Journal of International Management 17 (2011) 114–129

Contents lists available at ScienceDirect

Journal of International Management

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Coordinating decentralized research and development laboratories: A survey analysis

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ARTICLE INFO

Article history:
Received 3 August 2010
Accepted 19 September 2010
Available online 5 November 2010

Keywords:
Multinational enterprises
Decentralized R&D laboratories
Coordination mechanisms and instruments
Greece

ABSTRACT

The growing internationalization and strategic diversity of research and development (R&D) activities create important managerial challenges for the globally competing multinational enterprise (MNE). Driven by recent theoretical considerations and empirical studies, we provide complementary insights to the international management literature by investigating the impact of strategic variables (roles of decentralized R&D units) and some commonly studied FDI characteristics (industry, size and country of origin) on the coordination patterns used in the context of international R&D. As a conceptual background, five categories of coordination mechanisms are generated (structural, formal hierarchical, people-based, social and information technology platform infrastructures). Our findings, based on a quantitative inductive analysis, reveal that laboratory-related characteristics (roles, age and size) stand out as the most influential determinants of coordination mechanisms and instruments. The study also highlights that MNEs are moving towards a more complicated and multifaceted integration pattern of their decentralized technology strategies. Implications for international managers, academic researches and decision makers are discussed.

1. Introduction

Early analysis (e.g., Caves, 1971; Vernon, 1966) of the capability of firms to become multinational enterprises (MNEs) saw sources of innovation as entirely centralised and conceived the only international knowledge-related function as being the *transfer* to overseas use of centrally generated technologies (Manolopoulos et al., 2007). Hence, initial perceptions on the internationalization of technology saw no systemic role for decentralised research and development (R&D) activity, but only the limited one of supporting the ability of subsidiaries to *adapt* parent company technologies to the needs of their market environments (host countries and local conditions). This traditional explanation though, seemed unable to account for the acceleration in the worldwide diffusion of MNEs' elements of knowledge-related competitiveness and the redefined missions of expatriate R&D (Niosi, 1999).

Current work (e.g., Cantwell and Piscitello, 2007; Marin and Bell, 2006) has recorded a quantitative expansion of MNEs' basic research and industrial R&D activities, which now takes place at a much faster pace and spreads more widely with significant international cross border flows (Criscuolo and Narula, 2007). In addition, it involves more than the effective *application* of the parent's creative inputs to host environments, including also the generation of other asset-augmenting activities; derived mainly by the need of MNEs to employ distinctive technological competencies from geographically dispersed locations (Papanastassiou and Pearce, 1999). Three factors underpinning the gradually more advanced positioning of decentralized laboratories can be extracted from the literature.

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doi:10.1016/j.intman.2010.09.012

First, the new imperatives of global competition are increasingly related to: (i) original product *development* rather than mere technological *adaptation* (Hansen et al., 2005; Kuemmerle, 1999), and (ii) the importance of foreign subsidiaries in patenting (Belderbos, 2003), which will nurture major inventions and innovations for both the local and the world markets (Niosi, 1999). Second, supply-side influences (the extent to which MNEs may gain a competitive advantage by tapping into foreign located assets and innovation systems, such as highly skilled scientific personnel, proximity to universities, research centres and scientific institutions and access to low cost supply of R&D personnel) comprise another influential factor in determining the scale and scope of foreign R&D (Criscuolo et al., 2005; Dunning and Lundan, 2009; von Zedtwitz and Gassmann, 2002). Finally, the centripetal organizational forces that were supposed to secure MNE-specific advantages have now become weaker, mainly due to the improved means of international information and communication technologies (Gassmann and von Zedtwitz, 1999). For the individual decentralized R&D laboratory, this extended strategic diversity now underpinning its operations significantly increases the physical, financial, informational, knowledge, as well as temporal interdependencies, leading to an upgraded importance and complexity of the coordination function.

In spite of the apparent importance of how to coordinate globally dispersed R&D operations, our knowledge on the topic is still neither complete, nor conclusive (Ambos, 2005; Brockhoff, 1998). While the coordination concerns of R&D internationalized activities have been raised by strands of both an earlier (e.g., Hirshey and Caves, 1981) and a more nascent (e.g., Frost and Zhou, 2005; Manolopoulos et al., 2007) literature, there are three main deficit areas that have been identified; providing sources of new insights for research: first, while there exist many different instruments for achieving MNE inter-unit vertical integration, we are not aware (with the exception of Reger, 1999) of any systematic, empirical investigation of this wide variety of coordination mechanisms that are suitable for application in the context of international R&D. According to Reger (2004: 56), in most of the relevant studies "…the mechanisms are not explicitly systematized, and, in most cases only a small selection of possible instruments are described or analyzed". Second, the majority of research undertaken in the field has been done at the level of the parent firm (e.g., Asakawa, 2001; Belderbos, 2003). In fact, only a very limited number of studies have examined the determinants and characteristics of MNE integration at the subsidiary level (Ghoshal et al., 1994; Harzing, 2001). However, when research emphasis is placed on the management of MNEs' functional units which are characterized by internal diversity within the network and specialization (notably R&D units), the scholarly importance given to HQs is not quite attenuated, since decisions that impact on potential interdependencies should be better analyzed at the subsidiary level (Doz and Prahalad, 1984). Finally, much of the extant literature in the field is anecdotal, conceptual or limited in focus, in the sense that it mainly draws on qualitative information only (e.g., Reger, 1999; Asakawa, 2001) and/or empirically explore the influence of only few contingency factors that influence integration and inter-unit coordination (e.g., Martinez and Jarillo, 1989; Ghoshal et al., 1994).

We attempt to address these gaps in the literature by categorizing the coordination instruments identified in the broad international management literature and by providing some systematic, albeit limited, empirical evaluation of the impact of key strategic variables (together with some commonly studied subsidiaries' characteristics) on the coordination mechanisms employed in the context of internationalized MNE R&D activities. Hence, the broad question we address in this research is: *What are the suitable mechanisms employed for the coordination of international R&D in MNEs, and what are the relations between these coordination mechanisms and the strategic role of decentralized R&D labs?* By surveying these relationships we respond to the recent plea for research focused on the organization and management of global R&D (Hansen et al., 2005; Reger, 2004).

