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Introduction

The Internationalization of Industrial R&D From technology transfer to the learning organization

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Up to the 1980s, the internationalization of industrial R&D was a marginal topic of research, not only for economic and business theory, but also for governments and the national statistical agencies in developed countries. By the mid-1990s, however, it had become an important subject of inquiry for all the three above-mentioned constituencies. The main reason for this renewed interest was the rapid increase in foreign-funded and foreign-performed R&D that took place in most industrialized countries during the 1980s. Also, expatriate R&D laboratories were not confining themselves to adapting parent company technology to host countries, but were nurturing major inventions and innovations for both the local and the world markets. New research issues have thus arisen. Moreover, as governments fund, directly or indirectly, nearly half of the R&D effort of each developed country, questions were asked as to the desirability and opportunity to fund foreign companies and give them access to research results produced in national laboratories and universities.

In the 1990s, the traditional explanation of foreign industrial R&D, based on technology transfer to foreign subsidiaries from parent companies locating at home their innovatory activities, seemed thus unable to account for both the amounts and the missions of expatriate R&D. New explanations emerged to understand the rising trend. This special issue of *Research Policy* brings some of the most active authors that have explored the internationalization of R&D the concepts and themes that have risen to the forefront. This introduction recalls some of the empirical findings (Part I), the theoretical trends (Part II) and the structure of this special issue (Part III).

1. Empirical trends

Foreign R&D was noted by a few academics in the 1970s (Ronstadt, 1977; Mansfield et al., 1979), but the issue did not become a priority for research in most industrialized countries for at least 15 years. The 1989 OECD *Science and Technology Indicators Report*, i.e., did not mention the topic, and the United States National Science Board *Science and Engineering Indicators* did not treat it up to 1991. By the early 1990s, both publications brought fresh data showing an acceleration in the internationalization of industrial R&D, measured by funding sources (Table 1).

The new data showed wide international differences among industrial countries, both as hosts and home for expatriate R&D. Canada and the United Kingdom, i.e., were among the main industrialized hosts of foreign industrial R&D (which represented between 15% and 20% of their domestic R&D expenditures), followed by the United States and France (both at 11%), but Japan lagged far behind: only 0.1% of its domestic R&D was funded by foreign sources.

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Table 1
Percentage of R&D financed from foreign sources, selected countries, 1981–1995

Year	USA	Canada	France	Germany	Italy	Japan	U.K.
1981	6.2	7.4	7.2	1.2	4.3	0.1	8.7
1982	6.5	10.7	4.8	1.3	4.7	0.1	NA
1983	6.5	16.7	4.6	1.4	4.3	0.1	6.8
1984	6.5	17.2	6.5	1.5	6.2	0.1	NA
1985	6.4	14.3	6.9	1.4	6.1	0.1	11.1
1986	6.8	13.7	8.0	1.4	7.3	0.1	12.2
1987	7.3	16.9	8.7	1.5	6.9	0.1	12.0
1988	8.2	18.1	9.2	2.1	6.6	0.1	12.0
1989	9.5	16.9	10.9	2.7	6.5	0.1	13.4
1990	11.1	17.7	11.1	3.0	7.3	0.1	15.5
1991	NA	17.7	NA	3.1	5.1	0.1	16.0

Source: National Science Board, *Science and Engineering Indicators*, US Government Printing Office, Washington, D.C., 1993.

In the late 1980s and early 1990s, patent figures, mainly from the Sciene Policy Research Unit, in Sussex (S.P.R.U.) and University of Reading databases, confirmed these trends. The share of US patents attributable to research in foreign locations for the large corporations based in most industrialized countries increased between 1969–1972 and 1983–1986 (Cantwell, 1989, 1992). Patents granted to R&D units located abroad represented high shares —usually between 30% and 70% of total patenting in the United States—for corporations based in several smaller nations (Belgium, The Netherlands, Sweden, and Switzerland). The delocalization of R&D was not confined, however, to the smaller industrial nations: a high percentage of patents—between 30% and 50%—granted to the largest corporations based in Canada and the United Kingdom stemmed from their expatriate research and development activities.

