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INTERNATIONAL GROWTH AS INTEGRATION OF R&D ACTIVITIES. EVIDENCE FROM LARGE MULTINATIONAL COMPANIES

by

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SUMMARY

Corporate R&D internationalization has been analyzed predominantly in terms of the geographic diversification of multinational companies' research laboratories, and only to a lesser extent as a process involving the development of resources and capabilities within organizations and as a means of favoring international integration. This paper analyzes the relation between these two dimensions of internationalization, both of which are relevant for study of the multinational growth of R&D activities. Examination of the literature together with in-depth case reports of two large multinational clusters provides evidence in support of the following statements:

- *R&D internationalization can be seen as a "gradual" process that takes shape through the formation of specific resources and capabilities, which are developed within individual organizations but are designed to achieve integration both with foreign organizational units of the multinational cluster itself and also with other national innovation systems;*
- *Multinational R&D follows a strategy that is characterized by a strong inter-relation between the formation of foreign research activities and the character of the integration process;*
- *Corporate strategies may correspond to highly diverse and at times even contrasting R&D internationalization models, as shown by the emblematic case analyses presented here. The presence of these different models limits the scope of any general interpretation of the determinants and implications of R&D internationalization.*

1. INTRODUCTION

Within the framework of studies on corporate strategic behavior, attention has increasingly focused over the past few years on the international growth of R&D activities (Zander 1994, Granstrand et al. 1992, Patel and Vega 1998). The literature in this field has concentrated mainly on highlighting the determinants that lead multinational clusters to localize corporate laboratories in countries other than the national base of the parent company. This involves making a distinction between forces favoring centralization and those leading to geographic decentralization of corporate research (Pearce, 1989). Conflicting conclusions have been drawn on the extent (diffusion and meaning) of the internationalization process (Patel and Pavitt 1991, Pearce and Singh 1992, Doremus et al 1998)[1]. Recent investigations have pointed to a relation between such processes and the emergence of a state of tension among the components constituting national innovation systems. It has been suggested that this tension is generated, within specific national and sectorial contexts, by the development of more intense connections between corporate technological activities and national innovation systems of countries other than that in which the parent company is located (Patel and Pavitt 1998, Barré 1995).

The majority of studies on growth of international corporate R&D has examined the "horizontal" dimension of the internationalization process, as this is "externally" more visible and can more easily be attributed to the establishment of a number of R&D laboratories of one and the same company in different countries (*international geographic diversification*). Less attention has been devoted to the "vertical" process of internationalization that is acccomplished "inside" the individual R&D organizational unit. The latter type of process results in the formation of new specific capabilities, whose hallmark consists in their unique international aspects and their thrust towards integration of scientific and technological resources developed within organizations localized in foreign contexts (*development of the capabilities for international integration*). This second dimension is not exclusively restricted to large corporate entities that localize their research laboratories abroad, since it can also play a significant role for small and medium-sized concerns seeking to derive advantage from relations with national innovation systems that differ from their own[2].

[1] The issue of corporate R&D internationalization is also of relevance in defining the structural characters of national innovation systems (Nelson 1993, Patel and Pavitt 1994) and analyzing processes of international technological cooperation among firms (Varaldo 1987, Duysters and Hogedoorn 1996).

[2] The idea is that even firms with only one - and perhaps rather small - R&D organization may be able to draw advantage from interaction with foreign national innovation systems, if such firms succeed in developing and using a variety of tools to integrate their own technological resources with those found among organizations of foreign

Both of these dimensions of the internationalization process assume significance in large companies that devise a multinational R&D strategy (Julian and Keller 1991, Guercini 1997), i.e. in companies that operate with foreign research laboratories. Such companies will constitute the object of study in this paper, which will focus specifically on the relation holding between the two dimensions. We will analyze the interaction between the features that characterize geographic diversification and those inherent in developing the capabilities for international organizational integration (Cantwell 1995). Available literature in this field covers the existence of different modes of acquisition of foreign R&D units (corporate takeovers, direct placement, evolution of pre-existing technical units) as well as the different typologies of activities carried out within such units. The present study, on the other hand, will direct attention to in-depth investigation of the manner in which the behavior and strategies that lie at the origin of geographic decentralization enter into relation with the integration processes. This will bring to light additional types of variety in strategic behavior and internationalization of corporate R&D. Drawing on the results of a four-year study carried out both on the theoretical and empirical level, this paper offers an analysis of two emblematic cases of large multinational clusters, one based in the USA (General Electric) and the other in Japan (Matsushita), pinpointing the differences affecting the two dimensions of the internationalization process and shedding light on the relations found to hold between them.

Our main aim in undertaking this investigation is to demonstrate that in an overall managerial and economic framework the internationalization of corporate R&D is characterized by a broad spectrum of forms and contents, which may correspond to substantially heterogeneous goals, resources, abilities and contextual conditions. The underlying organizational models are therefore likely to be equally heterogeneous, signaling the marked path dependency and specificity of individual corporate entities. This, in our view, places considerable limitations on the explanatory validity of presumed general interpretations of the determinants and implications of this coroporate R&D internationalization[3].

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countries.

[3] International utilization of knowledge is seen as the main *raison d'être* of multinational companies in the mainstream economic theory that focuses on this type of firm. Naturally, "knowledge" is not generated by R&D alone; however, international exploitation of corporate scientific and technological know-how is of crucial importance in explaining why some companies choose to operate simultaneously in several national contexts. Even so, exploitation of technology on an international scale does not automatically require R&D to be performed abroad, and the tenedency to "develop at home and sell internationally" is still strong, as well as being in harmony with the basic theoretical model outlined by Vernon. The economies of scale achieved in R&D (Caves 1982), considered as one of the centripetal forces limiting corporate R&D internationalization, are known to reinforce this tendency.

2. INTERNATIONALIZATION AS DEVELOPMENT OF THE CAPABILITIES FOR INTEGRATION

The approach to internationalization that sees this process as a form of corporate development can be traced back to growth studies, where direct foreign investments were interpreted as the utilization of pre-existing corporate resources alongside with development of new organizational resources[4]. According to this view, internationalization becomes a learning curve and fulfils the task of shaping new skills within organizations. It can thus be studied from the perspective of the so-called "gradual approach" to the growth of corporate foreign activities, an approach that was favored in the 1960s and '70s by a group of international business scholars belonging to the Swedish school of Uppsala (Johanson and Vahlne, 1977). This vision is linked to the broader "process-oriented approach" (Andersen 1993, Cavusgil 1984), wherein corporate internationalization is seen in terms of a series of changes (commitment decisions, current activities) and states (effectiveness on the market, development of market knowledge). A distinction can be made between this approach and that of the international product life cycle (Vernon 1966), since international development is not conceived as driven by an inherent advantage that certain firms have achieved through their national base, but rather as a choice oriented towards the development of new resources and capabilities specifically designed to achieve a position of advantage (Cantwell 1995, Rullani and Grandinetti 1996). The "gradual approach" is based on empirical evidence obtained mainly through case analysis (Johanson 1966, Gruber, Mehta and Vernon 1967, Forsgren 1990) , which has made it possible to highlight those aspects of corporate internationalization that translate into processes of incremental adjustment within the framework of overall changes in a given company and its environment. Such aspects are viewed against the background of extensive empirical evidence on the processes involved in the internationalization of organizations, so that it also becomes possible to identify their impact in comparison with processes attributable to crucial investiments made at specific points of time.

It would be beyond the scope of this paper to provide an in-depth account of all the themes

[4] Even Penrose, in an article published a few years before her more famous contribution on the theory of development of the firm, addresses the relation between direct foreign investments and corporate growth (Penrose 1956). Analyzing the case of General Motors Holden (GMH), the Australian subsidiary of the main US automotive group, Penrose claims that "...once a foreign firm is established its continuous growth is an increase in foreign investment, but an increase which is more appropriately analyzed in the light of a theory of the growth of firms rather than a theory of foreign investment..." (p.224). The internationalization process is seen as linked to utilization of corporate resources, underlining that ... "the productive opportunity which invites expansion is not exclusively an external one. It is largely determined by the internal resources of the firm... depend[ing] as much on the kind of experience, managerial ability and technological know-how already existing within the firm as they do upon external opportunities open to all..." (p.225).

involved in corporate R&D internationalization[5]. What is important to note here is that the gradual approach, which sees internationalization as a developmental process leading to new corporate qualitative and quantitative characters, is of particular significance for a management-oriented analysis. In addition, this approach is consistent with a wide-angle perspective on the internationalization of corporate technology: thus the field of inquiry is extended beyond the mere establishment of foreign R&D units, to include development of capabilities within individual organizational units for purposes of international integration. In this sense, R&D internationalization within multinational clusters can be seen as comprising not only the path that results in the existence of laboratories belonging to the group but located beyond the parent company's national boundaries, but also the actual process of integrating - and therefore, in the first place, of developing - organizational resources and capabilities that can serve the R&D strategy. Integration proceeds at several levels (within the R&D function, in individual laboratories, among organizational units of the multinational localized in different countries, between the multinational and national innovation systems of other countries) and is closely linked to the pathway by which the multinational's R&D strategy is implemented.

R&D internationalization offers the advantage of allowing the achievement of integration between corporate R&D and a scientific base that is much wider than the science base offered simply by the national innovation system in the country of origin. Therefore, it is important to take into account not only "how much corporate R&D is carried out in a country different from the country of origin" but also "what R&D is carried out abroad". In other words, foreign laboratories do not necessarily replace activities carried out at laboratories in the multinational's country of origin. They may take on a support or developmental role with respect to the central laboratories of the parent company[6].

Differentiation within R&D activities

Corporate R&D is both highly specialized and extremely heterogeneous. This diversity plays a significant role in the management of corporate activities developed in different countries, contributing to defining the type of resources and capabilities for integration required within the

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[5] In this context, we take the liberty of referring the reader to the first chapter of Guercini (1999).

[6] R&D carried out abroad cannot replace that performed in the home country; if such a situation appears to exist, then it is strictly speaking incorrect to speak of "geographic decentralization" of R&D activities, because there is no "first stage" in which R&D is centralized, followed by a later stage in which previously centralized R&D is transferred from the center to the periphery. Instead, such a situation corresponds to the creation of activities that are different from, and complementary to, thsoe undertaken at the central level.

multinational framework. Thus within a multinational, R&D is typically differentiated into two broad categories, “Corporate R&D” (Cantwell and Barrera 1993), whose general orientation is towards medium and long term research, versus “Business R&D” carried out within the various GE businesses, which focuses predominantly on short-term programs at the development laboratories and technical centers of the multinational cluster (Rubenstein 1989).

A further type of heterogeneity within R&D organizations arises from the coexistence of more strictly “scientific” activities along with others that are more properly-speaking “technological”. Studies undertaken by Allen (1977) on communication processes within research laboratories have highlighted a distinction between “engineering researchers”engaged in expanding the frontiers of technology and “scientists”engaged in scientific research. Such studies emphasize that the characters and effectiveness of communication processes may be crucially influenced by the different connotations of these two professional figures[7]. More specifically, although engineers and scientists may at first sight appear to have numerous features in common, the nature of these two figures is underlyingly so radically different that they can hardly be expected to reveal similar behavioral patterns of communication. It has been shown that the two groups socialize in different subcultures, come from substantially different educational experiences, and differ not only in personality but even in their family background[8].