Two distinctive contributions emerge from our analysis: First, by adopting a quantitative inductive logic, we move away from the straight-jacket of conceiving the research within the boundaries of a deductive hypothesis-driven approach, which limitations are obvious from the scarcity of related literature. This approach enables us to generate a contingency-dependent typology of coordination patterns – modes and mechanisms – and analyze their applicability in integrating decentralized R&D activities. Thus, conceptually, we complement existing integration literature by considering the potential impact of specific coordination instruments that were underexplored in the context of international technology management. Second, by including in our analysis both organizational and strategic variables and adopting the decentralized "subsidiary-focused" perspective – which appears to has gained considerable momentum in the literature recently – we revisit and extend empirical research by providing insights on the following: (i) the prevalence of the "traditional paradigm" of the management of MNEs which assumes tight integration and de-emphasizes subsidiaries' autonomy and influence, and (ii) the explanatory power of contextual and strategic variables in determining coordination patterns within MNEs' technology trajectory.

The paper is organized as follows: we first propose the theoretical background and framework for classifying overseas R&D laboratories and coordination mechanisms and generate our research propositions. We then present the research methodology, followed by the evaluation of the coordination patterns of decentralized R&D in the focal country. Next, we present and discuss our empirical results. In the final section we conclude, by positioning our findings into a wider conceptual, managerial and strategic perspective.

2. Literature review and theoretical development

The pioneering studies by Lawrence and Lorsch (1967a,b) demonstrated how different conditions in the organizational environment result in differences in the nature and forms of coordination. For relative stable environments that are characterized by little differentiation and face routine problems, simpler forms of integration appear to be effective and usually take place at the higher levels of the organization (Moreno-Luzón and Lloria, 2008). On the other hand, for differentiated environments that are characterized by uncertainty, complexity and dynamism (such as the knowledge-creating units), coordination seem to be a complicated process that requires more sophisticated mechanisms (Moreno-Luzón and Lloria, 2008). Literature supports that in the context of international R&D, coordination is a multifaceted function that should be tailored to the specific tasks assigned to each distinctive unit (Asakawa, 2001; Nobel and Birkinshaw, 1998). Further, Reger (2004) argues that apart from organizational attributes, coordination at the MNEs'

R&D level correlates also significantly with various strategic variables. Accordingly, the theoretical background of this paper is based on two groups of studies: the first group is focused on the different roles played by foreign R&D labs. The second includes papers examining the major kinds of coordination mechanisms employed in the management of different organizational units. The combination of these two groups of studies allows us to survey the coordination function of decentralized R&D activities.

2.1. Roles of decentralized R&D laboratories

Any attempt to scrutinize, understand and evaluate the management of overseas R&D activities adopts the view that the international expansion of technology creation and application is central to MNEs' pursuit of global competitiveness (Pearce, 1999). This is reflected in the very distinctive roles played by specific MNE labs, reflecting, in turn, the strategic positioning maintained by the subsidiaries with which they are associated (Papanastassiou and Pearce, 1999). There is a substantial amount of studies on the typologies of industrial R&D. Based on groundbreaking research in the late 1970s and early 1980s (Behrman and Fischer, 1980a,b; Hakanson, 1981; Ronstadt, 1977, 1978), the extant literature was mainly focused on the location of R&D activities and the intended markets (local or global) for R&D results (Li and Yue, 2005). Increasingly, managerial and strategic aspects entered the discussion (e.g., Asakawa, 1996; Chiesa, 1996; De Meyer and Mizushima, 1989; Gassmann and von Zedtwitz, 1999; Kuemmerle, 1999; Niosi, 1999; Sachwald, 2008); indicating an evolutionary approach towards the dynamics and management of R&D internationalization. The different strategic mandates assigned to overseas R&D units are at the core of that research stream (Manolopoulos et al., 2007).

The classification we propose to adopt here derives from the works of Haug et al. (1983), Hood and Young (1982) and Pearce (1994) and identifies three distinctive roles for an overseas R&D laboratory: the first refers to the effective application of the existing technologies at the level of the MNE group. Its main function is, therefore, *adaptation development*, either of the product (so that it may need the distinctive characteristics of the subsidiary's market), or of the production process (so as to use most effectively the production environment of the host country). Laboratories playing this role are defined as *Support Laboratories* (SLs). The role of SLs is considered critical for the short term successful commercialization of subsidiaries' output in already determined target markets. As the limited adaptation role of SLs may decline in relevance over time, two other more ambitious positions can be found for overseas R&D in the pursuit of global competitiveness by MNEs (Manolopoulos et al., 2007). The first refers to an R&D unit in a particular country, which operates as a closely integrated part of a subsidiary there, to develop a distinctive product that can be supplied to a regional, or even global, market (Pearce, 1999). This type of R&D lab is defined as *Locally Integrated Laboratory* (LIL). Instead of using the existing MNE's technology in order to improve the adaptability of well-established products, LILs extend the scope of the subsidiary, by expanding the competitive product range of the group, i.e., they have a more "productive" scope. The remaining possible role that can be distinguished for a laboratory, or the second that plays a part in the longer-term competitiveness and global-innovative strategy, is to provide basic or applied research inputs into a program of pre-competitive work organized by the MNE (Papanastassiou and Pearce, 1999). Thus, in contrast with the previous laboratories' roles, this lab type should be integrated not necessarily with other subsidiary's functional departments, but with similar laboratories of the MNE in other countries, and especially with a parent laboratory, which is expected to coordinate the overall research program. The laboratories that are involved in such tasks are termed as *Internationally Interdependent Laboratories* (IILs). Table 1 bridge the divide among the different roles of decentralized R&D units, their contribution to the wider competitive context of MNEs and their expected coordination concerns.

Building on the previous discussion, the following research proposition can be formulated:

Research Proposition 1. *The integration of different strategically motivated types of decentralized R&D units with MNE technology strategies is subjected to distinctive coordination requirements, and, thus, is associated with the use of diverse mechanisms and instruments.*

2.2. Coordination mechanisms and instruments

Although MNEs' R&D is not as intensively internationalized as other business functions (such as marketing and production), its effective coordination into an operational whole provide MNEs with competitive advantages not available in single-country centralized R&D facilities (Li and Yue, 2005). In international management, coordination could be broadly defined as "…the integration of value-added activities that remain dispersed across subsidiaries" (Martinez and Jarillo, 1991: 431). This process of integration requires administrative tools which are called *mechanisms* and "…orient work-related processes and individual activities towards the aims of an organization" (Reger, 2004: 56). Based on both an early general and global integration literature (e.g., Baliga and Jaeger, 1984; Mintzberg, 1979; Ouchi, 1980; Ouchi and Johnson, 1978; Thompson, 1967; van de Ven et al., 1976), the coordination function is roughly divided into two types: formal and informal, akin to Barnard (1968/1938) formal and informal organization, respectively (Martinez and Jarillo, 1989; Tsai, 2002; Kim et al., 2003). These two modes map well onto (i) the hypothesized one-to-one direct relationship between different kinds of organizational dependencies and the coordination imperative (Galbraith, 1973; Mintzberg, 1979; Thompson, 1967; van de Ven et al., 1976), and (ii) the importance for international management to distinguish between *bureaucratic* and *social* coordination requirements (Cray, 1984; Ouchi and Johnson, 1978).