A stream of empirical national studies confirmed these findings. After the early works of Mansfield et al. (1979) and Ronstadt (1977) on American multinational's R&D abroad, several others (including Hewitt, 1980; Behrman and Fischer, 1980) examined the internationalization of American R&D. Later, other papers analyzed R&D conducted in the United States by foreign multinational corporations (including Serapio, 1993; Dalton and Serapio, 1995; Florida, 1996). The early internationalization of corporate R&D by Swedish multinational corporations had been analyzed from the 1980s (Håkanson, 1981; Håkanson and Nobel, 1993; Zejan, 1990 and more recently by Zander, 1994), as well as foreign R&D in Sweden (Håkanson, 1983). In the 1990s, the late rise of Japanese R&D abroad also came to be analyzed (Sigurdson, 1992; Sakakibara and Westney, 1992; Papanastassiou and Pierce, 1994; Odagiri and Yasuda, 1996). Other country's expatriate R&D, including the Belgian, the Canadian and the Dutch, the French, the Italian, the Swiss, while substantial, remained much less studied.

Wide industry differences appeared in the levels of internationalization of R&D. The manufacturing of pharmaceutical drugs and medicines was at the forefront of the globalization of R&D, followed by other industries like food and beverages, machinery and transportation equipment manufacturing. Zejan (1990) found that R&D intensity of the parent company and its expenditures in new product development were positively correlated with foreign R&D of Swedish firms. Similarly, Odagiri and Yasuda (1996) found that most Japanese R&D units abroad operated in the electronic equipment, pharmaceutical and automotive industries.

2. Theoretical Trends

New explanations followed the rapid development of foreign R&D, and theoretical frameworks changed accordingly to accommodate new realities and new data. Three phases can be found in the literature. Up to the early 1980s, during which centralized structures were the most common, few studies were devoted to the subject and the explanation offered was overwhelmingly one that emphasized technology transfer from the parent corporation to the subsidiary and the product life cycle model (PLCM). Since the mid-eighties to the early 1990s, new studies measured the growing importance of the phenomenon. Polycentric structures ('decentralized federations') appeared to be more frequent. Later in the 1990s, the many dimensions and missions of expatriate R&D were highlighted, and issues of management and coordination within a global network became more important. Håkanson (1990), i.e., suggested that organizational structures for international R&D went through three evolutionary stages: the centralized hub, the decentralized federation, and the integrated network. A new evolutionary framework

is on the rise to explain international business and R&D, and organization learning by MNCs is at the core of that explanation.

Product life cycle explanations up to the early 1980s

In the 1970s, the literature about expatriate R&D emphasized technology transfer and home country technology adaptation as the main missions of foreign R&D investments. The product life cycle model provided the general explanation: technology was supposed to be produced and developed at home by multinational corporations, and transferred within the MNC to its subsidiaries where it needed some adaptation to local markets. On the basis of the PLCM approach, Ronstadt (1977, 1984) had suggested a first evolutionary pattern in R&D establishments operating overseas, in which new missions were incorporated, from initial technology transfer units (TTUs, aimed at technical service to the subsidiary) to indigenous technology units (ITUs, where new products were developed abroad to service host markets), and then to global technology units (GTUs, foreign R&D establishments developed products for simultaneous launching in several foreign countries). Ronstadt suggested that his findings supported the PLC model and that TTUs were, and would remain, the rule in the foreseeable future. The centralized structure—one or several central laboratories in the home country and several miniature expatriate laboratories for the adaptation of the parent company technology to foreign markets—seemed then pervasive.

New empirical findings during the 1980s and early 1990s

Later, a more empirical literature came to the forefront. Major differences between corporations based in several industrial countries appeared: large firms based in smaller developed nations (such as Canada, The Netherlands, Sweden and Switzerland) had internationalized a higher share of their R&D than firms based in larger countries, but even among these, important differences subsisted: Japanese and Italian MNCs were conducting little R&D abroad, while their British counterparts were pursuing a strategy of R&D globalization. Also, high-technology industries showed a larger propensity to expand their R&D activities abroad, when compared to medium and low-technology industries.