The contrast between science and technology makes itself felt not only as regards the types of operators in these two fields, but also, as is well known, in the nature of the accomplishments to which their work gives rise. Thus in the scientific field, the results of research are deposited in the relevant scientific literature, consistently with what has been described (Price 1970) as the cumulative nature of science. Knowledge of basic research, linked to the models of scientific communication, is disseminated through the system of publications which are accessible to a potentially international readership. It may therefore be associated with different models of internationalization, involving for instance contributions to and feedback from international journals and joint research programs with other seats of learning. To a certain extent, a system of

[7] More specifically, Allen claims that “… Despite the fact that they should be the last to commit such an egregious error, social scientists studying the behavior of scientists and engineers seldom distinguish properly between the two groups … worse still, in many studies the populations are mixed, and no attempt is made to distinguish between the two subsets … the usual practice is to use the term scientist throughout a presentation, preceded by a disclaimer to the effect that “for ease of presentation, the terms scientist will be assumed to include both engineers and scientists” … one might almost as readily lump physicians with fishermen …” (Allen 1977, p. 35).

[8] In this regard, it is underlined that “… the science students place a higher value on independence and on learning for its own sake, while, by way of contrast, more students in the other curricula are concerned with success and professional preparation. Many students in engineering and management expect their families to be more important than their careers as major source of satisfaction … engineering students are less concerned than those in science with what one does in a given position and more concerned with the certainty of the rewards to be obtained …” (Krulee e Nadler 1960); furthermore “… engineers do not have the goals of scientists … while publication of results and professional autonomy are clearly valued goals of Ph.D. scientists, they are just as clearly the least valued goal of the baccalaureate engineer …” (Ritti 1971).

publications has also developed in the sphere of technological research, but in the view of some authors (Price 1965) it lacks the crucial characteristic of building on previous achievements by other scholars working in the same field, as shown by the fact that citations of previous reports or patents are far less frequent than references to previous technical experiences of the contributing author himself/herself. Those engaged in technological research publish less and devote less time to reading than scientists, while technological information is disseminated primarily through personal contacts. This has the effect of reinforcing "localism" in engineering communication models. Furthermore, since such information has a "proprietary" character and must be protected in order to preserve the company's position in a highly competitive market, free communication among engineering personnel of different organizations is to a large extent inhibited[9]. A substantial proportion of the information generated in an industrial laboratory is not published because it is considered as subject to property rights, and is therefore registered only within the organization. Consequently, the system of internal corporate documentation is regarded as a highly important source of information for engineers seeking to achieve technological innovation[10].

By taking over foreign organizations, a multinational cluster can gain access to a "goldmine" of internal publications and new interpersonal networks that are of the utmost importance to researchers in the industrial laboratories. It is for this reason that the move towards internationalization may fail to fully develop its true potential if it is limited to establishing a group of laboratories - set up by the multinational itself through external or organic growth operations - rather than being oriented towards integrating technological know-how that has arisen in different national contexts. This in turn means that the role of research laboratories will vary from case to case and is subject to change over time. Thus in contrast to the commonly held view that they fulfil a role assigned to them by their "parent", it is the nature of the R&D units in faraway locations that may actively contribute to determining what kind of research they should be called upon to perform.

An additional factor leading to internal differentiation of R&D is the presence of personnel from different national backgrounds or different cultural traditions. The problem of the distance between different national contexts may also have repercussions on the operative level. It may for

[9] Allen points out that "… it is always amusing to observe engineers from different companies interacting in the hallways and cocktail lounges at conventions of professional engineering societies. Each one is trying to draw the maximum amount of information from his competitors while giving up as little as possible of his own information in return ..." (Allen 1977, p. 41).

[10] Even Allen himself states that he had failed to find "gatekeepers" in basic research (Allen 1977 p. xi), and while product and process development projects show higher performances when the team includes a gatekeeper, research (both basic and applied) teams with a gatekeeper actually achieve lower performances than teams without such a figure. The need for a gatekeeper is created by the organization and its culture, so that the local nature of technology, as opposed to the universal nature of science, is such as to intrinsically require a gatekeeper. The gatekeeper must translate external information into a form that can be understood locally, so that an external technology can be made relevant. Scientists, on the other hand, are not hampered by organizational culture; therefore, not only do they need no translation, but their scientific performance will actually be hindered by this "funneling".

instance result in conflictual relations among R&D professionals from different countries, paralleling the known pitfalls that may occur in negotiations among operators from different national backgrounds[11]. International negotiations are often fraught with difficulties due to the fact that the parties involved appear to be following different lines of reasoning. As has been underlined in the literature, the likelihood of misunderstandings and misconceptions in such contexts is particularly high (Gulbro and Harris 1994).

However, it has been pointed out that throughout the world highly qualified professionals such as those of R&D laboratories share certain cultural traits regardless of their sectorial discipline. Thus researchers show a clear preference for challenging tasks that allow them a considerable degree of autonomy, good working relations with the managers, and cooperation (Yeh 1996). They are characterized by considerable willingess to engage in international work experiences, and the motivating factor of "achieving a contribution" may prove more powerful than mere financial gain. The concept of "researcher" depicted by such studies tends to blur the distinction between science and technology, although the emerging profile is actually more similar to the "scientist" than the "engineer" of Allen's description. This has led to the hypothesis that researchers of corporate laboratories are more likely to appreciate a type of management that is orientated towards consultation of those engaged in research; in addition, they are thought to be less concerned about job security than other categories of employees and more willing to express disagreement with their superiors or to call organizational rules into question (Hoppe 1993).

Overall, then, these hypotheses sketch a profile of R&D professionals as a group characterized by specific "cultural" connotations independently of the nationality to which they belong. Their world view has a common core of values that appears to require the same management approach anywhere in the world. Such a suggestion is however criticized by some authors, who have noted that one also finds R&D professionals whose outlook and lifestyle is strongly marked by their national origin (Kedia et al. 1992). According to this interpretation, researchers may well be similar as regards "what" they appreciate in the workplace, but there are likely to be different gradations that vary from country to country. In particular, it is claimed that while R&D profesisonals throughout the world may share preferences for a strong degree of autonomy, cooperation and the thrill of "challenge" in their research tasks, the meaning attributed to, and behavioral expression of, these values is filtered by national culture and therefore shows

[11] There is a connection here with the so-called "convergence hypothesis", according to which management is the same or is becoming the same throughout the world (Decastri 1993, p. 187 ff, Miller 1984, Child 1981). It has been pointed out that "...when two people communicate they rarely talk truly and precisely about exactly the same object/subject, since the effective meanings are filtered through the cognitive world and cultural condition of each person"(Gulbro and Herbig 1994). On inter-organizational relations in an international setting, see the work edited by Håkan Håkansson (1982) in the framework of the IMP Project Group.

pronounced differences among countries (Smith and Peterson 1988, Hoppe 1992 p. 319).

Formation and integration of multinational R&D

As is known, firms may come to possess foreign R&D laboratories through a number of different paths:

(1) *direct placement* of laboratories in a foreign context;
(2) indirect consequence of the *take-over* of firms that possess foreign R&D organizations;
(3) *evolutionary process* within technical units (for instance, in production organizational units) located abroad and originally endowed with only limited capabilities.

Of these three developmental paths, only direct placement corresponds to strategic international planning (Guercini 1997). In contrast, the formation of foreign research laboratories as an evolutionary process of pre-existing technical units often takes place beyond the control of the parent company, and although it may be supported or even boosted by the central organization, the evolution itself may be more closely linked to objectives of subsidiary companies. Finally, as far as takeovers are concerned, the R&D activities of acquired companies and their integration with the purchasing company's technological know-how may not necessarily constitute the most important motives behind the merger itself, and the decision to take over another company may be driven by quite different aims than that of the establishment of a network of foreign laboratories (Gerpott 1995, Pausemberger 1982, Howells 1995). Studies have therefore been undertaken to determine the relative importance of these three modes, based on empirical observations, carried out at different times, of samples of firms of varying size, and startlingly conflicting results have been obtained[12].

Management of international R&D activities presents firms with new and highly problematic issues. Extensive sectors of the organization may encounter serious difficulties in adjusting to the process of internationalization, sometimes regarding it as "closer to a marketing gimmick than to an effectively contributing R&D outlet" (De Meyer and Mizushima 1989, p. 139).

The establishment of a series of R&D laboratories abroad raises important questions in connection with two integration processes that can be observed as part of R&D internationalization:

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[12] Of the activities of 7 American MNC examined by Ronstadt (1977), roughly one-quarter of R&D labs had been obtained by takeovers, while Berman and Fischer (1980), who examined a sample of over 50 American and European MNC, found that roughly half of the units resulted from the evolution of pre-existing units, 28% from direct placement and 25% from takeovers. More recently, other authors have suggested that roughly two-thirds (69%) of new units are the result of direct placement (Pearce and Singh, 1992).

(1) what can be achieved within the multinational cluster among the different organizational research units localized in different countries;
(2) what can be developed between the parent company and the set of subjects composing the national innovation systems of the country of origin or of the other countries with which the company enters into contact.

At this second level of integration, the national system that exerts the most momentous effects in internationalization processes may not be the one to which the parent company belongs. According to Patel and Pavitt (1998), the link between the forms of innovation achieved by a company and its national scientific base (Freeman 1995, Lundvall 1992, Chesnais 1992) is subjected to increasing tension because of a skew between that which the national scientific and technological system is capable of offering and companies' requirements. This tension may be compounded by other problems such as inconsistency between the development rate of technological know-how at a national level and the mounting range of technological fields potentially exploitable for the activities of individual firms. Imbalances of this kind have long affected large firms whose parent company is located in small countries (such as multinationals whose parent company is in Holland, Belgium or Switzerland), but they are now increasingly affecting firms in large countries such as Germany, Japan or the United Kingdom, as shown by studies conducted at the SPRU of Sussex University (Patel and Pavitt 1998). For even in advanced countries endowed with strong scientific and technological resources the national scientific base may prove insufficiently broad to satisfy the requirement of scientific and technological know-how[13]. This problem is particularly acute for larger-sized companies, which are highly diversified and typically multitechnological, and for which the strategy of integration (or "fusion") of different fields of scientific and technological knowledge is vital (Patel and Pavitt 1994, Hobday 1998, Iansiti 1998).

Integration has a twofold character, comprising both the definition of roles for the units involved and the need to devise communication and coordination mechanisms[14]. The first aspect is

[13] The central components of national innovation systems in advanced countries include R&D carried out by firms and other operators as well as basic research and training undertaken within universities. These knowledge-generating activities rely on two essential components: firstly, in all countries, the education and training system plays a vital role, and secondly, this system interacts with the R&D activities conducted by organizations operating in industrially advanced countries (Fagerberg 1994). The close link observed between the national scientific base and innovative activities performed by national operators reflects the advantage of physical agglomeration in promoting innovation, allowing firms to obtain the maximum benefits from their investments (Edquist 1997).

[14] Lawrence and Lorsch (1969) define integration as the quality of cooperative relations holding among organizational units that are called upon to produce a joint effort in response to environmental requirements. This definition underlines three aspects: (1) a *relation* between distinct entities, whiich translates into "establishing relations", "connecting

addressed by the literature focusing on the following concepts:

(1) "world product mandate" (Science Council of Canada 1980, Etemad and Séguin Delude 1986, D'Cruz 1986, Rugman and Douglas 1986);
(2) "center of excellence" (Surlemont 1994, Lorenzoni and Baden-Fuller 1995);
(3) "R&D mission" (Pavitt 1996, Paoli and Guercini 1996).