By the early 1990s, coordination had become an important subject of inquiry for the study of MNEs. Based on the seminal work of Thompson (1967) that has identified three coordination types (coordination by plan, by mutual adjustment and by standardization), Martinez and Jarillo's (1989, 1991) studies are considered the cornerstone for further developments in the international business field. The authors have developed a comprehensive classification framework for coordination (coordination by plan and coordination by feedback), referring to five categories of "formal" (p. 431–432) mechanisms (departmentalization, centralization or decentralization,

Table 1
Roles and characteristics of decentralized R&D units, their support to MNE competitiveness and coordination concerns.

Typology of decentralized laboratories	Role	Contribution to MNE competitiveness	Characteristics	Coordination concerns of the unit
Support laboratory (SL)	Tactical support for the localized application of established commercial MNE technology	Effective rationalization of the supply of a limited part of MNE product range close related to the distinctiveness of host country (short-term)	Goal oriented functional unit with clearly commercial aspect, employs mainly technicians.	SLs serve to strengthen the subsidiary's scope in ways that remain securely anchored by the mainstream technology of the group. Thus, they are characterized by a high dependency from the HQs and/or a central hub. Tight monitoring and centralized control is expected.
Locally integrated laboratory (LIL)	Entrance into new globalised approaches to innovation in MNEs by developing new products (or very distinctive product variants) for key segments of the global marketplace	Development of strategic competitiveness by the commercial evolution of existing core technologies through enhanced embodiment in major new generations of globally competing products (short- and medium-term)	Functional unit aiming at promoting new products/ processes, use of inventions and patents, employs mainly inventors and engineers.	LILs individualize their technological capacity by deriving distinctive perspectives from a position in two knowledge communities; that of the MNE group and that of the host country research institutions and science base. Thus, they are characterized by high interdependencies with subsidiaries' internal and external environment. A multifaceted use of coordination mechanisms is expected.
Internationally independent laboratory (IIL)	Carry out basic or applied research as a part of a precompetitive R&D programme	Regeneration and revitalization of the MNE group's core technology itself through participation in programmes of basic research (long-term)	Promote new knowledge, use of discontinuous and in-depth methodologies, employs mainly scientists.	IILs are based on academic interest and hypotheses in order to advance knowledge. They utilize a wide range of information from (probably) different scientific disciplines. They are not close interconnected with other subsidiaries' functional units but with other MNE similar units and scientific institutions. Informal, people-based coordination is expected.

formalization or standardization, planning, output and behavior control) and three types of "informal" (p. 432) mechanisms (lateral ties, informal communications and socialization). Since then, there have been various attempts to classify and sort the different modes and instruments an MNE employs in order to coordinate its geographically dispersed activities (e.g., Ghoshal and Nohria, 1993; Harzing, 1999; Kim et al., 2003), including R&D (e.g., Asakawa, 2001; Nobel and Birkinshaw, 1998).

For the purpose of this research, we have used as starting-point for our systemization of coordination mechanisms the literature review by Martinez and Jarillo (1989), the work of Tsai (2002) on the social structure of coordination and competition within intra-organizational knowledge sharing, the empirical research of Kim et al. (2003) related to the global integration of MNEs' business functions, as well as the classification provided by Reger (1999) for the coordination mechanisms employed in internationalized R&D. This leads us to delineate five sets of coordination mechanisms: (a) structural, (b) formal hierarchical, (c) people-based, (d) social, and (e) information technology platform infrastructures.

2.2.1. Structural coordination mechanisms

Following the Aston studies (Pugh et al., 1968) and the studies by Gerybadze and Reger (1999) and Moreno-Luzón and Lloria (2008), structural mechanisms formalize the ways in which functional activities are coordinated across units. Broadly defined, structural mechanisms pertain to the use of rules and official procedures in prescribing organizational behavior (Hall, 1996). They have an impersonal character and their purpose is to regularize and routinize work processes so as to reduce the ambiguity associated when linking highly specialized operations (Miller and Droge, 1986). This set of mechanisms is well manifested in the coordination of business activities through written policies, formal reporting systems, programs, or processes, which March and Simon (1958) identified as key means for task coordination. In structural mechanisms, we also include here some formal (non-structural) elements that provide "…a unique complement to structural mechanisms, facilitating the organization of work" (Moreno-Luzón and Lloria, 2008: 259), such as the *standardization* of skills and outputs (Mintzberg, 1979).

2.2.2. Formal hierarchical coordination mechanisms

Organizational scholars have long studied and recognized the antecedents of hierarchical controls as a mechanism to manage uncertainty and achieve integration (e.g., Ghoshal et al., 1994; Gulati and Singh, 1998). Hierarchical governance modes, through vertical referral, can effectively address the anticipated coordination concerns resulting from various interdependencies.

Literature (e.g., van de Ven et al., 1976; Scott, 1992; Tsai, 2002) has considered several features, including *centralization*, *formalization* and *specialization* as effective indicators of command structures and authority systems. The common denominator of all of these attributes is that they facilitate task coordination by clarifying decision-making procedures and anticipating issues before they arise (Gulati and Singh, 1998). However, according to Child (1972), these features are not independent. In particular, "…centralization itself represents a somewhat partial but parsimonious operationalization of the structure domain" (Ghoshal et al., 1994: 100).

While recognizing that centralization itself does not adequately capture all the elements of a formal hierarchy, we consider it as a focal aspect. Arguably, since centralization defines a structural organizational design dimension (Egelhoff, 1988; Miller and Droge, 1986), it cannot be conceived *per se* as a coordination mode or instrument. Though, in an abstract way, it can be considered as an *enabler*, i.e., a process that allows an organization to achieve its objectives (Moreno-Luzón and Lloria, 2008). This could partially explain why centralization has such a long academic tradition within the coordination/integration literature (e.g., Martinez and Jarillo, 1989, 1991; Tsai, 2002; Reger, 2004). A high degree of centralization implies that "…decision making authority lies in the business head office, where there exists a more complete understanding of various units and activities scattered all around the world" (Kim et al., 2003: 330). Accordingly, a hierarchical structure is built upon centralization of decision-making authority, where coordination is achieved through vertically imposed bureaucratic processes (Tsai, 2002). To extend this argument, high levels of centralization enable MNEs to retain control of critical aspects of both strategy implementation and the value chain. In that sense, centralization restrict the relative autonomy of local R&D units; allowing in that way the parent company to acquire all the advantages derived by the increased coordination, such as easier communications, economies of scale from tightly coordinated activities and reduction of R&D redundancy and uneconomical product differentiation (Granstrand and Fernlund, 1978).