Centripetal and centrifugal forces were found, and sometimes measured and weighted (Terpstra, 1985; Granstrand, Håkanson and Sjölander, 1993); demand, supply and environmental factors appeared to explain a wider variety of missions and organizational structures than previously thought (Granstrand et al., 1992; Taggart, 1993); patent data showed that a majority of corporate R&D was still conducted at home (Patel and Pavitt, 1991). Large corporations organized several types of decentralized federations of laboratories with different missions, resources and coordination patterns.

Towards new models

In the 1990s, several models of internationalization were highlighted on the basis of case studies and/or small samples of large corporations (Asakawa, 1996; Chiesa, 1996; Kuemmerle, 1997). Bartlett and Ghoshal (1990) suggested four different types of management in international innovation projects: central-for-global (developing new products or processes at home for the global markets), local-for-local (developing products and processes independently in each R&D establishment around the world for use in the local market of the subsidiary), locally-linked (developing novelty in each location for global exploitation), and globally-linked (developing novelty through the collaboration of R&D units located in different countries for exploitation in the world market). They also showed that each type of management had specific advantages and disadvantages, and suggested that all the four could be used at the same time for different projects within the same multinational corporation. Issues of efficiency and coordination in a global corporation with multiple R&D centers were also raised (Håkanson, 1990; Howells, 1990).

Much in line with the emerging literature on the company as a learning organization (i.e., Nonaka and Takeuchi, 1995), expatriate R&D also appeared to be at the roots of learning processes through which multinational corporations increased their stock of knowledge in foreign markets (de Meyer, 1993). This approach was particularly helpful in understand-

ing the missions of foreign laboratories of Japanese corporations (Sakakibara and Westney, 1992).

The new theoretical arguments and empirical data also changed the perception of previous missions and importance of expatriate R&D. Historical patent data (Cantwell, 1995) showed that the internationalization of R&D had started much earlier than previously thought, and questioned the usefulness of the product life cycle model even for past periods. Evolutionary approaches of international production reappeared, under the new framework of evolutionary economics and business theory, which shed a new light on the internationalization of R&D (Cantwell, 1989; Kogut and Zander, 1993; Zander, 1994). It was now argued that, through internal R&D, innovative corporations generate a stream of proprietary advantages that lead to rapid growth in international markets, and the spread of their productive and R&D networks over other affluent and innovative markets abroad. Also, the incorporation of new knowledge is path-dependent: each firm's direction of technological search is heavily constrained by its prior competencies (Patel and Pavitt, 1997). Large MNCs master an array of complex and interrelated technologies which they incorporate to the repertoire of their competencies one by one, in an evolutionary way.

Another new issue related to globalization of R&D was the growing frequency of international technology alliances (Dunning, 1995; Duysters and Hagedoorn, 1996). The Coasian approach of international business explained international R&D by the transaction costs of transferring technology to third parties; multinational firms would thus, prefer to market the technology to their own subsidiaries than incur the costs of marketing an intermediary product consisting mainly of information. Thus, strategic technology was produced through in-house R&D and internalized within the multinational corporation. Since the late 1980s, however, empirical findings had shown that MNCs conducted technological alliances with foreign companies in order to create new and improved products and processes. Far from internalizing the production of all strategic technologies, they were creating new ones in partnership with competitors, suppliers and clients. The borders of the MNC became more porous and less clear, with all large firms conducting dozens of R&D partnerships with foreign counterparts. International R&D alliances aim at accessing new complementary technologies, reducing risk and uncertainty for all partners, accelerating the rate of innovation, penetrating new markets, gaining economies of scale in R&D and/or financing costly R&D projects through the pooling of resources, while at the same time maintaining or even increasing their flexibility. The result is some sort of international 'alliance capitalism' that somehow modifies the eclectic model of international business (Dunning, 1995). In the evolutionary approach, alliances are seen as emerging routines of the firm, designed to cope with a more turbulent, open and risky (both in technological and economic terms) environment (Niosi, 1995).

Finally, the methodologies for the study of the internationalization of R&D are also changing. Many of the first studies were simply based on figures of R&D funding by source, and the allocation of R&D expenditures by large multinational corporations. Since the late 1980s, a second source has increasingly been used: patent figures, mostly drawn from the US Patent database, added new dimensions (both historical and technological) to the understanding of expatriate R&D; the process of internationalization of R&D appeared thus as much older than previously thought, and encompassing many different industries, countries and technologies. The use of surveys is a third type of methodology, and increasingly widespread, as many different missions, coordination strategies and types of overseas R&D units appear to co-exist even within the same MNC.