A "world product mandate" is understood as a mandate assigned to a foreign subsidiary which is empowered to act on a world-wide or regional level as the main supplier of a particular product. The subsidiary thus in effect becomes the headquarters for the product in question, since the main corporate decisions concerning the object of the madate are actually made by this subsidiary. Such an approach contrasts with the concept of the "center of excellence", which endows one organizational unit within the multinational cluster with the responsbility for worldwide or regional marketing of a given product or product line. The "R&D mission" contrasts with both of these concepts. As compared to the "world product mandate", the R&D mission may pertain to subsidiaries of the multinational cluster situation within the same country as the parent company (in which case it takes on a broader meaning) and in any case it requires the presence of organized R&D activities (in which case it assumes a more limited scope as compared to the "world product mandate"). In comparison to the "center of excellence" the "R&D mission" may receive its definition without any necessary implication that the organizational unit to which the mission is attributed plays a crucial role in a specific product line. At the same time, it requires the presence of organized R&D activities but not of other functional areas (production, marketing), which may be engaged in activities linked to the role of the "center of excellence". Furthermore, on a more general level, while the "world product mandate" and the "center of excellence" assign a particular responsibility to the organizational unit within the framework of the multinational cluster, the "R&D mission" may be implemented in various forms of mission (such as sectorial, adaptive or basic) without this automatically corresponding to a definition of specific responsibilities[15].

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organisms, bodies", in which the relational concept takes the form of cooperation among elements that are to some extent still distinct and individually recognizable; (2) the moment of *union*, corresponding to a "fusion" of originally distinct aspects that is designed to constitute something new embracing a plurality of original elements; (3) the fact that the entities involved need to be functional, both individually and taken as a whole, to the *environmental conditions* in which they are operating.

[15] The phrase "sectorial R&D mission" indicates specialization of the subsidiary's R&D activities in a particular knowledge sector, and involves strong vertical integration of knowledge-production activities within the R&D organization (that is to say, integration starting from any existing basic research activities, extending up to research and development activities, and continuing into production and marketing). Such specialization occurs in relation to a particular setting that can be defined either in disciplinary terms or with reference to application typologies or, more often, product lines. An "adaptive R&D mission" refers to R&D organizational units that are committed above all to the adaptation of technologies produced elsewhere - which may also mean elsewhere within the same multinational cluster

Regional and organizational differentiation of R&D within a company may require a sophisticated set of modes of integration rather than a single tool, to be used both at the corporate level and within individual organizational units. Clearly, this in turn raises the need to devise powerful communication and coordination tools that will ensure rational action within individual organizational units that are involved in corpporate technological internationalization.

Communication and Coordination Tools in Multinational R&D

The integration of international R&D activities is linked to another two major issues (Hagström 1995):

(1) Functioning of an international communications network
(2) Nature and role of geographically dispersed R&D units within the multinational cluster.

One key issue is the sharing of knowledge across organizational boundaries (Dosi and Teece 1993) and within international organizations. This is highlighted by the case analysis approach, which has outlined some of the problems that arise in multinational clusters operating in science-based sectors whenever knowledge-sharing is inadequately developed (Cerny 1996). It is a particularly important issue in companies that have established their international growth by the creation of decentralized and highly independent organizations, allowing managers considerable freedom in decision-making and in building up local-level relations and processes[16].

Study of the means by which technological know-how is transferred were central to the research program launched by Allen and continued by other scholars at MIT (Taylor and Utterback 1975). This program was expanded to include an international perspective (Allen et al. 1971,

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- in order to make such technology compatible for use in a specific market context in which the organization is localized. In contrast, a "basic R&D mission" is defined as that found in organizations which exhibit a powerful thrust towards investment in corporate research and knowledge, i.e. organizations characterized by a concentration of basic research activities representing the central core of the multinational cluster's store of scientific and technological knowledge (Paoli and Guercini 1996).

[16] In the case study by Cerny (1996, p.23), it is shown that this structure can constitute a point of strength for development of the organization in a wide range of contexts that are strongly differentiated according to their national base; however, it may represent an element of weakness if there is a change in the contextual conditions in which the company operates (a pharmaceutical company in the case analyzed). Thus the company analyzed by Cerny required a system designed to facilitate the flow of knowledge between its organizational borders, and traditional integration mechanisms (including a "survival course" designed to increase communication and trust between participating top managers, instalment of a system of global electronic mail, right up to the creation of international project teams entrusted with revising the production strategy) proved to be insufficient. In order to make a company truly global, freely sharing best practices and critical information throughout its internal borders, the case study in question suggests that a vital role could be played by "friendship".

Herzog 1975), which proposed a gatekeeping model among nations similar to that envisaged among organizational units. More specifically, these studies have pointed out that R&D professionals belonging to a given national community tend to communicate with foreign colleagues on matters concerning technical issues. Some of these professionals appear particularly committed to this aspect, and ultimately become a storehouse of knowledge consultable by other colleagues within the national community, so that they take on the role of gatekeeper in relations between the national community and the international context (or part of the latter)[17].

Thus in order to devise a strategy for R&D internationalization, it is vital to set up and develop organizational capabilities that will be in a position to successfully address the coordination of dispersed R&D activities. Most importantly, coordination must aim to avoid duplication of efforts, reduce variation in products on geogrpahically diverse markets, facilitate technology trasfer, ensure compatibility asmong systems, and draw advantage from the potential benefit of the combination of different aptitudes and skills present in different parts of multinational clusters (hagström 1995, p. 361). Considerable interest has focused on exploitation of electronic information networks as a means of achieving communication between different localizations of multinational R&D, although there is as yet no universal agreement on the precise implications of and mode of utilization of such networks (De Meyer 1993). For although the use of new technologies may have the potential to reduce the critical mass of an R&D department to a single person, it also introduces further complexity, so that many R&D personnel tend to feel that electronic communications are no more than a complement to or temporary replacement of direct physical contact[18].

In some cases, totally new R&D departments whose task is to undertake pioneering corporate research on completely new fronts are deliberately localized away from existing subsidiary organizations, for the express purpose of ensuring that neither the subsidiaries nor even the headquarters themselves dominate the activities of the new unit. This type of operation is generally referred to as a “locational push” rather than a “locational pull”. A “locational pull” is found in cases where the localization of new R&D laboratories is “pulled” by the presence of pre-existing corporate activities in given locations (so-called “corporate locational pull”) or by other activities in the area even though not belonging to the company itself (relational locational pull).

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[17] On this point, Herzog (1975) showed that this was more likely to occur in fields that are most relevant to the economic development of the country to which the gatekeeper belongs.

[18] In a recent study based on explorative interviews with six selected multinationals and on a collection of data from 105 R&D units in Swedish multinationals, Hagström (1995) examined the role of communication and information technologies in management of international R&D, showing that this constituted an increasingly important aspect. A questionnaire administered in the early 1990s (1991) to 96 R&D units belonging to twelve Swedish multinational clusters showed that little use was made of videoconferencing technology (only 4% of the organizational units interviewed declared that videoconferencing was used more than ten times a year, while 84% of the units had never made use of it). The same questionnaire also showed that the common use of CAD/CAM systems and computerized databases was far more widespread (present in three-quarters of the companies sampled).

The case of the "locational push", on the other hand, as mentioned above, occurs when the developmental thrust is given by factors that are not only independent of the presence of pre-existing organizations within the area, but are also attributable predominantly to features of the external context. Such cases include the potential advantage of carrying out research in relative isolation, or the opportunity to acquire inputs (engineers, public funds) independently of relations with other organizations. However, the locational push is seen by some authors more as a process of adaptation and refinement than as resulting from a need to actively exploit a given localization[19].

Studies conducted in the 1990s on R&D in multinational clusters have emphasized that a multinational's research laboratories should not been seen as a homogeneous group: rather, each should be considered as having its own special role to play, which is to some extent shaped by its specific capabilities and external advantages (Bartlett and Ghoshal 1990, Caeldier and Moenaert 1993, Gupta and Govindarajan 1991). Role assignment thus should not be interpreted as a process carried out unilaterally by a centrally made decision, since it is by no means clear that central headquarters can acquire sufficient knowledge on peripheral units to be able to assign them a precise role (Hagström 1995, p.372). On the other hand, the process of role assignment can certainly be favored by the use of sophisticated international information systems, which ensure interactivity among remote locations.

The uncertain, complex and unstructured nature of R&D tasks, taken together with the growing geographic diversification and organizational differentiation arising from R&D internationalization, entail the need to set up a special set of R&D coordination tools within multinational clusters. Some authors have claimed that a purpose-designed set of tools (the latter term is at times explicitly used as a synonym of "mechanisms") is required to coordinate multinational R&D, and a number of studies focusing on this issue have already been conducted (Bartlett and Ghoshal 1989, Casosn and Singh 1993, Kenney and Florida 1994, De Meyer and Mizushima 1989, Westney 1994). The type of mechanisms envisaged include administrative regulations used to coordinate work-related processes and to orient the activities of individual units towards the overall aims of the organization.

A recent study proposing the benchmarking (Roberts 1995) of Western and Japanese

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[19] Some studies have suggested that difficulties encountered in managing R&D are mainly due to communication problems, both among R&D staff and between the latter and external information sources. It is underlined that studies on R&D have focused predominantly on product R&D, defined as "hardware-oriented"; such studies have tended to emphasize the unstructured quality of R&D-related knowledge, which is mainly stored in a product and in the head of research staff. It is known that the "software" component of the product supply is on the increase (Rubenstein 1989). Genuine - literal - software is already prepackaged for electronic transport; the idea of the "software factory" (Cusumano 1991) illustrates the way in which the modularization of software components can dispense with the need for an integrated approach (Langlois and Robertson 1992)It is also proposed that the concept of modularization should be extended to refer not only to the product but also to many associated R&D tasks (testing, recording, scanning the environment, etc.).

companies that are involved in R&D internationalization has suggested a variety of coordination mechanisms, including (Reyer 1997):

(1) Structural and formal mechanisms;
(2) Informal mechanisms;
(3) Hybrid mechanisms;
(4) (Quasi) markets and internal prices.

The "structural and formal mechanisms" may range over a considerable variety of forms, such as centralization or decentralization of decision-making processes, structural coordination bodies that make use of linkage persons, strategic committees (between top executive officers and R&D), transfer committees (between R&D and Divisions), transnational committees, integrators (eg. the Technology Leaders), planning and standardization (R&D policies, job descriptions, handbooks), R&D planning programs as well as budgeting and R&D/technology portfolio planning, control over results and behavior (technical reports, R&D progam/project evaluation, data on R&D results). These formal mechanisms contrast with "informal" tools which are represented by various types of personal and informal contact (personal contacts through R&D managers, visits, conferences, seminars, exchange of scientific personnel, and so on) as well as socialization, which covers such aspects as the creation of an organization-specific culture by means of joint strategies and goals, common values and rules, job rotation within R&D as well as within production and marketing, bonuses, premiums and other incentive devices. One may also find various hybrid mechanisms that occupy an intermediate position between the 'formal' and 'informal' types: for instance limited duration teams generally described as "task forces", multifunctional and interdisciplinary projects, strategic projects, technology/innovation platforms. Finally, the concept of "internal markets" covers both prices within the company and research contracts for the multinational cluster's organizational units. Thus free negotiations are held between groups that express potential supply and demand within the overall organization, such services then being coordinated by internal mechanisms involving discounts or fixed prices. However, such a mechanism presupposes the existence of "profit centers" within the organization, with each organizational unit being responsible for its own profits and endowed with powers of decision-making as regards its choice of customers and suppliers; it also presupposes the existence of company-internal prices[20].

[20] According to Reger (1997, p.306), coordination of multinational R&D activities requires special attention to questions such as: (1) the manner in which R&D interacts with other corporate-level and business/divisional strategies; (2) coordination of central R&D with divisional R&D; (3) fusion of various technological fields for future innovation;

Overall, then, international R&D coordination can be examined from various different perspectives, including both corporate and business/subsidiary-level strategic integration, coordination of central corporate research with divisional development, and the management of transdisciplinary technology[21]. Product technology is becoming progressively complex and science-based, while sources of innovation are more and more linked to a combination of breakthroughs in various technological fields. It is therefore increasingly difficult to attribute innovations to single technological fields (Gruypp 1992), so that the focus of attention is turning to transdisciplinary knowledge management. Some companies have set up central laboratories to address the competences required for technologies of this type[22].