2.2.3. People-based coordination mechanisms

People-based coordination mechanisms principally involve a "…number of members who interact between units" (Asakawa, 2001: 10). MNEs rely heavily on interaction and communication to achieve coordination of business functions across borders (Cummings, 2004; Kim et al., 2003). In this set of mechanisms, we can include the interaction of formal groups who share a common objective and are responsible for a particular output, but also organizational members not formally integrated in any group (Moreno-Luzón and Lloria, 2008). In this regard, people-based coordination mechanisms comprise a dynamic administrative dimension, contributing to organizational development through the relational ties that take shape and facilitate the efficient exchange of knowledge in ways that may, or may not, be an explicit or institutionalized part of the organizational structure (Harzing, 2001). In this category we include interpersonal relations, informal communications and more formal corporate practices, such as visits and the international transfer of managers and teams.

2.2.4. Social coordination mechanisms

Social coordination mechanisms guide employees within an organization to share values and develop common understanding, vision and expectations (Van Maanen and Schein, 1979). This category subsumes a range of instruments related to the creation of a common set of believes, such as corporate culture and shared language. The importance of common language as an influential coordination instrument in international setting was firstly developed by Hedlund (1986) and tested by Nahapiet and Ghoshal (1998: 253–254) who have argued that "…shared language influences the conditions for resource combination and exchange both through direct impact and perceptual filtration". Conversely, differing language and codes can keep people apart and restrict their access to each other (Gudykunst, 1991; Gudykunst and Kim, 1992; Kim, 1988). This is especially the case for research activities where the use of a common technical vocabulary creates a common understanding, limits the duplication of researchers' effort, lead to consistent analysis and increases the effectiveness of communications. Corporate culture consists of some basic elements, such as shared behaviors and values, joint goals and strategies, norms and beliefs, reward and incentive schemes and every evidence that promote the understanding of an organizational entity (Schein, 1996). A strong "corporate culture" serves as a very valuable coordination instrument, since it enables the firm to respond successfully to changing environmental constellations. This set of mechanisms is consistent with *socialization and mutual adjustment* (Mintzberg, 1979).

2.2.5. Information technology platform infrastructures (ITPI)

Information technology platform infrastructures (ITPI) coordination mechanisms, such as intranets, electronic mail, corporate databases and video-conferencing, are instrumental for linking technological and organizational advances in enterprises (Kim et al., 2003; Söderquist and Nellore, 2000), and are mainly used when "…large volume of information can be easily analyzed and interpreted without extensive face to face communications" (Kim et al., 2003: 331). These instruments of coordination through data management (Doz and Prahalad, 1984) enjoy a rapidly increasing importance in organizational theory, since by summarizing the works of Nickerson (1992), Sproull and Kiesler (1991) and Miles and Snow (1986), information sharing imply a more than sufficient communication sharing; making coordination in the procedure of information exchange and knowledge development more complex and unstructured.

The different attributes and characteristics of the coordination mechanisms identified and analyzed within international management integration literature indicate that:

Research Proposition 2. *There exist a variety of possible coordination mechanisms and instruments from the field of international management that can also be suitable applied in the context of international R&D.*

Table 2
Five categories of R&D coordination mechanisms.

Coordination mechanisms	Characteristics	Aim	Coordination Instruments (examples)
Structural (and non-structural)	They have an impersonal and structural character; detaching the process of aligning decisions and actions from the human being. In those mechanisms, no direct intervention or personal interaction between different agents actually takes place	To set standardized procedures for channeling and monitoring independent activities	*Standardization* *Planning* *Output control* *Manuals* *Job description* *Written policies*
Formal hierarchical	Formal elements of hierarchical corporate governance that impact on both organizational and functional efficiency by providing a structure and authority system with defined responsibilities; clarifying in that way decision-making authority.	To coordinate through vertically imposed bureaucratic processes	*Strategic and operational centralization* [a] *Specialization Formalization*
People-based	Mechanisms, which are in favor of periodic, aligned with organizational hierarchy, personal interaction between different levels of managers and personnel and/or interactive and informal communications	To delegate managerial potential from one subunit to another for a defined time period so that a direct co-work of home country, host country and third country, when necessary, nationals occur and to promote horizontal communication and interaction	*International transfers* *Cross border visits* *Strategic teams* *Social events* *Team building* *Conferences, workshops*
Social	Employees learn which behaviors and perspectives are acceptable inside an organization, through informal, permanent and difficult to change mechanisms	To create a common background for the whole organizational entity and provide the power associated with implicit norms to guide the behavior of organizational members	*Corporate culture* *(Technical) Language*
Information technology platform infrastructures	Mainly informal and impersonal, dynamic, both communicative and system oriented mechanisms	To coordinate through ICT	*Video conferencing* *e-mails* *Intranet*

[a] Enabler.

3. Methodology and research design

Aiming at exploring the quite under-researched field of what factors determine the adoption of various coordination mechanisms for facilitating the integration of internationalized R&D activities, our study adopts a quantitative inductive research design with the purpose to provide further insights and extend existing conceptual and empirical research perspectives. In the following, we detail our methodological approach.

3.1. Sampling

The current research is part of a wider survey providing evidence on the strategic bases of MNEs' expansion into the EU "peripheral" economy of Greece. While there is a tendency among researchers to study wider geographical and economically integrated areas (see for example Mizra and Freeman, 2007), single-country studies are still the most prevalent research context in the international business field (Hyman and Yang, 2001), mainly due to the specific advantages derived when empirical investigations are focused on a research environment with similar cultural and psychographic characteristics (for example the research design minimizes a number of sources of extraneous variance).

The research took place between 2001 and 2004. Our data sources used here were the Business Directories of *ICAP Greek Financial Directory* and the database for foreign direct investment of *National Bank of Greece*. Both are widely used as standard sources for researchers, since they are considered as the most reliable and original sources of information on foreign operations in the country (e.g., Dimitratos et al., 2004). The population sampled was 315 foreign-owned subsidiaries. In the end, we received 144 responses, indicating a response rate of 45.71% which is very satisfactory when compared with similar postal surveys (Harzing, 1997; Yang et al., 2006); and considering the well-documented difficulties of obtaining questionnaire responses in the focal country (Souitaris, 2002). To further corroborate, mail questionnaire surveys usually receive lower response rates compared with other research methods (Malhotra et al., 1996). The firms in our sample represent fairly well a cross section of locally received foreign investments – both with regard to sector and geographic location – with that having a positive effect on the reliability and validity of the sample. Moreover, because of the diversity of respondent firm-specific characteristics (they vary by size, year of entrance and so on); the risk of any systematic bias in the empirical analysis is minimized. Potential for any systematic bias between responding and non-responding firms was further investigated by comparing specific company characteristics (size, mode of entry and industry distribution) between responding and non-responding firms. The unpaired *t*-test results show that all statistics along these attributes between the two samples were non-significant. Our sample characteristics are presented in Appendix A.