3. The Issue

The present issue brings together some of the most active researchers in this topic. All papers bring fresh data, together with new concepts and models to understand the internationalization of R&D.

New data

Interviews and public information about large corporations have been used for several decades as the main source of knowledge about MNCs and their technological activities. Ronstadt classic work was founded on the in-depth analysis of innovatory activities of seven US-based MNCs. This is the method employed in the research supporting the articles au-

thored by Gassmann and von Zedtwitz, Gerybadze and Reger, Kuemmerle, Zander.

Some articles within this set of papers used this method; others used at least two other procedures. One is the study of the US patents granted to large MNCs. In this issue, Cantwell and Janne, Patel and Vega, and Zander use patents to understand the types of technology that is produced abroad and compare it with the technology that MNCs produce at home.

The second method is the survey. The number of firms conducting R&D abroad has increased very rapidly in the last 20 years, and methods for data gathering which are more appropriate for large numbers of firms can now be used. Dalton and Serapio use data on both R&D spending by US corporations and foreign companies in the United States. These data have been collected by the US Commerce Department's Bureau of Economic Analysis and the National Science Foundation through large surveys. Granstrand conducted a survey on a group of selected Swedish and Japanese firms. Niosi and Godin use the result of a survey on Canadian firms with R&D facilities located abroad.

New typologies

Established classifications of R&D activities conducted abroad (Ronstadt, 1977, 1984; Bartlett and Ghoshal 1990; Håkanson, 1990) are based on both the location of innovation and the use, the intended markets of expatriate technological innovation: TTU, ITU, GTU (Ronstadt) or local-for-local, local for global and global-for-global technology units (Bartlett and Ghoshal) (Fig. 1).

New taxonomies presented in this issue are based on the comparison of technologies produced at home and abroad (Zander, Niosi and Godin), on the size of the home market and the location of critical factors and on the type of innovation (science-based vs. lead-market based) (Gerybadze and Reger). Other typologies (Gassmann and von Zedtwitz) are based on the centralized/dispersed continuum and the behavioural orientation of the international R&D organization. It is argued in these new typologies that part of the expatriation of R&D activities is the result of mergers and acquisitions, and not the consequence of a clearly defined technological strategy. Also, the number of variables that are proposed as key explanations for the internationalization of corporate R&D has increased. Some of these new typologies can be understood as updates, refinements and improvements to established ones. This the case of Gassmann and von Zedtwitz's taxonomy, based on that of Bartlett (1986) and Perlmutter (1969). Other typologies break entirely new ground.

Some of the new classifications are closely linked. Patel and Vega relate their Type 2 to the Home-Based exploiting category of W. Kuemmerle, and their Type 3 to the same author's Home-Base augmenting activities. Niosi and Godin's typology contains categories which are close to those of both Håkanson, Gassmann and von Zedtwidt, and Zander.

It is still too early to predict how successful these new taxonomies will be in the future. All of them, however, tend to enrich the debate about the motives, key factors and behavioural orientations of MNCs technological activities. The articles in this issue

The national capabilities of both home and host countries are major determinants of the nature of technological activities that MNCs conduct abroad. Cantwell and Janne improve our knowledge on the national differences in R&D activities. They organize their paper on two propositions. (1) When MNCs based in countries with the highest technological capabilities in a given industry move to less competent nations in the same industry, they tend to differentiate their technological activities. (2) Conversely, when firms of smaller/less advanced nations create innovative units abroad, these remain specialized within the same areas of the parent company at home. Thus, when German chemical firms operate in countries like France, Italy or the United Kingdom, their innovative activity abroad 'clusters away' from their home activity, into new but related fields. Conversely, when the Dutch electrical giant Philips conducts R&D abroad, it does so in complementary but differentiated technologies. Also, Cantwell and Janne argue that (1) firms based in leading centers in an industry tend to specialize in accordance to local patterns of technological development in hosts countries, while (2) firms based in less important centers tend to rely on their home-based capabilities, thus, replicating their home specialization when conducting foreign research. The study is supported by data on 79 corporate groups based in Europe, active in