Let us now examine the above aspects of international R&D coordination in slightly greater detail As far as corporate and business/subsidiary-level strategic integration is concerned, a number of structural and formal mechanisms are available (strategic committees, strategic departments, management of technology portfolios, more recently strategic projects) as well as hybrid forms. Coordination of central with divisional R&D can be achieved by a broader spectrum of tools, which include both formal and hybrid mechanisms. Since the end of the 1980s, the share of research contracts deriving from the business units has increased substantially in large western companies[23], while the proportion of corporate funding has undergone a rapid decrease, giving rise to the phenomenon of internal market mechanisms and structural coordination tools designed to link “corporate research” more and more closely with requirements expressed by the businesses and, through the latter, by the end markets. In Japanese companies, on the other hand, the situation in the mid-1990s was markedly different, with no development towards an internal market yet observable. Apart from a few exceptions, the main trend was still that of a predominance of funds allocated by headquarters to finance corporate R&D: indeed, in cases where the share of funding obtained from

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(4) coordination of geographically dispersed R&D units. Reger also conducted an empirical analysis on a sample of companies encompassing three typologies with differentiated characteristics: multinationals that operate as global players guided by R&D and have their base in small highly developed European countries (Philips, ABB, Ciba, Roche, etc.); companies with their base in large European countries and whose technological base is predominantly established in the country of origin (such as Siemens or Bosch, although the chemical and pharmaceutical sector does also feature several large operators with a strong foreign presence, such as Hoechst); Japanese multinational companies, in which international development of R&D activities does not yet appear to be strongly developed (Mitsubishi Electric, Sony, Hitachi), even though notable exceptions can also be found (Eisaj) and there are also some companies that have reached a fairly advanced position (Matsushita Electric).

[21] A fourth element indicated in the recent literature concerns governance of international R&D activities (Reger 1997, pp.310 ff).

[22] An example of this is offered b y Matsushita Electric, which has set up the “Corporate Multimedia Promotion Divison”, with its multimedial central laboratory.

[23] For example, in 1993 this generated two-thirds of the funds that finance Corporate R&D in Siemens, 85% in BASF and 70% in Philips. Up to the end of the 1980s, the main source of funding was represented by “corporate funds”: thus in Siemens two-thirds of the Corporate R&D budget derived from corporate funding, and in Philips corporate funding represented the principle source of funds.

contracts constituted a majority share, this share appeared to be decreasing[24]. Japanese companies rely mainly on informal mechanisms such as holding conferences, workshops and above all exchange of scientific personnel and job rotation systems, with the aim of creating a "cross-company" culture[25].

[24] In this regard, it is again worth quoting Reger (1997, p.315), who states that Sony, unlike the majority of Japanese firms, funds 80% of corporate research through divisional contracts; Hitachi also shows a majority percentage of divisional funding (55% in 1994) but this percentage was actually found to have declined over the previous decade (70% in 1987).

[25] These aspects are confirmed in the above-cited research by Reger, which also shows that while western European companies rely mainly on internal markets, Japanese companies essentially turn to socialization processes.

3. «DIRECT PLACEMENT» AND THE MISSION OF FOREIGN LABORATORIES: THE CASE OF MATSUSHITA.

Matsushita Electric is a major Japanese multinational cluster with over three-hundred subsidiaries, half of which are located abroad, in over thirty countries. A total of 265,000 employees work for this company, whose turnover exceeds sixty billion dollars. Matsushita Electric produces and sells information and communications audiovisual equipment, household appliances, heating and air conditioning systems, telephone networks and systems, audiovisual software, and industrial equipment. The growth of the company has been marked by many changes, among which one may note the 50% take-over of JVC in 1953, the foundation of the first trading subsidiary in the U.S.A. in 1959, the fierce competition with Sony for leadership in the consumption electronics market, and the collaboration with Philips. The latter move led to the creation of a joint venture with Matsushita Electronics Corporation in 1952, and subsequently to total control by Matsushita Electric in 1993.

Features of Matsushita Electric's technological research activities

The first Matsushita «structured» R&D laboratory was established in 1953, representing a milestone in the expansion process of corporate research activities. Today the company has about sixty laboratories, fifteen of which are located abroad. But in spite of this proliferation of technical units, the company's innovation pattern still appears to be characterized by strong centralization[26]. Such centralization is made practicable by a series of «multiple connections» between the headquarters and the foreign subsidiaries, whereby the managerial personnel of subsidiary companies may at the same time fulfill a consultative organizational role within the parent company. This may imply a system of transfers and personnel relocation on an international basis, including the hiring of hundreds of Japanese «expatriate» managers « (over seven hundred in 1995), who operate as managers in the foreign subsidiary companies (Decastri 1993)[27].

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[26] In their definition of a typology of global innovation processes, Bartlett and Ghoshal have also recognised the presence, in Matsushita, of a form of «central innovation process» (the others being the «local innovation process», the «locally exploited innovations» and the «globally connected innovations» – see the two authors' contribution in Bartlett, Doz and Hedlund, 1990).

[27] To describe the mechanism with an example, the vice-president of the video sector of the U.S. associated MESA comes from one of the Matsushita-Japan companies (METC – *Matsushita Electric Trading Company*), and continues to spend about one third of the year in his native country as an active member of MTEC top management, «… thus ensuring that the local unit efficiently implement the strategy arranged with the video sector …» (comment by a manager from Matsushita headquarters). The general manager of the same department of the U.S. associated company has worked at the video product division of the parent company for fourteen years, and is presently maintaining close

The research projects carried out by the central laboratory can be distinguished into two types: the so-called «total corporate plans», concerning the development of relevant technologies for Matsushita's long term strategic position, and the second type, involving projects that are less demanding from the scientific point of view, but essential to developing the activities of the cluster's product divisions. The definition of this second type of projects includes some «internal mechanisms» aimed at governing the interface between R&D and operational units. These mechanisms are found not only in Matsushita, but have also become common in some other Japanese companies (Westney and Sakakibara, 1985). They include annual meetings within the group where the research laboratories of the multinational cluster undertake a commitment to provide information concerning the most promising projects for the future, while, similarly, product divisions present the research programs they would like to sponsor. Allocation of the available resources for R&D activities is scheduled by seeking to match the «demand for» and «offer» of scientific and technological research. This process increases rivalry among the laboratories competing for financial resources and, as a consequence, this phenomenon produces a stronger «market orientation» in R&D corporate activities.

The foreign Matsushita Electric laboratories: development process and mission of the organizational units

Over 40% of the employees of the Matsushita multinational cluster work in the foreign subsidiaries. Company data show that overall R&D activities involve over 10% of its employees, operating both in Japan and abroad. Data regarding the year 1993 indicate that Matsushita Electric R&D investments amount to approximately 5.7% of the multinational cluster's sales, 12% of which abroad, thus positioning the group among the Japanese companies with the strongest foreign presence with regard to R&D activities (Reger 1997). Based on information directly acquired by our observers and referring to 1996, about one quarter of the corporate research laboratories (fifteen out of a total of sixty laboratories) are located abroad. In terms of employees, however, these foreign organizations have a relatively small incidence, with a definitely lower average rate of laboratory workers per individual laboratory located abroad, as compared to the proportion of employees working in the laboratories located in Japan.

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relationships with his Japanese colleagues. The presence of managers from the country of origin of the parent company in the management of the foreign research laboratories is also found within the framework of the foreign research activities of U.S. multinational groups (Krogh 1994, page 25 and the following).

The first Matsushita foreign research unit was started up in the United States in 1976, somewhat earlier than for most big electronics Japanese companies. During the first half of the 1980s, additional research centers were opened and, at the beginning of the 1990s, new plants in North America, South-East Asia and Europe were rapidly established, thus giving the internalization strategy of R&D activities an unprecedented dimension in corporate history.

Table 1. - Foreign engineering centers within the multinational group Matsushita Electric.

Country	Name	Fields of Activity
Germany	ATVC (Audio Video Technology Center)	Audio-video hardware engineering
Singapore	TVRC (TV R&D Center)	Audio-video hardware engineering
Malesia	MACRAD (Matsushita Air-Conditioning R&D Center Sdn. Bhd)	Air conditioning equipment engineering
United States	MIECO-US (Matsushita Industrial Equipment Company US)	Industrial equipment engineering

Source: data provided by the company

Four among the fifteen Matsushita Electric foreign laboratories considered in our study are exclusively engineering centers, while the remaining eleven foreign units carry out various research activities, mainly in the field of applications. Seven of these are located in the United States (four in New Jersey, one in California, one in Massachusetts and one in North Carolina), two in Europe (one in Edinburgh - United Kingdom, and the other in Langen - Germany) and two in South-East Asia (one in Taipei - Taiwan and the other in Singapore). The centers located in the U.S.A., with only one exception, belong to the subsidiary Panasonic Technologies Inc. (PTI), with headquarters in Princeton, New Jersey, and a western office in California. Excluding the Scottish laboratory, which has been included in international technological activities as a result of its take-over, the multinational development strategy of R&D has been implemented by Matsushita Electric through internal growth processes by means of *direct placement* of laboratories abroad. Some characteristics of these foreign research units are described below individually[28].

[28] The data were collected by use of questionnaires and refer, except when otherwise specified, to January 1996.

R&D activities in North America

U.S. research organizations are particularly concentrated in the state of New Jersey: Burlington and Princeton have four out of the seven U.S.-located Matsushita plants - the Matsushita Applied Research Laboratory, the Panasonic Advanced TV-Video Laboratories, the Communications Systems Technology Laboratory and the Matsushita Information Technology Laboratory. All these laboratory have only few tens of staff members.

The first research laboratory to be established abroad by the large Japanese electronics group was the *Matsushita Applied Research Laboratory* (MARL), set up in Burlington in 1980, operating in research activities in the field of video technology development. More precisely, the unit designs software for the processing of digital signals, and is working on computer simulations and the development of programmable digital filters, with results such as the alignment of high-resolution video transreceiving applications, circuits for the processing of video transreceiving signals, and digital video simulators. The number of experts working in this laboratory has progressively increased over time. According to the management, in the 1980s the center essentially focused on applied research activities, while today it engages mainly in development activities. However, the role of applied research is still important, as clearly shown by the range of subjects treated by the unit. Since its establishment, MARL has been 100% financed with resources from the parent company that pass through the control of central Matsushita Electric laboratories. In Burlington, a second research laboratory - *Advanced TV-Video Laboratory* (ATVL) - has been operating since 1990; unlike MARL, it belongs to Panasonic Advanced TV-Video Laboratories Inc. and is a subsidiary of Matsushita Electric Corporation of America (MECA), therefore not formally dependent on PTI. The staff of the research center is composed of members among whom only one is Japanese, while the others, including the unit manager, are from the local area. The number of employees has increased throughout the '90s. The research unit operates in the field of the development of advanced television systems and, in particular, in the development of high-resolution technologies, to meet the high U.S. standards. Since its establishment, the center has carried out development, rather than applied research activities, as clearly shown by the description of its fields of activity and by its management's declarations. Moreover, the center maintains relationships with the other laboratories of the group located in North America (MARL, CSTL), Asia (AVIRC) and Europe (PERDOC). In particular, AVTL has close relations with MARL (the two centers are located within the same building), as they also have common subjects of research. The same building also houses another technical unit of the Matsushita Electric group, called MTOL, which is engaged in fields associated with television technology activities.