Among these 144 subsidiaries, 70 have identified to have an in-house R&D department, of which 4 did not wish to collaborate in the survey; reducing the total number of useable responses to 66 (45.83%). Among these labs, 44 (67%) have considered that the

adaptation of existing products and/or processes was their defining role (SL laboratories), 15 (23%) are involved with the production of innovative products (LIL) and an only 10% reported basic research as a core functional commitment (IIL).

3.2. Setting and instrument design

The main data source was a structured questionnaire. In general, mail questionnaire survey is the most popular data collection method, accounting for 50% of the empirical studies in top IB journals (Yang et al., 2006). In this research, a survey methodology was considered as the most appropriate, since relevant published data were either not available or did not capture the specific variables of interest. The development of the questionnaire was guided by the literature, consultation with experts and a pilot test. The questionnaire was pre-tested during a three-stage process. First, it was scrutinized by two academics and a professional consultant, who provided improvements on the wording and advises on the layout. This resulted in a major revision of the questionnaire. Second, it was sent to five chief executive officers (CEOs) of subsidiaries operating in different industrial sectors. The questionnaire was given a positive assessment along with a few suggestions for improvement which led to some small modifications, subsequently incorporated into our scale measurement of coordination instruments. Finally, the questionnaire was posted to ten randomly selected firms, chosen by their country of origin, for the final testing.

In line with the work of Hyman and Yang (2001), that has shown the attractiveness of key executives as a source for retrieving data in empirical investigations, the survey questionnaire was posted to all CEOs, followed by a second mailing four weeks after the initial one. Questionnaires were sent together with an introductory letter describing the objective of our research. Both the questionnaire and the letter were sent in English. To provide a motivation for accurate responses, the respondents were guaranteed anonymity and were promised an accurate summary of the main findings (if requested). Given their senior position, we trust that our respondents are knowledgeable and competent informants whose responses should be reasonably accurate. However, given that the majority of data assessed for this research refer to issues pertaining to a specific functional unit (R&D), we recognize that CEOs' responses may entail a certain degree of bias and, thus, this could consist of a potential limitation of our research. In order to enhance the quality of the data related to the factors that influence the application of coordination mechanisms, we have also used semi-structured field interviews with four R&D directors, since due to their direct involvement in R&D management, these individuals could provide us the source of information with the greatest precision and reliability. All four interviews were conducted by the lead author. Each interview lasted approximately half an hour and covered a variety of topics, including directors' assessment of their decision-making and operational independence, frequency of cross border visits and transfers and background laboratory characteristics (year of establishment and number of employees). Our major purpose was to crosscheck the information provided by the questionnaires and to identify some qualitative information that could not be extracted from the questionnaire (potential R&D alliances and joint projects with local partners). We considered that as quite important, because a possible collaboration of the laboratories' field work with external units could potentially alternate our results on the decentralized R&D roles' identification. Overall, questionnaires responses have been confirmed and no partnerships with local firms and research institutions have been reported by the interviewees. In a nutshell, we believe that this multiple data-collection method assured the quality and accuracy of the subsequent data analysis. The same procedure was followed by Li and Yue (2005). The technical datasheet of the empirical investigation is presented in Table 6.

3.3. Variables, operationalization and measurement

Two sets of variables were operationalized. The first set contained variables intended to measure the coordination mechanisms utilized by decentralized R&D, while the second set consisted of variables designed to capture the strategies of labs and some – well identified by past researchers – contextual influences (functional- and firm-level characteristics). All the measures for the variables used in this study were drawn from the literature and were adapted to fit the context of MNE R&D units.

Overall, 11 regressions were run with each coordination instrument as the dependent variable. As a proxy of structural mechanisms, we use the concepts of standardization (y_1), planning (y_2) and output control (y_3). In order to identify elements of the formal hierarchical authority in decision-making, we have examined both the strategic (y_4) and operational (y_5) centralization, and – following the literature – we have used transfers (y_6) and cross border visits (y_7) as instruments of people-based coordination. The coordination instruments y_1–y_7 were developed by Martinez and Jarillo (1991) and also used by Nobel and Birkinshaw (1998), Harzing (1999) and Reger (2004). Corporate culture (y_8) and shared language (y_9) derive from the works of Welch and Welch (2006) and Marschan-Piekkari et al. (1999), respectively. Finally, the instruments provided by new technologies (y_{10}–y_{11}) were adapted from Kim et al. (2003). In order to assess the prevalence of each instrument in coordinating decentralized R&D activities, a four-point Likert-type scale was prepared, where the scale value "4" indicates a defining role of the instrument and the scale value "1" the opposite case. Coordination instruments are defined and operationalized in Table 3. All the reliability coefficients (Cronbach α) for the five categories of coordination mechanisms that we have created were above 0.55, which is considered the cut off point of basic research (Tharenou, 1993) and three were higher to 0.70 (see Table 4) which is the suggested reliability level proposed by Nunnally (1978).

Our analysis comprises of 9 contingency factors that may impact on coordination modes. Of these, 5 (λ_1–λ_5) relate to laboratory — level characteristics (role, size and age), and 4 (c_1–c_4) relate to subsidiaries' "profile" factors in the form of country of MNE origin, subsidiary sector of activity, age and size. The impact of laboratory roles (λ_1–λ_3) on the coordination of decentralized R&D activities has been identified by Nobel and Birkinshaw (1998) and Asakawa (2001). The relationship between the size of

Table 3
Operationalization of coordination instruments.