Authors	Variables used	Types (and number of classes)
Existing classifications		
Ronstadt (1977, 1984)	Location of R&D activities and intended market of R&D results	TTUs, ITUs, GTUs (3)
Bartlett and Ghoshal (1990)	Same as Ronstadt	Local-for-local; local-for-global; global-for-global (3)
Håkanson (1990)	Centralized/dispersed and behavioural orientation	Centralized hub; decentralized federation and integrated network (3)
New taxonomies in this issue		
Gassmann and von Zedtwitz	Centralized/dispersed and behavioural orientation	Ethnocentric centralized ; geocentric centralized; polycentric decentralized; R&D hub model; integrated R&D network (5)
Gerybadze and Reger	Large vs. small markets and critical assets, and science-based vs. lead market innovation	Large R&D base in home country, small R&D base in home country, lead market in home country, lead market abroad (4)
Kuemmerle	Knowledge exploiting vs. knowledge-augmenting activities	Home-based exploiting sites and home-based augmenting sites (2)
Niosi and Godin	Related diversification, vertical integration and global networks	Internationally diversified firms, vertically-integrated firms, global networks (3)
Patel and Vega	Revealed technological advantage at home or abroad	T. 1: Strong at host, weak at home; T. 2: Strong at home, weak at host; T. 3: Strong both at home and host; T.4: Weak both at home and host
Zander	International duplication and international diversification	Home-centered Internationally duplicated Dispersed Internationally diversified (4)

Fig. 1. Established and new typologies of international R&D activities.

three major industries (namely chemicals and pharmaceuticals, metal products and mechanical engineering, and electrical equipment and computing) and it is based on the US patent database, for the 1969–1995 period.

In line with the previous analyses by Patel and Pavitt, Patel and Vega argue that home country conditions are the major determinants of foreign innovatory activities of large firms. They try to understand the type of technical fields in which firms undertake foreign technological activities, and their most important locations. Using again the US Patent database, for the 1969–1996 period, for more than 220 of the world's largest corporations, with the highest patenting abroad in the period 1990–1996. Chemical, pharmaceuticals and electrical/electronics firms dominate the list with over 60% of the inventor/technical fields combinations. Firms are active in their home technology fields, and a large proportion of their foreign innovative activities are linked to machinery and process technology. Also, Germany, the United Kingdom, and the United States are the main location of expatriate R&D, while Japan is the least favoured one. In over 75% of the cases involved, the companies have relative advantage at home. Only the Dutch firms display a high proportion of Type 1 cases (where firms are weak at home and strong abroad): barely 10% of the cases, thus, involve firms that went abroad to gain knowledge in which they were weak at home. Patel and

Vega, as Cantwell and Janne, maintain that their analyses support both the more recent perspectives in terms of national innovation systems.

Oliver Gassmann and Maximilian von Zedtwitz interviewed 33 large and highly internationalized MNCs based in Europe (17), Japan (11), and United States (five). Their data cover the 1994–1998 period. They found an increased dispersion of R&D activities, particularly pronounced in firms based in small industrialized countries. This increased dispersion is mostly the result not of R&D decisions but of other decisions (i.e., mergers and acquisitions with market-driven rationales). Their typology is based on both those taxonomies of Bartlett (1986) and Perlmutter (1969). Five categories accommodate their observations: ethnocentric centralized R&D (similar to Zander's home-centered strategy) where all R&D is concentrated in the home country; geocentric centralized where R&D remains in the home country, but R&D employees are regularly sent to foreign markets and/or foreign-born employees are hired to increase sensitivity to external clients; polycentric decentralized R&D (where many local R&D units have been established abroad); the R&D hub model, with a home-based center tightly coordinating smaller foreign labs; and the integrated R&D network, with many labs in different locations and no center.