The *Communication Systems Technology Laboratory* (CSTL) has been operating since 1990 in Princeton in cable TV technology development, particularly in the field of telephone systems based on cable optic/coaxial hybrid networks. The researchers operating in the unit are all from the U.S.A. (including the manager), except for one Japanese engineer. As stated in the management's report, CSTL's activities, as well as MARL's, have also shifted from genuine applied research to more typical development work, even though, in this case, the contents of applied research are still predominant. This organizational unit has research relations with the other laboratories of the group, particularly with those of the parent company, but also with those of MITL and ATVL. The other laboratory in Princeton is the *Matsushita Information Technology Laboratory* (MITL), established in 1991, operating in the development of advanced information and data collection systems, with applications designed for use in multimedia databases, portable computers, pen computers, customized interface computers.

Established in Santa Monica, California, in 1981, the *Speech Technology Laboratory* (STL) carries out research in the field of intelligent information processing and analysis, automatic speech recognition, comprehension and synthesis with an extensive English vocabulary, natural language processing and software engineering, achieving results in the definition of Japanese-English-Chinese speech synthesis. Among the company's research projects carried out in collaboration with other laboratories of the group, it is interesting to note the "Automatic Speech Recognition" and "Text-to-Speech Synthesis", where STL is the leader within the multinational cluster. The management of this research laboratory likewise reported a shift from mainly applied research to product development activities.

The *Kyushu Matsushita Electric Research Laboratory* (KMERL) was established in December 1990 and is located in the Research Triangle Park, North Carolina. Among the staff members some are Japanese; the researchers operates in the field of technologies for satellite communication systems terminals and advanced software for industrial automation.

The most recent research laboratory established by Matsushita Electric in the U.S.A. is the *Panasonic Technologies Boston Laboratory* (PTIB), first created in 1990 as a connection laboratory and then converted into a research unit in 1993. The unit is located in Cambridge, Massachusetts, and operates in the field of laser applications in the implementation of process production technologies, particularly in the development of precision laser devices and field discharge machinery, also based on research programs involving multiple organizations both in Japan and in the U.S.A.

Table 2. - Foreign Research and Development laboratories within the Matsushita Electric group

Country	Name of the Laboratory	Date of Establishm ent	Modes of establishme nt	Localization	R&D field
United States	Matsushita Applied Research Laboratory (MARL)	1980	Direct placement	Burlington, NJ	digital image technologies
United States	Panasonic Advanced TV-Video Laboratories Inc (AVTL).	1990	Direct placement	Burlington NJ	advanced television systems
United States	Speech Technology Laboratory (STL)	1981	Direct placement	Santa Barbara, CA	audio recognition and speech synthesis systems
United States	Communication Systems Technology Laboratory. (CSTL)	1990	Direct placement	Princeton, NJ	cable TV systems based on optic/coaxial hybrid networks
United States	Matsushita Information Technology Lab. (MITL)	1991	Direct placement	Princeton, NJ	data processing systems
United States	Kyushu Matsushita Electric Research Laboratory (KMERL)	Dec. 1990	Direct placement	Research Triangle Park, NC	satellite communication systems and software
United States	Panasonic Technologies Boston Laboratory (PTIB)	1993	Direct placement	Cambridge, MASS	lasers for production processes
Taiwan	Matsushita Electric Institute of Technology of Taipei (MITT)	Sept. 1981	Direct placement	Taipei	text processing with Chinese ideograms
Singapore	AV / Information Research Center (AVIRC)	1990	Direct placement	Singapore	audio-visual software
United Kingdom	Office Workstation Ltd. (OWL)	Dec. 1989	Take-over	Edinburgh, Scotland	multimedia technologies
Germany	Panasonic European Laboratory (PEL)	Sept. 1991	Direct placement	Langen	Advanced coding and transmission audio-visual systems

Source: data provided by Overseas R&D Office at Matsushita Electric headquarters, referring to the situation in January 1996.

Asian research units

The *Matsushita Electric Institute of Technology of Taipei* (MITT) is located in Taiwan (Taipei). It has been in operation since 1981 and its staff is the largest amongs the overseas R&D laboratory of the firm. The personnel of this organizational unit increased throughout the '80s and then remained constant in the 1990s; the entire staff is local, except for the laboratory manager, who is Japanese. This unit carries out research for the development of text processing in the Chinese language, and particularly in the field of systems for the reproduction of Chinese ideograms, English-Chinese translation and related software applications. It has obtained results in the development of software packages for keying in Chinese ideograms and the related word processors. Noteworthy among the main research projects are the «Chinese Input Method» and the «Card database (DB Form)». MITT is the only laboratory committed to these fields within the Matsushita group. The research activity contents are also evolving, as in the U.S. laboratories, towards an increasing importance of the product development component to the detriment of research[29].

In 1990, the AV / Information Research Center (AVIRC) was established in Singapore, later renamed *Panasonic Singapore Laboratory* (PSL), with an increasing number of employees, which work in applied research activities and mainly new product development, such as applications of advancements in the field of algorithm coding for audio and video digital compression, as well as in the development of consumption electronics products including digital signal processors and their related software. The unit has achieved results in the field of algorithm coding corresponding to moving images, high-quality sound, and in the field of image recognition. Among the main projects carried out by the unit in collaboration with Japanese research centers of the multinational cluster (which are the leader units in these research fields), «LSI Design» and «Multimedia System Development» deserve special mention.

Foreign Research & Development in Europe

Office Workstation Ltd. (OWL) is the name of the Matsushita Electric subsidiary company to which the research unit of Edinburgh, Scotland (United Kingdom), also belongs. It was established

[29] Based on MITT management's estimates, in the period 1985-1990, their activities could be defined as 50% basic research, 30% applied research and only 20% product development. In the period 1990-1995, the situation appeared to be completely different: the estimated percentages were now 10% (basic research), 20% (applied research) and 70% (product development). Source: results from a mail questionnaire sent to the foreign research subsidiaries of Matsushita Electric.

in December 1989 following take-over of the present organization (existing since 1984) by the Japanese multinational cluster. Therefore, OWL is the only case, among the foreign laboratories examined belonging to this large Japanese company, of a unit not established through direct placement. But this is not the only peculiarity of OWL: the evolution of its activities has also followed a different path compared to the other laboratories, partly due to the special manner in which it was incorporated into the multinational group (external growth through take-over) and partly to the distinctive initial features of the British unit. More precisely, the activities of the organization have shifted from mere adaptation of existing products to an increasingly marked orientation towards technological development and a commitment to research activities. The laboratory is active in the field of multimedia and special connection technologies. Two among its most important research projects are particularly worthy of note: «Electronic Publishing» and «Electronic Publishing Technology Development», as this center is the only reference point for these projects within the multinational group. The research budget is entirely financed by the parent company - over one million £ sterling - and the structure of the center is similar to that of the other Matsushita Electric research centers. Among the staff member, some are Japanese managers responsible for the laboratory and local technical personnel. The number of staff members has remained virtually unchanged over the last few years.

The *Panasonic European Laboratory* (PEL) was established in Langen, Germany, in September 1991. Its staff members, five of whom are Japanese managers and engineers. The budget is entirely financed by the parent company and is subdivided into three divisions: (1) the R&D Division, operating in the field of new audiovisual technologies, development of advanced coding and transmission techniques; (2) the European Technological Center, which collaborates with the European Telecommunication Standard Institute (ETSI) and with the European Computer Manufacturers Association (ECMA) in the development of high-resolution and cable TV technologies, television and information standards (in particular, the PAL+ system and computers); (3) the Product Design Center, devoted to the design of European products.

Features of the multinational growth strategy of Matsushita Electric's R&D

As a whole, the foreign R&D activities of Matsushita Electric increased during the early 90s, mainly following direct placement of new laboratories in the United States, Europe and Asia. Closer examination shows that these research units have rather small dimensions as compared to the aggregate proportion of technological activities within the Japanese multinational cluster. As we have seen, one quarter of the Matsushita organizational research units are located beyond the Japanese borders, but only 12% of the expenses for the multinational's R&D is spent abroad. A total of scarcely more than a few hundred employees operate in the eleven Asian, American and European research laboratories examined in our study, representing a very small number as compared to the size of the R&D function within the multinational cluster. Investment by the company in these foreign centers also represents a rather small portion of the total scientific and technological effort sustained by the Japanese multinational group.

In Matsushita, the recently implemented internationalization strategy has actually affected the features of corporate structure much less than was the case in other multinational clusters. In this regard, one of the major examples of a company with substantial R&D activities abroad is Philips, with its over twenty years' research experience in Manor, in the North-American state of New York. The Manor research laboratory, alone, accounts for about 15% of the total research activities undertaken by Philips, and is an integral part of the network of laboratories of the large Netherlands-based company[30]. Another case of a European company with more extended foreign R&D activities than Matsushita's is Siemens, with its great research laboratories located in Princeton, New Jersey which carry out independent R&D activities in the field of imaging, software engineering, applications concerning multimedia technologies and learning systems[31].

Based on our investigation into the multinational development strategies implemented by Matsushita Electric for its research activities, some further considerations can now be suggested. In the first place, all the Matsushita Electric foreign research laboratories involved in our fact-finding

[30] The activities of the U.S. The Netherlands-based laboratory mainly consists in supporting the extensive manufacturing activities of Philips in the United States. The company has four corporate R&D units in Europe: the central laboratory in Eindhoven, Holland, and the three smaller laboratories located in France, Germany and the United Kingdom, respectively. International development of research activities has long represented a real need for the Dutch multinational group due to the size of its national basis; therefore, the annual demand for researchers by the group may in some years exceed the number of engineers graduating from the universities of The Netherlands (De Meyer, 1989). Even in the Philips case, however, the relative majority, if not the absolute majority, of basic research is still carried out in Eindhoven, even though each laboratory of the Dutch multinational has its own technological skills and research programs. In this regard, see Philips Electronics NV (1994) *Annual Report 1993*, Eindhoven, The Netherlands; Philips Electronics NV (1993) *Electronics for people*, in-company brochure, Eindhoven, The Netherlands, p. 13; Philips Research (1993) *Philips Research: A Gateway to the Future*, in-company brochure, Eindhoven, The Netherlands.

[31] This mission is mainly linked to the activities of the headquarters rather than to those of the Siemens divisions in the United States, but the budget of the Princeton laboratories represents only 5% of the entire Siemens R&D budget, which is traditionally one of the largest among the R&D budgets of the major multinationals. In 1994, the budget of the Princeton laboratories was 21.8 million dollars; these data were drawn from the presentation by Knut Merten, Siemens Inc., at the National Academy of Science of the United States, on May 30th, 1995 (quoted by Doremus et al. 1998). As a whole, in 1990, approximately 43,000 staff members were already engaged in research activities in Siemens (3,000 in basic research activities and 40,000 in applied research); among these, over 33,000 worked in Germany and less than 10,000 were abroad. The main foreign research centres of the German multinational group were located in the United States (over 3,000 employees working in communications, medical systems, microelectronics), Austria (2,800 employees working in software and office technologies), Italy (700 employees, in telecommunications), Belgium (650 employees, software, production engineering, telecommunications) Switzerland (500 employees, switch systems); the remaining minor establishments were in other countries. The information concerning Siemens' R&D activities reported in this study were drawn from an editorial of issue 7/8 of the magazine *Fortune*, Italian edition, July-August 1991, p.34.

investigation (with the single exception of the Scottish research laboratory) were the result of direct placement operations[32].

In the course of the 1990s, the evaluations expressed by the management of Matsushita laboratories testify to a gradual shift in focus: activity within the foreign laboratories underwent a transformation from specific applied research to activities more typical of new product development. Such a process might even be considered to be physiological for those centers that were set up in the early ‘90s, which, before expanding to full operational capabilities, carried out predominantly theoretical activities. On the other hand, this evolution could be interpreted according to at least two different, but possibly concurrent, perspectives, as listed below.