Variable	Coordination instruments	Survey question	Likert-type scale	
			4	1
y_1	Standardization	How the work implemented in your R&D department is regularized?	By extensive use of job descriptions, manuals and formal R&D policies	Through discussion and informal meetings with the personnel of the department
y_2	Planning	How the decisions concerning the annual budget of the R&D department are taken?	Through pre-determined strict deadlines and rounds of one-way decision making from the corporate financial department	Through informal procedures, not strict deadlines and where the R&D manager has bargaining power to negotiate
y_3	Output control	How the corporation monitor the output of R&D department?	The R&D department follows detailed rule-based instructions concerning the output standards. Everybody is very cost conscious regarding time and material used	The R&D department follows procedure-based instructions concerning the output standards. R&D professionals do not care about the cost of time and material used
y_4	Strategic centralization	How the critical strategic decisions are taken in your R&D department?	They are dictated by the HQs	By the R&D manager
y_5	Operational centralization	How the critical operational decisions are taken in your R&D department?	They are imposed by the HQs	They are imposed by the members of the R&D lab of the subsidiary
y_6	International transfer of managers	How many times have you received foreign R&D managers in your department?	More than 4	Never
y_7	Cross border visits	How many times have you visited a foreign R&D lab in another country?	More than 4	Never
y_8	Corporate culture	How would you characterize the culture of your corporation?	Professional, results-oriented, normative, imposing tight control	Parochial, process-oriented, pragmatic, imposing loose control
y_9	Language	Does your subsidiary encourage seminars and training in order R&D personnel to get used in technical vocabulary and MNE's technical procedures?	Very often	Never
y_{10}	Video conferencing	How many times have you participated in a video conferencing last year?	More than 4	Never
y_{11}	Intranets	How often do you use intranets for the transmission of data across different units?	Extensively	Not so often

organizational units (λ_5 and c_3) and coordination finds support in the work of Gates and Egelhoff (1986), whereas the relationship between the age (year of establishment) of organizational units (λ_4 and c_2) and coordination was investigated by Garnier (1982) and Harzing (1999), among others. Country of MNE origin (c_1) as a proxy of geographical distance and coordination was developed by Allen (1985) and Katz and Allen (1982). Finally, the influence of the market context (sector-c_4) on the application of

Table 4
Coordination instruments and decentralized R&D roles.
Source: Authors' survey.

Variable	Mechanisms and instruments	Mean	Std. dev.	SL	LIL	IIL	*F* score, probability
Structural (Cronbach α: 0.81)							
y_1	Standardization	3.46	1.25	3.52	3.04	3.19	3.42 ($p=0.051$)
y_2	Planning	3.29	1.46	3.24	3.11	3.41	2.84 ($p=0.084$)
y_3	Output Control	3.33	1.17	3.30	3.32	2.96	2.07 ($p=0.062$)
Formal hierarchical (Cronbach α: 0.84)							
y_4	Strategic centralization	3.52	1.58	3.65	2.88	3.40	3.04 ($p=0.095$)
y_5	Operational centralization	3.40	1.64	3.50	2.90	3.20	3.57 ($p=0.110$)
People-based (Cronbach α: 0.76)							
y_6	International transfer of managers	2.08	.97	1.86	2.70	1.90	1.40 ($p=0.330$)
y_7	Cross border visits	2.36	1.12	2.20	2.85	2.05	2.24 ($p=0.115$)
Social (Cronbach α: 0.67)							
y_8	Corporate culture	3.15	1.24	3.15	2.90	3.20	3.88 ($p=0.006$)
y_9	Language	1.69	0.88	1.65	1.80	1.50	1.17 ($p=0.340$)
Information technology (Cronbach α: 0.63)							
y_{10}	Video conferencing	1.89	1.02	1.90	1.60	2.20	1.74 ($p=0.486$)
y_{11}	Corporate intranets	1.81	1.13	1.62	2.12	2.18	2.58 ($p=0.097$)

Note: All the Cronbach reliability coefficients were above 0.55, which is considered the cut off point of basic research (Tharenou, 1993) and very close or higher to 0.70 which is the suggested reliability level proposed by Nunnally (1978).

Table 5
Operationalization of independent variables.

Independent variables		Mnemonic	Type[a]	Operational definition
Laboratory-related				
	Strategic role of lab			In order to evaluate laboratories' role respondents were asked to grade each of the following roles in terms of the importance in the operations of the research department as being: (i) not part of their role, (ii) main role, (iii) secondary role and (iv) only role (i) Adaptation of existing products and/or processes to make them more suitable to our markets and conditions (ii) To play a role in the development of new products for our distinctive markets (iii) To carry out basic research (not directly related to the current products) as part of a wider MNE group level research program
λ_1	Support laboratory (SL)	SL	L/D	Laboratory that adapt existing products and/or processes (4 = only role, 3 = main role, 2 = secondary role, 1 = not part of role)
λ_2	Locally integrated laboratory (LIL)	LIL	L/D	Laboratory that has a distinctive role in the development of new products (4 = only role, 3 = main role, 2 = secondary role, 1 = not part of role)
λ_3	International independent laboratory (IIL)	IIL	L/D	Laboratory that carries out basic research (4 = only role, 3 = main role, 2 = secondary role, 1 = not part of role)
λ_4	Age of laboratory	AGELAB	L/D	Age of Laboratory (Number of years the laboratory has been established in Greece). According to the years of operation laboratories were characterized as well established, recently established and latecomers. Well established are the laboratories that operate in Greece before 1970 and take the value of 3. Recently established are the laboratories that begun to operate between 1971 and 1990 and take the value of 2. Latecomers are the laboratories that identified their presence after 1991 and take the value of 1.
λ_5	Size of laboratory	SIZELAB	C	Size of Laboratory (Number of personnel the laboratory employs)
Subsidiary-related				
	Country of MNE origin			
c_1	EU countries	EU	B/D	1 = parent from EU, 0 = otherwise
c_2	Age of subsidiary	AGESUB	L/D	Age of subsidiary (number of years the subsidiary has been established in Greece). According to the years of operation subsidiaries were characterized as well established, recently established and new established. Well established are the subsidiaries that operate in Greece before 1970 and take the value of 3. Recently established are the subsidiaries that begun to operate between 1971 and 1990 and take the value of 2. Newly established are the subsidiaries that identified their presence after 1991 and take the value of 1.
c_3	Size of subsidiary	SIZESUB	C	Size of Subsidiary (Number of personnel the subsidiary employs)
	Sector[b]			
c_4	Global	GLOBAL	B/D	1 = Firms belong to globalized industries, 0 = otherwise

[a] Binary (B); /Likert-type (L); /Continuous (C); /Discrete (D).
[b] Based on the work of Roth and Morrison (1992), chemicals, electronics and pharmaceuticals consist globalized industries.

suitable coordination mechanisms is demonstrated in the works of Reger (2004) and Pugh and Hinings (1976). All the constructs (as well as the source of the items) used in this research are defined and operationalized in Table 5.

