above, this variable will obtain value 1 whenever technological efforts undertaken abroad are identical in their distribution by technical field to the technological efforts undertaken by the corporation as a whole. As the value of the indicator increases, international efforts increase their dissimilarity in relation to corporate efforts as a whole. If the value is very high, it may be said that international technological efforts achieve a quite high level of specialization, if the value is low it may be said that they duplicate technological efforts of the corporation. The only two significant independent variables in equation (3) are IRD and IRD's quadratic form $(IRD)^2$. The sign of IRD is negative and its quadratic form assumes a positive value, suggesting a convex form of the relationship between the variables. This relationship suggests that as firms get more internationalized their international efforts get more similar to their total efforts as a whole. This result has two possible explanations. First, there is a bias in the indicator, in order to avoid infinite values in certain technical fields, we used patents filed by foreign inventors in the denominator of the indicator as well. As a consequence, the importance of international technological efforts in total corporate efforts also increase and therefore it should be natural that it WISI gets a lower value. Second, it may be an indication that whatever mode of organization prevails, similarity in the exploitation of technical fields tend to prevail.

It should still be noted that the variable for technological diversification obtains a positive sign and just misses the 10% level of significance. This may suggest that the greater the level of technological diversification the more the firm would be specializing their technological efforts in different locations. This is in line with speculations about the behavior of technologically diversified firms in the international scenario (Cantwell and Janne 1999).

3. Conclusions

This paper has shown some evidence that may help understand the relation between the level of internationalization of R&D and the types of organization of R&D activities have been taking place in recent years. Aggregate results seem to show that the level of internationalization of R&D activities may be higher than believed and mostly they duplicate competencies already developed in the home country.

Sectoral level analyses find three important regularities:

(i) mostly internationalize R&D are characterized by low level of R&D expenditures and high requirements of adaptation of the product to the needs, tastes and institutional requirements of demand, that is, the results seem to suggest that R&D performed abroad is mainly adaptive;

(ii) sectors higher levels of specialized foreign R&D in core-distinctive competencies – a configuration that would be expected in a highly coordinated network with high level of specialization of R&D levels – are low level R&D performers;

(iii) three of the sectors with higher level of specialization of foreign R&D activities coincide with the sectors of higher R&D expenditures.

Results of the firm level analysis, show that:

(i) there is still a correlation between the level of R&D performed abroad and the level of internationalization of productive activities;

(ii) there is a very high correlation between the level of R&D activities and the level of technological diversification;

(iii) the level of specialization of foreign R&D activities is negatively associated with the level of internationalization of R&D activities, that is, mostly internationalized firms in R&D tend to duplicate their home based competencies;

The gathering of these results seems to put in doubt the existence of a intra-firm network stricto sensu. Foreign technological efforts seem to be associated with three very important features: internationalization of productive activity, technological diversification and duplication of competencies (that is, non-specialization). It seems therefore that the internationalization of R&D activities is a consequence of the globalization of production and the need to adapt production to clients in a scenario where home markets lose relative importance. One may speculate about technological diversification as a consequence of globalization and the need to serve diversified needs, tastes of consumers and user-producer specifications.

In respect to the organization of R&D, the results suggest that:

(i) the presence decentralized and specialized R&D units does not seem to be a rule. This type of organization prevail, on contrary to what was hypothesized above, in those sectors where demand-pull (Chesnais 1988) conditions seem to be more likely to prevail (Patel 1995). These sectors are also characterized by low levels of R&D and high levels of R&D internationalization; and

(ii) duplicative R&D occurs mainly in those technical fields where firms hold core-distinctive competencies. Furthermore, most firms that are associated with very low levels of specialization of R&D activities are located in sectors with very high levels of R&D expenditures, mainly science-based sectors (Pavitt 1984). In these sectors, there seems to be the prevalence of technology-push conditioned technical progress. These are also the sectors with lower levels of internationalization of R&D. These findings suggest that the need for absorptive capacity is the main driving force for the internationalization of R&D.

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