(1) First of all, an evolution of Matsushita foreign laboratories in line with more widespread trends in the industrial research setting in specific country contexts, such as those seen, for instance, in the United States, where increasing emphasis has been placed on integrating R&D activities (both «corporate» and «divisional») with the needs expressed by the divisions of the big companies of some sectors of the industrial world (Coombs and Richards 1993, Reger 1997).
(2) In the second place, a reduction of commitment to scientific research resulting from a decline in the original specific role of these centers as driving contributors to the formation of scientific knowledge in the Japanese multinational cluster, i.e. loss of the role for which they were created in the ‘80s and ‘90s.

The presence of an overseas R&D Office within the central Matsushita R&D organization is also observed for several other Japanese companies (Reger 1997), underlining the high degree of integration in the sphere of development of multinational R&D activities. This is particularly striking when one considers the difference in size and characteristics of such activities as compared to those located in the Japanese national base.

[32] The same sort of choice is observed in various Japanese multinational groups that we analyzed, such as Canon and Mitsubishi Electric.

4. Corporate Take-Overs and R&D Internationalization: the case of General Electric.

Corporate R&D in General Electric

The research laboratories included in General Electric's Corporate R&D (CRD) are ranked among the most extensive and most diversified research structures owned by an industrial company. They represent a crucial explanatory element in the production history of General Electric (GE) and in its direct commitment to achieve technological leadership[33].

Today, CRD declared mission is to act as a team with the eleven GE businesses to achieve technologica excellence in the new genereation of products, processes and services, to develop innovations that "change the game", to share technology among GE businesses, to attract and train technical leaders in GE; CRD depend from the GE corporate level, but it is not a "profit center". The laboratories, located in Schenectady, New York, carry out activities integrating the first phases of the research process, including both basic and applied research. Some of the research carried out in these laboratories has received international recognition and has been honored with the award of two Nobel prizes (in 1932 for chemistry, at Langmuir, and in 1973 for physics, at Giaver). Many of the achievements of these laboratories have marked significant progress in various scientific fields[34].

The position of the central laboratories within GE has undergone a substantial change during the 1990s. Change has affected at least two interconnected aspects: the sources of funding for the organization's activities and the internal organization of the research center. A third aspect might be identified as the role of CRD within the framework of the more complex R&D activity carried out by GE.

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[33] The information on the research laboratories and General Electric laboratories was gathered during interviews with managers of the *Corporate Research and Development* unit of the U.S. multinational complex at Schenectady (New York – USA). Some of the considerations developed in this study are based on information that cannot be reported integrally in its original form, due to confidentiality restrictions. The author is the sole person responsible for the statements contained in the text.

[34] The central GE laboratories devised the first reproducible process for the manufacture of diamonds (in 1955), the creation of new high-performance plastic materials (such as Lexan in the 1950s, which subsequently led to the creation of Noryl), the modern X-ray tube for medical use, the first TV transmission in the U.S.A. (in the 1920s), studies on silicon blocks (semiconductors) as early as the 1930s, the electronic development of radon detection, the construction of systems for electronic countermeasures in the military field and the invention of the modern jet plane combustor (in the 1940s).

Corporate R&D activities are not limited to CRD, which receives only a part of the two billion dollars per year spent by the multinational cluster in R&D[35]. In the United States alone, GE'S activities of research, development and engineering involve over 7,000 employees with a degree in some technical or scientific branch. But R&D activities are also found in the foreign subsidiaries, whose importance has increased following the substantial corporate take-overs carried out by GE during the last decade. Within GE'S R&D activities, the role of CRD is predominant, as this function represents the major concentration of resources and scientific/technological skills of the multinational cluster[36].

The staff of the CRD division is composed of 1,590 members, including about 1,100 scientists, engineers and technicians, of whom 515 holding a Ph.D. in scientific or technical subjects. Highly qualified human resources thus form a significant critical mass within the organization. The sectors in which these educational qualifications were obtained cover a very broad range of branches, and over time, during the history of the corporate laboratory and the pre-existing organizations from which it derived, the company has acquired such a vast cumulative body of expertise and know-how that expertise effects must now be added to scale effects[37]. The CRD personnel represent almost all scientific and technical disciplines (chemistry, chemical engineering, physics, electric and electronic engineering, mathematics, mechanical engineering, metallurgy, microbiology, systems engineering, etc.). This variety of talents allows the CRD to set up large interdisciplinary R&D teams to tackle the challenge of complex projects. The extent of scientific and technological skills is demonstrated by the results achieved in the history of the research laboratory. The CRD employs about 10% of scientists and engineers working in GE'S R&D fields, but some outcome indicators attribute greater weight to the CRD within the framework of the entire range of R&D activities of the multinational group. For instance, approximately 30% of the patents and one third of scientific publications (technical papers) are generated in these central laboratories by GE personnel[38].

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[35] Data collected from documentation provided by General Electric's *Corporate R&D*, referring to the year 1997.

[36] The Senior Vice President ofR&D refers directly to the Chairman and CEO; he is directly responsible for CRD, with a role of supervisor of the R&D activities of the whole multinational group.

[37] The CRD was born in 1965 from the merger of the GE Research Laboratory, established in 1900 and among the first U.S. business laboratories committmed to basic research, with the GE General Engineering Laboratory, established in 1895 to develop advanced engineering and instrumentation development activities.

[38] In 1997, out of 811 Us Patents received by GE and its subsidiaries, 229 had been obtained by the CRD research personnel. The employees of the CRD published about two hundred articles, book chapters and conference proceedings. Among the R&D personnel within the CRD, some researchers can boast a significantly high number of patents: four researchers, in particular, have reached as many as a hundred patents each, and two of these have reached the figure of a hundred and fifty. Five more researchers have between seventy-five and ninety-nine patents to their name, seven researchers have between fifty and seventy-four, and fifty-two researchers have associated their name with a number ranging between twenty-five and forty-nine patents.

The CRD is the research center that produces scientific and technological knowledge for the various GE businesses. It is therefore engaged in various fields that may be scientifically remote from one another, requiring the skills of scientists from many different fields of specialization. The core of CRD is represented by the twelve R&D laboratories employing about a hundred researchers each. Up to the beginning of the ‘1990s, the CRD was distributed over a greater number of research centers, each composed of multiple laboratories: thus there were twenty-three laboratories in the early ‘90s, which later, through mergers and reorganizations, became the twelve of today. This evolution has resulted in less specialized research laboratories, moving instead towards interdisciplinarity in the organization of transdisciplinary research tasks (Paoli 1992, p. 231). In general, the research staff working in all the CRD laboratories seems to be rather diversified[39].

[39] The educational qualification of the research staff members of the CRD include the following disciplines: chemistry (18% employees), electric engineering (18%), mechanical engineering (17%), information science (11%), physics (9%), materials science (7%), chemical engineering (5%), mathematics (4%), other disciplines related to engineering (7%) and other scientific disciplines (4%) (Source: data provided by General Electric’s *CorporateR&D Center*).

Table 3. - Corporate R&D (CRD) laboratories of General Electric

Name of the laboratory	R&D Field
Control & Systems & Electronic Technology Laboratory (CSETL)	(a) electronics for control systems, locomotives, gas turbines, aircraft engines (b) power electronics, including locomotive generators, medical systems, elec (c) motor controls for various applications (railway, aircraft engines, medical s
Physical Metallurgy Laboratory (PML)	new metallurgic materials and processes for aircraft engine applications and powe systems; materials life, processes based on gaseous substances, development of
Electronic Systems Laboratory (ESL)	magnetic resonance, ultrasound medical imaging, computer graphics display, adva electronic signaling systems for medical applications, aircraft engines, capital servi
Ceramics Laboratory (CL)	diamond synthesis technology, electronic and optoelectronic materials, technology of ultrasound transducer materials, of ceramic structures and composites;
Industrial Electronics Laboratory (IEL)	high-resolution sensors, electronic lighting, X-ray sensors; light and X-ray physics, indirect applications in control tests of other equipment (aircraft engines).
Characterization and Environmental Technology Laboratory (CETL)	organic and metallic materials; surface analysis, crystallography, implementation o well as chemical monitoring processes
Engineering Mechanics Laboratory (EML)	mechanical technology, design, advanced materials and superconductor analysis, engineering and construction of prototype-phase equipment
Information Technology Laboratory (ITL)	financial modeling, decision-making systems, statistics, data retrieval for quality sys capital business, engineering and software
Manufacturing and Business Process Laboratory (MBPL)	time and cost reduction in process cycles; technology for the industrial us composites, measurement sensors, tomography, infrared, ultrasound, etc.
Polymer Material Laboratory (PML)	study of polymers and their properties (inflammability, stabilization, etc.); new mate
Mechanical Systems Laboratory (MSL)	technology of low-emission combustion for gas turbines, engines for aircraft and lo fluid dynamics for turbomachinery; heat transfer; equipment monitoring and diagno
Chemical Process Technology Laboratory (CPTL)	innovative chemical processes and development of product platforms for the optim environmental impact reduction by chemical and biochemical catalysts, environme

Source: data provided by General Electric Co. Corporate R&D Center

New orientation towards research purchasers and business interface managers in the CRD

Simultaneously with the reorganization of research laboratories, in 1993 a new role was introduced within the central laboratories activities, the business interface manager. This role was designed to be a unit with a highly streamlined organizational structure, sometimes composed only of one manager and the manager's secretary, whose task was to act as an interface between the customers of the research center and the laboratories. For this aim, each manager was assigned a specific technology/program portfolio (Table 4).

The introduction of the business interface management represents the outcome of previous changes in the funding sources of the CRD's R&D activities. Thus since the end of the 1980s, the amount of funds directly granted by headquarters to the Schenectady laboratories has been drastically reduced. The CRD had to devise new modes of financing for its activities, primarily through the acquisition of research job orders from the GE businesses in national and foreign locations (internal contracts) or through external contracts with different organizations requiring the collaboration of these corporate laboratories in their R&D programs.

Table 4. – The « technology/program portfolio» of the eleven business interface managers of the CRD

Advances Technology Business Development
Aircraft Engines Programs
Capital Services Programs
Consumer Programs
Environmental Programs
Industrial Programs
Lockheed Martin Programs
NBC / Information Services Programs
Plastics Programs
Power Systems Programs
Medical Programs

Source: documentation provided by General Electric Co.'s CRD.

This change in the structure of funding sources is linked to other changes in the center's activities. Between the end of the '80s and the beginning of the '90s, some of the research staff with a greater involvement in scientific activities left the CRD for new posts elsewhere, particularly in the field of university research. At that time, the top management had established the requirement that the central laboratories should achieve greater integration of their resources with those of the businesses of the multinational cluster. This in turn had implied a change in research funding sources, consisting in a reduction of the budget allocated by the corporate level and, in parallel, compelling the CRD to focus more closely on the needs of the GE businesses in US and non-US locations, which were in effect becoming the main funding body of the center in the form of research job orders. This increased focus on the interaction with research job orders necessarily involved in this process (Håkansson 1982) was one of the main characteristics of the role of the business interface manager. The CRD did not provide R&D only for its internal customers, but also for external customers, such as Lockheed Martin Corporation and some U.S. government agencies (Department of Defense, the Energy Department, etc.). The financial resources coming directly from the corporate level, which up to the end of the 1980s had constituted about three quarters of the aggregate amount, ten years later had been reduced to approximately one quarter of the CRD financing. If we add internal contracts to the funds made available by the top corporate management, we obtain a rate of CRD financing sources similar to the amount which, in the past, came directly from the corporate level, but which today is being «won» by the CRD through the contracts (mainly research job orders) with the GE businesses in US and abroad.