The study authored by Ivo Zander analyzes 24 Swedish MNCs, using the US Patent database over the 1946–1990 period, representing between two-thirds and three-quarters of Swedish industrial R&D. Using Ward's cluster analysis, and two major variables (international duplication and international diversification), Zander finds that his observations fall into four different categories. A first cluster is made of nine 'Home-centered' firms, keeping their R&D activities close to headquarters; a second cluster is that of six 'Internationally duplicative' firms, whose technological activities abroad are in the same areas as those at home; seven firms are in the third cluster, that of firms which are both 'Internationally dispersed and diversified'; a final fourth cluster includes two corporations that are 'Internationnally diversified' but not dispersed. As Gassmann and von Zedtwitz, Zander allows for historical factors (such as mergers and acquisitions) more than rational planning of international R&D to explain such a variegated group of innovative strategies.

Close to the above-mentioned papers, Jorge Niosi and Benoît Godin conducted a national study on Canadian MNCs based on a survey of expatriate R&D units. They obtained data on 18 highly internationalized corporations (representing over 40% of Canada's industrial R&D) through 22 different foreign R&D units. Most of Canadian-owned and controlled research units operating in foreign countries were the result of acquisitions; a few others were created without direct link to foreign direct investment or added to newly acquired manufacturing facilities abroad. Canadian corporations allowed much flexibility to these R&D units operating abroad, both in the choice and approval of projects and in the managers they hire. Three types of networks appeared. Most of these acquisitions of foreign technological capabilities could be described as related diversification: companies acquired new capabilities close to their existing competencies. This strategy was operating in the production of machinery, transportation equipment, biotechnology, building products or packaging materials. A second group of corporations practiced a strategy of vertical integration: they kept in Canada their facilities for the production of basic metals and petrochemicals and acquired abroad advanced materials and semi-finished or finished products manufacturing and R&D capabilities. Only one truly global network, with many R&D facilities abroad ('internationally dispersed', in Zander's taxonomy) appeared in the sample.

Walter Kuemmerle makes the distinction between knowledge creation and knowledge exploitation as main missions of foreign laboratories. He arrives to this conclusion, through a systematic study of 32 multinational corporations (12 based in Japan, 10 in the United States, and 10 in Europe) operating in high-technology industries. He recalls that most firms have started their international expansion through the establishment of sales facilities abroad, then moved some manufacturing overseas and only finally did they increase their R&D commitments in foreign countries. While making location decisions for new R&D sites, managers of MNCs analyze two types of benefits and costs: those determined within the firm boundaries (costs of transferring R&D outputs and inputs across locations, monitoring costs arising from the dispersal of assets, possible externalities between

the firm's R&D function and the marketing and manufacturing functions, and economies of scale in R&D) and those determined across the firm's boundaries (such as local costs of inputs, and potential externalities from competitors and local universities). The latter are the basis for knowledge creating activities from foreign R&D, as opposed to home-based-exploiting foreign R&D (or technology transfer units, in Ronstadt taxonomy).

Using a sample of 21 large corporations which are industrial leaders worldwide (11 from Western Europe, eight from Japan and two from the United States), Alexander Gerybadze and Guido Reger arrive to a conclusion which is similar to that of Kuemmerle: corporations are increasing able to create and operate multiple centers of learning at different geographical locations, and to manage cross-functional learning from different sites. This development is associated with the transition to a polycentric structure in the world economy, where several national centers of excellence compete in basically every technology. MNCs adapt to this multipolar world by developing complex structures that depart from the home-centered classical structure with or without satellite R&D units for the transfer abroad of the technology generated at home. The types of structure that emerge from this picture depend on whether the company operates in science-based industries or in market-based ones (science and technology push activities or demand pull innovative ones), and whether it emerges from a large country (or from a country with a critical mass in R&D relative to that industry or not). Thus, they conclude that the specific structures and modes of coordination that corporations develop for international R&D depend on these critical variables of their close environment.

A comparison of Japanese and Swedish MNCs by Ove Granstrand finds that national differences matter in the internationalization of the R&D function of the firms. His findings are parallel to those underlined by both Cantwell and Janne and Gerybadze and Reger. Using survey data from 24 corporations based in Japan and 23 others based in Sweden (these represent over 50% of Japanese industrial R&D and over 90% of industrial Swedish R&D), Granstrand finds that supply-side factors (such as access to foreign science and technology) are important for Japanese corporations but much less so for Swedish ones, for which traditional demand factors remain key. In the same vein, industry–university collaborations (knowledge-augmenting activities in Kuemmerle classification) are central in Japanese MNCs, while Swedish firms tend to rely on local industry–university externalities at home. Also, the 'psychic distance' between home and host countries is a consideration for Swedish MNCs, but it does not influence the behaviour of Japanese ones. These findings add to the different national characteristics and determinants found in previous papers, showing that home country basics (such as size, importance of critical science and technology critical masses, national competencies, etc.) cannot be obliterated in the discussion of internationalized industrial R&D.