4. Results and discussion

Table 4 reports descriptive statistics pertaining to our dependent variables. In particular, it shows the means and standard deviations of the intensity of the coordination instruments under investigation and their relationship with our R&D typology that has been developed in Section 2.1. We were expecting that the integration of different strategically motivated decentralized R&D units would require diverse mechanisms and instruments (Research Proposition 1). The results provided are in line with our research assumption and extend existing literature by associating laboratories' contribution in the different stages of MNE competitive evolution with distinctive coordination requirements. In particular, SL laboratories support the short-term competitiveness of MNE subsidiaries through the adaptation of existing products and/or process technologies. Their integration within MNEs' production and technology strategies seems to be mainly achieved through a combination of structural coordination mechanisms (notably standardization and output control) and hierarchical solutions (high levels of decision-making centralization). Our findings complement the works of Hakanson and Nobel (1993) and Nobel and Birkinshaw (1998) indicating that vertically imposed formal coordination mechanisms comprise a very efficient organizational mode for achieving the benefits of global scale and learning.

The development of MNEs' strategic competitiveness by the commercial evolution of existing core technologies through enhanced embodiment in major new generations of globally competing products (LIL role) assumes the inter-connectiveness of such laboratories with foreign and local sources of knowledge (see Table 1). In this vein, LILs should exploit simultaneously the MNEs' ownership advantages (such as the knowledge-based assets developed at home) and the capabilities of the local knowledge community (such as the use of technological and research infrastructure of the host country). Since the successful accomplishment of LIL role calls for knowledge inputs from dispersed parts of MNE activity, it can be argued that these laboratories have a more international profile than the other two types of labs. This should result in the formation of a more complex organizational

network where coordination is achieved through the use of a wider spectrum of mechanisms. Indeed, while the use of structural instruments is at significant levels (especially output control), results also highlight a strong prevalence of more informal and subtle (people-based and social) coordination mechanisms that promote horizontal communication and interaction. That was expected, since according to the works of Edwards and Ferner (2004), Bjorkman et al. (2004) and Pedersen et al. (2003), interpersonal coordination mechanisms facilitate knowledge sharing and transfer. Since LILs seek to capture the advantages of decentralized technology strategies, interestingly but not surprisingly, they exhibit the lowest level of operational and strategic centralization among all different R&D types.

For Internationally Independent Laboratories (IILs), the prevalence of planning as manifestation of structural mechanisms is stressed. The well recorded high levels of standardization and centralization, together with the low use of people-based coordination mechanisms imply that, under pressures for global efficiency, decentralized R&D that involves basic research inputs tends to require extensive centralization and formalization-based integration. Our results furthermore indicate that these laboratories may be independent (stand-alone) units within subsidiaries, but they operate as a specialized component of an international programme of mutually supported pre-competitive research facilities directed and closely monitored by the parent multinational. However, since the IIL status assumes its contribution to the longer-term evolution of the MNEs' technological trajectory, we would expect a more intense prevalence of international transfer of managers and cross border visits. Though, the advantages of face-to-face direct communication of researchers may derive from a more systematic participation of IIL employees to conferences, workshops and seminars.

Our second research proposition related to the prevalence of various coordination mechanisms identified within international management literature in the context of internationalized R&D activities. According to our results, all instruments were exhibited in all three roles, confirming views that international R&D management requires a set of diverse coordination mechanisms (Reger, 1999) and that these mechanisms are predominately complementary rather than substitutes (Bjorkman et al., 2004). However, we find notably endorsement to support that the relative emphasis on the different mechanisms varied significantly. Thus, the evidence presented here clearly confirms that formal hierarchies (both strategic and operational centralization) and structural coordination is utilized more intensively; supplemented to an extent with forms of people-based communication and organizational culture. This finding indicates that MNEs are moving towards a more complicated and multifaceted integration pattern of their decentralized technology strategies. We attribute this evidence to an attempt of MNEs to capture national differences, exploiting at the same time the advantages that economies of scale and scope can provide to their decentralized research activities. In this regard, our results provide support to the work of Gerybadze and Reger (1999) suggesting that MNEs continue to decentralize their research activities but at the same time these companies attempt to remain as hierarchical and integrated as possible.

A very interesting finding revealed from Table 4 is that the use of ITPI coordination mechanisms is at almost insignificant levels. This is especially surprising for intranets that are considered as a very timely instrument that makes information more broadly and easily accessible within a firm. One would expect that the mutual dependence of R&D labs – especially those that seek to expand the commercial (LIL) and knowledge (IIL) horizons of their MNE – with other departments and business units would call for the extensive use of intranets as a tool to exchange ideas, establish mutual goals and track progress. This reluctance to use mechanisms derived by the new technologies could imply that the underlying cultural characteristics of Greek employees promote mainly interpersonal communications rather than interacting over an IT interface or that the local business context may deter the promotion of a scientific and technological culture in Greek-based subsidiaries.

In order to gain further insights on: (i) the explanatory power of strategic and organizational variables as influential factors in determining the coordination pattern of MNEs' decentralized research activities, and (ii) the impact of lab types on addressing integration concerns, eleven ordered probit (OP) regressions were run with the coordination instruments (y_1–y_{11}) operationalized in Table 3 as our dependent and the varied lab roles and subsidiaries' contextual factors as our independent variables. OP was applied here, since according to the construct of the research our dependent variables are *ordinal* (respondents to the survey had evaluated the use of specific instruments based on an attitudinal survey scored using a 4-point Likert-type scale which generates data in the form of ordinal responses), *qualitative* (they are measured on a nominal scale) and *polychotomous* (they can be classified into more than two categories). We had also used confirmatory factor analysis by grouping the coordination instruments into the categories proposed in Table 2 but the overall results have proven to be slightly inferior from those of OP.

Table 6
Technical datasheet of the empirical investigation.

Subject of investigation	All foreign operations located in Greece
Sample source	ICAP Greek financial directory, National Bank of Greece database
Total population	315 subsidiaries
Number of respondents	144 subsidiaries (46%)
Size of sample that fullfil the scope of investigation	66 subsidiaries with in-house R&D activities (46%)
Level of sample reliability	95%
Data source	Structured questionnaire and four semi-structured interviews with R&D directors
Geographical range	Greece, nationwide
Sample unit	R&D department
Date of fieldwork	January 2001–April 2004

Table 7 reports the means, standard deviations and pair-wise Pearson correlations between the regressors used in our analysis. We checked for multicollinearity in the models through the examination of variance inflation factors (VIF) for each independent variable. The VIF values range below the upper limit of 0.10, which is typically suggested as the highest acceptable value (Hair et al., 1995; Netter et al., 1989). This suggests that multicollinearity does not pose a problem for our results.