The task of the business interface manager is to identify any possible contact among GE businesses, and among external purchasers, (usually, the top management of the technical units operating in each one of these bodies, the so-called «Technology Leaders») in order to highlight and propose the CRD potential in the manager's relevant technological field of interest. In seeking to understand the nature of these relations with the other units of the multinational cluster, the example of Nuovo Pignone can be considered emblematic. Nuovo Pignone was taken over in the first half of the 1990s and is now included in Power Systems; a few specific contacts have been identified within the Italian subsidiary, particularly in the research laboratory working on the design engineering and construction of new products. This laboratory is therefore interested in the opportunities offered by collaboration with the CRD.

A «map» of the technology/program portfolio available in GE central research laboratories can be plotted by the CRD divisional top management based on the historical documentation collected within the organization, concerning the profiles of the technical and scientific staff, the expertise and skills of the various research laboratories and the products developed by the latter during the course of their history. These data can be assumed also to be relevant for assessment in the decision-making process concerning technologies (technology management), both as regards the definition of strategies and also from a more operational and contingent point of view. Such evaluative approaches allow partial and simplified information to be obtained which, in some cases, is also disseminated beyond the confines of the laboratories within the framework of reports on research projects and scientific and technological collaboration relations submitted to the attention of partners and customers for research job order assessment. For in spite of its confidential nature, advances in scientific and technological know-how must be at least partly publicized, in the most appropriate manner and according to specific needs and requirements, in order to facilitate decision-making and enhance general awareness of the potential and skills of the research center.

Over the last decade, the quantity of scientific and technical staff has remained virtually unchanged. The new funding mechanism is matched by a stronger integration between the CRD and R&D carried out in the GE businesses in US and non-US locations, above all following the external growth process implemented by General Electric over the last few years. From this viewpoint, the relation between the roles of business interface manager and Technology Leader at the laboratories of the parent company and the subsidiaries represents a primary interface element for integration of geographically dispersed R&D corporate activities. Meetings are officially held twice a year among the vice-presidents of the eleven businesses of the company, while less official meetings are held once a month among the technical managers of the various production units grouped under the eleven businesses. The goal of these meetings is to develop contacts that will help to clarify which R&D collaborations can most suitably be launched as joint projects between units of the multinational cluster (Robinson 1973). However, given that the subsidiaries maintain constant relations with a multitude of research organizations, it would appear that the CRD management imposes no constraints on the subsidiaries as regards choice of subjects from whom scientific and technical knowledge and programs can be commissioned.

External growth and R&D multinational activities: the case of the Nuovo Pignone and General Electric laboratories.

General Electric took over its current Italian subsidiary Nuovo Pignone in May 1994, purchasing the company from the ENI group[40]. The organization purchased was over a century old and its planning activities, as well as the presence of technological know-how, was rooted in time-honored tradition. In the 1960s, Nuovo Pignone started to operate an R&D unit carrying out research in the technological sectors that were of greatest interest for the company (compression technology, fluid dynamics). At that time, the activities of the company were mainly directed towards the field of mechanics for the energy sector, a field that was boosted to develop new products linked to the needs of the ENI group, to which the company then belonged.

Research and development activities are carried out in two distinct contexts in Nuovo Pignone: (1) in the central research and development laboratories; (2) in the organizational units located in each individual business. To these should be added technical activities connected to customer support for installed equipment. As regards the first among these fields of activity, the central laboratories operate under the Direzione per la Ricerca e Qualità (DI/RIQ) (Research and Quality Management), which acts as a central service dealing with research, application and technology development projects, while business activities mainly consist in adjusting and providing direct support to production needs[41]. As a whole, the distribution of financial resources for R&D activities at Nuovo Pignone seems to show that funds are allocated predominantly for research in the central laboratories, to the disadvantage of divisional laboratories. This predominance has become even more pronounced in the last few years and has relatively increased in the presence of an overall reduction of research expense.

Table 5. - Investments and employees in the Italian GE subsidiary's R&D function (in billion lire)

	1993	1994	1995	1996
Total R&D expense	34,6	35,2	25,8	27,2
Central laboratories	18,9 (54,6%)	20,9 (59,4%)	15,6 (60,5%)	-
Divisional R&D	15,7 (45,4%)	14,3 (40,6%)	10,2 (39,5%)	-
DI/RIQ staff (1)	100	86,1	96,3	-
% on the total business staff	2,3%	2,1%	2,3%	-

(1) index 1993 = 100
Source: data provided by the company

The Nuovo Pignone research laboratories have about a hundred employees, subdivided into a planning department, a mechanics and fluid dynamics laboratory, a chemistry-metallurgy and metallography laboratory[42]. Among the approximately thirty graduate employees working in these

[40] At the end of 1996, Nuovo Pignone had 4,771 employees and a 3,012 billion Liras turnover (slightly less than 2 billion dollars).
[41] The Nuovo Pignone R&D function considered, except when otherwise specified, is the DI/RIQ organisation.
[42] Among the technological research sectors treated by the central R&D unit of the company, the field of fluid dynamics, and therefore its related *mechanics and fluid dynamics laboratory*, plays a prominent role. This unit (which is administered jointly with the planning department), has the third of staff members of DI/RIQ, including engineers (some of whom also operate in the planning department), surveyors and a certain number of internal workers. The *chemistry/metallurgy/metallography laboratory* has a fourth of the employees, with some engineers, chemistry and mineralogy graduate. One fifth of staff members work in the *planning department*, including engineers, design

laboratories there are also some graduate researchers with previous experience in academic institutions.

Nuovo Pignone's business research activities cover multiple disciplinary sectors, among which fluid dynamics plays a prominent role, as well as thermal exchange, combustion techniques, stress analysis, materials science, the study and prevention of cold and hot oxidation and corrosion phenomena. The characteristics of these R&D activities are much more similar to «development» than to «research». Nuovo Pignone innovation processes are defined by the management of the central laboratories essentially as «market driven» innovation. This does not imply that R&D resources are exclusively devoted to the development of needs defined (and definable) only by the customers and identified by the «product leaders» in each business. Together with the projects developed to meet the market needs one finds some products that are directly developed by the management and which may be characterized by a rather elevated degree of uncertainty as to the commercial use of their results. Roughly 10-15% of the laboratory resources are devoted to this type of projects.

Before the take-over, the Italian company's R&D had developed relations with several external organizations, in particular with some public research institutions or institutions controlled by public-capital state holding companies, such as Enea, CISE (Enel) and CSM (Iri), as well as with several foreign research institutions, such as the Belgian Von Karman Institute, the U.S. Northern Research Institute, Concepts and South-Western Institute. Nuovo Pignone also maintained intense relations with some Italian university institutions operating in the field of training and updating of research personnel. In some cases, collaborations with other companies regulated by technology-based agreements also involved the large clusters at the forefront of the high-tech market (such as the German Siemens, the Japanese Hitachi, the French Schlumberger, the U.S. Borg-Werner and General Electric itself).

Post-acquisition integration processes in research activities

Following the acquisition of Nuovo Pignone by General Electric, strong relations between the Italian R&D laboratories and the U.S. CRD have been established. The relations of Nuovo Pignone R&D with the technological activities of the multinational cluster that took over Nuovo

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surveyors and a greater number of workers than the previous units (there are therefore no graduates in mathematics, physics or other scientific disciplines in this department) and the proportion of research activities is lower. In recent times, planning activities have focused on the study of «calculation codes», developed both internally and elsewhere, which are then convalidated on an experimental basis.

Pignone are mainly implemented through the relationship with the CRD laboratories, as there are virtually no direct relations with the R&D units of the other GE subsidiaries worldwide. In its relationship with GE'S R&D, the Italian subsidiary preserves its own specific profile and an independent technology development path, based on its own know-how and on the long-standing relationships with the many research organizations that had worked with the company before the take-over. Nuovo Pignone has a form of «sectorial» specialization, having the position of leader within the multinational cluster in the production of small-size turbines (up to 30 megawatt) and in the field of compressor in oil industry .

The collaboration with GE in research and development activities is the continuation of a pre-existing situation for Nuovo Pignone; thus its relationship with the U.S. multinational is not a novelty, as the two organizations worked together before the take-over both in a relationship as licensee and as partners in technology-based agreements.

In becoming a member of the GE cluster, Nuovo Pignone experienced the change from a parent company (ENI) deriving from the same national background - ENI is an Italian company - but remote from the technological point of view, to another parent company endowed with extensive technological know-how, much of which of great interest for Nuovo Pignone's activities. Following the take-over, the opportunities offered by the vast store of resources of the new parent company have contributed to the excellent performances achieved by the Nuovo Pignone[43]. The CRD's research activities represent a veritable «library» offering a wealth of know-how and skills that can be of considerable use in on-going research projects. The relationship between the CRD and the Italian company's R&D displays a number of unique features, including the difference in size between the two research laboratories: the CRD is much greater (twenty- or thirty-fold greater if one considers the respective number of graduate staff) than the central Nuovo Pignone laboratory. The range of competencies of CRD covers a much wider range of application sectors than has so far been the case for Nuovo Pignone, as the latter turns to U.S. laboratories essentially for their know-how in the sectors of industrial turbines and motors.

The approach adopted by the CRD is to offer its own research skills to the laboratories of subsidiary companies like Nuovo Pignone. GE'S central laboratories «... develop marketing strategies for the opportunities they offer … and introduce themselves on the market as a resource made available for the development programs of the companies belonging to the multinational cluster... the R&D laboratories of the subsidiary company are certainly conceived more as a

[43] The balance sheets of Nuovo Pignone show that the turnover rose from 1,394 billion Liras in 1993 to 3,012 billion Liras in 1996, while in the same period the net operating profit rose from 57 to 233 billion Liras, and the net equity passed from 345 to 748 billion Liras.

customer than as a subject to be controlled... on the other hand, CRD is a particularly interesting technology supplier …»[44].

Entry into the GE group has generated many changes in operational processes and in the formalization of research programs. The new corporate requires greater formal control over the procedures to be followed during project development. This is translated into greater process formalization, in the form of the introduction of tall gates and assessment procedures. What seems to be unchanged, and is indeed confirmed and reinforced within the framework of the American multinational, is the customer-oriented attitude of the new product development process that already characterized the Italian company. On the other hand, elements of the multinational's own culture are visible just as strongly in the training of human resources as they are in process formalization, and process and procedure control. Application of the new in-house training methodologies in the subsidiary company results in costs connected to their implementation accompanied by the fear that they might represent a disincentive to allocating resources for research goals.

The relationship between CRD and R&D in Nuovo Pignone has also brought communication and coordination problems. The tools that have been used to favor knowledge and integration of the resources of the two laboratories include: (a) remote interaction means based on new technologies (videoconference, e-mail, file transfer, various forms of telework by the Internet or dedicated networks); (b) mature technology tools (telephone, telex, telefax, etc.); (c) action aimed at developing face-to-face interactions and socialization (researchers' exchange visits, business trips, journeys, etc.). Communication and collaboration between the U.S. CRD and the Italian R&D is not only based on advanced technology investments (such as videoconference means, introduced in Nuovo Pignone in 1995), but also include a development plan for long-term relations with special emphasis on exchange visits, enabling engineers of the Nuovo Pignone laboratory to visit and work in GE'S CRD even for relatively long periods (up to one year). This investment is intended by the subsidiary company to achieve in-depth understanding of the knowledge and know-how that can be found at GE'S central laboratory, partly by personally meeting the people and witnessing their working methods but also by discovering «... many other aspects with which we are not yet familiar but that can only be discovered this way...»[45]. In summary, a sort of «dense network» must be established between the R&D units of the purchaser and of the purchased through typical network relations (Baker 1992, Paoli and Guercini 1996). However, remote communication means are not

[44] These observations were collected during interviews with some members of the R&D laboratories management of Nuovo Pignone.
[45] The quoted sentences are statements made by a manager of the research and development activities of Nuovo Pignone.

sufficient for this kind of integration, as only face to face relations for sufficiently long periods of time can be considered to be genuinely satisfactory.