Decentralized R&D has moved from the realm of the tactical to the strategic. Traditionally, foreign R&D was aimed at supporting the ability of the MNCs to apply their established technology in overseas markets. Strategic internationalized R&D today means both acquiring new technologies through overseas research units, and sustaining existing core technologies. Robert D. Pearce uses data from two surveys conducted in the United Kingdom, one towards production subsidiaries of foreign MNCs and the second to foreign-owned and controlled laboratories conducting R&D in the United Kingdom. In spite of the fact that most subsidiaries had received much of their basic technology from their parent companies, product development (not adaptation) is the key mission of R&D in these subsidiaries. Also, most of these affiliates expected the growth of their R&D activities, suggesting that innovation, not technology transfer, was in their future agenda. Pearce concludes that the new innovative role of foreign R&D is pushed by several key developments, one of which is the increasing dispersion of industrial and technological capabilities in a wider range of countries, forcing the multinationals to a more complex innovation strategy including the upgrading and extension of foreign R&D.

In spite of this increasing dispersion of overseas R&D, the United States continues to be the main home for MNCs and foreign research and development, as well as the main host for expatriate innovative activities. Donald Dalton and Manuel Serapio using the US Department of Commerce and National

Science Foundation data, show that their is a rapid increase in the number of foreign R&D facilities in the United States and in the foreign funding of American industrial research, as well as in the number of countries participating in American industrial R&D. The main reason for this upsurge has been the acquisition of American pharmaceutical, chemical and biotechnology firms with large research and development budgets by foreign MNCs. By mid-1990s, foreign R&D represented 16.3% of all industrial R&D in the United States, and employed over 100,000 scientists and engineers. Most of the growth had occurred from the increase of the spending of Japanese, British, Swiss and German MNCs. These same countries were those with the largest expenditures in foreign industrial R&D in the United States.

The policy implications of the globalization of innovatory activities is the subject of the contribution co-authored by Daniele Archibugi and Simona Iammarino. On the basis of the taxonomy that Archibugi has developed elsewhere (globalization understood as exploitation throughout the world of home-grown technology; global generation of innovations through foreign R&D, and global innovation through alliances), the authors study the public policy environment of this multi-layered globalization process. They suggest that it requires the expansion, not the reduction, of the public policy portfolio, in order to properly monitor the new activities and to insure adequate returns for public investments in R&D.

Conclusion

The rapid increase in expatriate R&D activities is being analyzed by growing numbers of academics and national statistical offices. On the basis of these new data, we are now able to distinguish wide differences among countries, both as foreign investors and as hosts of these innovatory activities. Also, large differences appear among corporations, the strategies of which broadly differ even within the same industry. A few general conclusions seem, however, to appear through the reading of this special issue.

One is that companies are increasingly moving R&D abroad regardless of the industry in which they are involved, and that this process follows previous investments in foreign marketing and production facilities. Market factors appear much more important for corporations based in smaller industrial nations than for those based in larger industrial countries. The former tend to invest abroad in the same technologies that they master at home, while the latter, when acquiring or creating overseas R&D establishments, tend to broaden the scope of their technological portfolio. Also, corporations from small countries tend to transfer abroad some (or all) of their central R&D capabilities.

Learning is a key element in the development of the new internationalization of R&D. Locating close to major innovatory centers (where universities, public laboratories and major private R&D units from competitors are already based) is a major mechanism for the absorption of technological spillovers in foreign centers of excellence. Learning takes place also on the basis of the closer relationship with lead markets and lead customers, those that have a major role in the development of the technology.

These new patterns show that the internationalization of R&D is slowly but surely moving past the transfer to the periphery of technology developed close to headquarters, and that at least the most advanced multinational corporations of all industrial nations are now trying to absorb externally-developed science and technology. It remains to be seen what the new policies will be to monitor and frame these coming trends.

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