R&D internationalization of General Electric

The external growth operations that have led to the incorporation of further organizations into the GE multinational network during the last few years characterize the corporate geographical diversification process and determine strong path-dependency conditions in the international development of corporate scientific and technological development. GE did not establish new R&D laboratories abroad by direct placement ,and, in general there were no greenfield plants even in the United States. However, the great multinational cluster has enhanced its R&D international effort through at least two strategies corresponding to external modes of development:

- either by means of the take-over of businesses that had research or engineering units inside their organization;
- or by the creation of joint ventures including collaborative research activities.

The company has accomplished a number of external growth activities in the last few years, particularly through acquisitions that determined an increase in the activities of some businesses of the group (such as Power Systems, with the purchase of the Italian Nuovo Pignone, or Lighting Systems, with the purchase of Tungsram, in Hungary; additional operations also involving management responsibilities have been carried out in France, Russia, Ukraine, the Czech Republic, etc.)[46]. This has led to a stronger presence of technical and research activities abroad. However, the critical mass of scientific and technological skills to be found within the CRD is unequaled in any other foreign unit. The new units introduced in the multinational cluster and, in particular, their research and development organizations, appear to be increasingly considered as «internal customers» for research job orders for the Corporate R&D.

The technological effort of the cluster abroad is becoming increasingly important in some countries of the main continental areas, eg. North-America (Canada and Mexico), Europe (United Kingdom, Spain, Italy, The Netherlands, France, Hungary, Russia, Ukraine) and Asia (China, India and Japan). The company has carried out research in the field of engineering plastics in India with a joint venture with NCL (National Chemical Lab.), an Indian governmental agency with which an agreement was signed for the development of research programs that would offer employment for

[46] One manager of CRD recalled that «… during the last decade, GE has taken over companies for nineteen billion dollars, as against transfers amounting to ten billion dollars … thus redefining its activity portafoglio …».

local scientists and technicians. Significantly, one of the factors that lie at the basis of R&D agreements with Indian and Russian organizations, as well as research investment in Mexico and China, is precisely the availability of highly qualified technical personnel in those countries at definitely lower costs compared to the Western world[47].

During the 1990s, GE'S CRD activities have evolved through several well-defined and interconnected stages including: (1) a gradual change in the modes of financing corporate scientific and technological research, starting from the end of the 1980s; (2) a different manner of organizing the activities carried out by the central laboratories, introduced gradually during the 1990s, (3) greater integration between the research center and businesses activities, particularly with foreign activities.

The development of a stronger orientation of central laboratories towards research job orders required the introduction of the new professional figure termed business interface manager, as well as greater investments in the relations with GE businesses in US and non-US locations. Such investments included the promotion of more intense two-way exchange and communication aimed, respectively, at disseminating information on the potential of the multinational's central R&D laboratories, and acquiring greater understanding of the technological needs of each individual GE business/subsidiary.

In terms of geographical diversification, the internationalization process is significant in applied research and development activities and does not involve any reduction in scientific and technological resources available at the Corporate R&D, as no foreign unit has the same characteristics as the central laboratories. There appears to be a drive to integrate CRD resources with those acquired abroad rather than encouraging them to compete with each other in development of the same activities. Integration in this case appears to be particularly useful due to the complementary nature of the resources available to the various organizations and may be spurred by the new modes of financing the central laboratories, where the ongoing internationalization process is bringing about new processes of integration with the other subsidiary research organizations of recent acquisition.

[47] A further sector of activity is the growth of product-related services, involving three hundred projects at the CRD (acting as a support to the twelve GE businesses), with an R&D expense of 45 million dollars in 1997. These projects focus on advanced equipment inspection and remote monitoring technologies, and on diagnostics for the customer equipment.

5. OVERVIEW: A COMPARISON BETWEEN INTERNATIONALIZATION MODELS

The cases presented in this paper reveal that R&D internationalization in multinational clusters involves a wide range of different phenomena (formation of foreign R&D units, typology of activities carried out abroad, integration processes within the multinational cluster), which contribute to the specific and differenatiated characteristics that can be observed and analyzed within individual businesses. This in turn suggests that the concept of international R&D is in effect an umbrella concept that may cover a broad spectrum of highly diversified situations, representable in terms of different models of corporate research internationalization leading to different combinations among the processes that come into play. For example, the development of foreign corporate laboratories may be associated with decentralization of central R&D, or on the contrary with further concentration of research activities at general headquarters; foreign laboratories may be assigned a research budget with funds allocated by the parent company or, alternatively, they may act as the purchasers of research developed in the corporate laboratories. Thus if R&D internationalization can be associated with such varying types of corporate behavior and modes of R&D management, it seems unlikely that any one evaluation of the motivations and implications of corporate technological internationalization will cover all observable phenomena.

The cases examined here consider two different modes of multinational development of corporate research laboratories: (1) that based on the direct placement of foriegn research laboratories, and (2) that achieved by acquisition of pre-existing organizations already endowed with R&D units. Attention does not focus on R&D internationalization achieved through the evolution of pre-existing technical units into corporate R&D research centers, since the two above-cited modes appear to be those that have the most significant strategic significance. Thus direct placement abroad is emblematic of essentially intentional internationalization strategies, while company takeovers may frequently take place in situations where internationalization is the natural result of an emergent strategy: in the latter case, the external growth maneuver is not (or is not exclusively or not principally) motivated by the aim of endowing the company with (additional) foreign research laboratories (Gerpott 1995).

The combination of these different ways in which a multinational may come to possess foreign laboratories (geographic diversification of R&D activities, through organic or external growth) with the process of R&D integration (through development of purpose-injected resources and capabilities within the organization) corresponds to two dimensions through which one can outline different *models of internationalization of corporate research activities*. The term “model” is used here with the meaning of simplified and standardized representation of the internationalization process taking place in different corporate frameworks. An overview of some aspects of the relation between the pathway of multinational R&D formation and various dimensions of the internationalization process characterizing the internationalization model is given in Table 6:

Table 6. - Dimensions of R&D internationalization models

	Geographic diversification of R&D activities	**Development of resources and capabilities for international integration**
Internal growth	• Direct placement of foreign laboratories • Evolution of pre-existing technical activities into research laboratories	• Ability to read the international scientific and technological context • Development of international R&D visibility and acclaim • Research personnel with international experience
External growth	• Business takeovers • International research agreements; joint venture R&D	• Ability to achieve integration with merged organizations • Relational capabilities to liaise with international research organizations (companies and institutions)

Source: present author's elaboration

Adopting the perspective of strategic pathways of corporate organization, the characters of R&D internationalization have been highlighted in this paper through case studies focusing on the behavior of the parent company vis-à-vis its subsidiaries in two large multinationals: General Electric and Matushita Electric. Analysis of these cases shows that the central and foreign laboratories carry out notably different activities, which may be strongly influenced by conditions arising partly from their previous history but also from the very process of internationalization of corporate technological activities (*path dependency*). In effect, there are clearly observable differences in internationalization model between the two multinationals, affecting both the type of geographic diversification and ithe ntegration processes set in motion, and such differences cannot be described merely in terms of the growth of organizational units in an international framework. Foreign laboratories can perform different activities, and can be acquired in different ways; consequently, it is often considered more appropriate to place emphasis on a "vertical" rather than "horizontal" level of study of this phenomenon. In the two multinationals in question, the observable internationalization processes are quite heterogeneous as regards their developmental models, contrasting not only in the emphasis they place on different aspects of integration (at corporate level or with other components of the national integration system), in the role of foreign labs within the corporate system, in the manner of funding research (and the way in which this interacts with different corporate governance systems). It can in effect be stated that these two cases are emblematic of the contrasting underlying forms and logic of internationalization.

The manner in which foreign units are formed generates path dependency, in particular when pre-existing firms are taken over. This is because the history of the firm in question may exert a strong influence over the role assumed by the business laboratories within the multinational complex and indeed over the subsequent integration processes. More specifically, the acquired firm may have had ongoing relations with other organizations within its own national context, and may therefore experience less difficulty in integrating these research units into the innovation system of which they have long formed part. Thus the presence of consolidated relations between the pre-existing organization and the other components of the environmental system could result in a situation whereby integration with the local - i.e. the "foreign" system could effectively already be in place, so that the only remaining integration task would be that of rendering the acquired company compatible with the rest of the multinational cluster. In the case of direct placement, it is frequently possible *ab initio* to obtain greater integration with foreign workers, on account of the possibility of operating in greenfield conditions during formulation of the organizational variables under examination here.

Table 7. - Some characters of the internationalization models corresponding to the two emblematic cases examined

Matsushita	**General Electric**
• Foreign R&D units funded by the corporate level of MNC. Financial flows from Corporate level to foreign R&D units. • Laboratories created by direct placement as the effect of a purpose-made strategic decision by the center, where there is an *Overseas R&D Office.* • Role of foreign labs focusing on knowledge acquisition, on development of market-specific products, assistance to local production activities (basic or adaptive mission). • Emphasis on integration of the foreign R&D unit with its local setting.	• Foreign R&D units act as "customers", funding the activities of corporate laboratories by sending job orders. • Laboratories obtained by take-over of pre-existing companies. • Role of foreign labs oriented towards specific sectors of competence, include research job orders, and therefore as customers for the central R&D laboratories (sectorial mission). • Emphasis on integration of foreign R&D units with Corporate R&D activities.

Source: present author's elaboration.

Comparison between these two multinationals highlights the features that make them truly emblematic of the different corporate R&D internationalization models- These two large companies both developed their multinational R&D strategy during the early 1990s, but they followed significantly different approaches (Table 7). Matsushita's emphasis on direct placement of new foreign R&D laboratories reveals its commitment to constant monitoring of the evolution of scientific and technological know-how in contexts characterized by the presence of other important research centers. This is underlined by the fact that their laboratories are often localized within spatial agglomerations that of are relevance for other innovation systems in the host nation, or offer easy access to important market outlets. But even when there is diversification (including deliberate), the most "basic" part of R&D is retained within the country of origin (that is to say, the headquarters carry out radically different activities compared to those of the subsidiaries). Furthermore, Matsushita's R&D activities are carried out on a far smaller scale in its foreign labs than in those forming part of the parent company. In the case of General Electric, the core research, i.e. the most basic part, is kept within the organizational context of the parent company (see for example the type of relation holding between General Electric's Corporate R&D and the R&D carried out in some of the subsidiaries' laboratories, eg. Nuovo Pignone). It should also be noted, however, that after the series of takeovers conducted during the 1990s, local R&D has increasingly taken on the role of a scientific and technological knowledge interface between parent company and subsidiary, where the parent company gradually fosters new interfacing skills and competences designed to fit new roles that fulfil an integrating function (such as the business interface management at General Electric). In both cases these foreign laboratories by no means replace "in-house" research: instead, the foreign laboratory may actually represent the multinational company's best research customer.

Finally, to complete the picture, it cannot be overlooked that both for General Electric and Matsushita, a closer examination of the development of some of their foreign research organizations reveals significant limitations. Where direct placement has been used (Matsushita), the foreign units do not appear to have experienced substantial growth since the ealry 1990s, while in situations where takeovers have been carried out (General Electric), the merged company's R&D budget may actually have undergone a decrease during the post-acquisition years.

In conclusion, even when multinational companies appear fully on a par with one another in terms of the extent of their R&D effort (equal number of laboratories localized abroad, similar number of employees or similar quantity of funding), multinational R&D can still take on a markedly different nature in the level of integration processes. As we have seen, these differences pertain to the pathway by which the multinational cluster comes to possess such laboratories. The two case studies presented here show the presence of this relation between the mode of formation and integration processes in multinational R&D.

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