The robustness of our regressions is quite satisfactory, ascribing a considerable predictive explanatory power to our models. From these analyses (Table 8), a number of interesting results were observed that complement or partially extend existing knowledge. As a whole, survey evidence demonstrates that strategic are more important compared to organizational variables in determining the coordination imperative of internationalized R&D units. In most of our models R&D strategic missions and mandates have a clear bearing on coordination, whereas the impact of the other subsidiaries' and laboratories' contextual and 'profile' factors appears to be less influential.

SLs do have significant and positive impact on formal structures (at both strategic and operational level) and the use of monitoring-based output control. This relationship indicates that minor product adaptations are implemented by one-way movement of technologies and methods from the HQs to subsidiaries. This strong observed prevalence of centripetal forces to SL management confirms views that in the case of product adaptation, HQs like to retain full control over the whole development process (Sawhney and Prandelli, 2000). Structural mechanisms and command authority are efficient integrators in that case because they reduce transaction costs occurring from more complex coordination techniques. Decentralized labs that have gained the resources and decision-making power to develop specific knowledge and technologies to be embodied in new products (such as LILs) are associated with more dynamic and flexible organizational arrangements. More specifically, the positive statistical relationship between LILs and transfers indicates that laboratories that should have access to advanced knowledge create strong cross-functional integration links through the exchange of research personnel. To further corroborate, LILs, in order to achieve a level of substantial creative competence, need to work in a closely integrated function with other MNE functional units such as marketing, engineering and general management (Papanastassiou and Pearce, 1999). Here, the commitment to product development is also negatively associated with standardization and operational centralization, leaving a wide space for these laboratories to express their core, creative mandate. For IILs, the only statistical significant relationship relates R&D employees with cross-border visits. That was anticipated, since researchers employed in IILs are conceived to be revenue creators and not cost drivers, therefore, they may seek knowledge wherever is available. In that sense, it seems that R&D labs whose work requires high levels of knowledge inputs in a rather not-routinised manner are positively related with people-based coordination instruments.

Global sectors (c_4) are portrayed as working with a strong head office in technology strategy. The statistical significant relationships between the independent variable c_4 with structural and hierarchical organizational structures, which in our case relate to planning, standardization and operational centralization, confirms that these industries are conceived to have high pressures for integration due to strong common customers' needs, global economies of scale and high learning effects (e.g., Arora and Fostfuri, 2000). As far as country of HQs origin (c_1) is concerned, evidence provided here indicates that decision-making in relation to the operational function of the unit is generally less centralized to European compared with subsidiaries from other continents. Although we could consider European countries as a homogenous whole only at a very high level of generalization, it seems that geographical distance can create challenges for formal coordination and tight control and should be further investigated as a factor imposing specific organizational norms.

Regression results relate also the size of the laboratory with the use of structural coordination mechanisms. Thus, the statistically significant positive association between lab size (λ_5) and the coordination instrument and output control (y_3) indicates that larger labs experience a need to be more formally integrated compared with smaller units. This finding is even more reinforced by the negative relationship between labs' size and transfers (y_6), providing support to the work of Ambos and Schlegelmilch (2007), who confirmed a high and positive impact of R&D size and the use of structural and formal coordination techniques. The age of laboratory (λ_4) is positively associated with cross border visits (y_7) and negatively with hierarchical control in the operational level (y_5), indicating that "latecomer" foreign R&D is subjected to tighter control and centralized forces. Contrary with previous work that related subsidiaries' size and years of establishment with the deployment of specific organizational patterns (e.g., Gates and Egelhoff, 1986; Ghauri, 1992; Hakanson, 1981), our results do not appear to support this literature, since only a statistical significant negative relationship between social coordination instruments (culture and language) and the variables c_2 and c_3 (subsidiary size and age) was observed at the marginal 10.0% level of significance. This

Table 7
Descriptive statistics and zero-order correlations.

Variable	Mnemonic	Mean	Std. deviation	min	max	λ_1	λ_2	λ_3	λ_4	λ_5	c_1	c_2	c_3	c_4
λ_1	SL	3.04	0.856	1	4	1								
λ_2	LIL	2.36	0.670	1	4	−0.125	1							
λ_3	IIL	1.97	0.411	1	4	−0.227	−0.104	1						
λ_4	AGELAB	1.64	0.715	1	3	−0.291	−0.183	0.072	1					
λ_5	SIZELAB	22.86	74.9	4	68	**0.291**	0.046	−0.138	**0.4**	1				
c_1	EU	0.64	0.367	0	1	0.146	**−0.329**	0.148	**−0.274**	−0.187	1			
c_2	AGESUB	1.84	0.802	1	3	−0.140	0.206	−0.084	0.229	−0.088	−.231	1		
c_3	SIZESUB	189	477.4	23	645	−0.116	**0.274**	−0.109	0.162	−0.138	−0.114	0.059	1	
c_4	GLOBAL	0.33	0.109	0	1	0.206	−0.179	**−0.447**	−0.182	−0.181	0.294	**−0.380**	0.137	1

Figures in bold are statistical significant at the 1% level (2-tailed).

Table 8
Effect of functional and organizational variables on coordination instruments.
Source: Authors' survey.

Independent variables		y_1 Standardization Eq. (1)	y_2 Planning Eq. (2)	y_3 Output control Eq. (3)	y_4 Strategic centralization Eq. (4)	y_5 Operational centralization Eq. (5)	y_6 Transfers Eq. (6)	y_7 Cross border visits Eq. (7)	y_8 Culture Eq. (8)	y_9 Language Eq. (9)
λ_1	SL			0.565** (0.227)	0.012*** (0.002)	0.385** (0.120)				
λ_2	LIL	−0.289** (0.087)				−0.740* (0.416)	0.431** (0.105)			
λ_3	IIL							0.554** (0.381)		
λ_4	AGELAB					−0.454** (0.140)		0.180** (0.098)		
λ_5	SIZELAB			0.845** (0.304)			−0.102* (0.031)			
c_1	EU	−0.584* (0.311)					0.241* (0.197)			
c_2	AGESUB									−0.202* (0.111)
c_3	SIZESUB								−0.089* (00.11)	
c_4	GLOBAL	0.588* (0.311)	0.147*** (0.84)			211* (0.120)				
	Pseudo *R* square	0.19	0.18	0.18	0.19	0.23	0.21	0.16	0.17	0.16
	LR Chi-square (8)	15.10**	17.52***	21.56**	20.74**	26.52***	40.81***	15.12*	16.04*	7.50
	Log likelihood	−76.053	−75.414	−59.622	−50.260	−59.271	−55.327	−86.492	−74.327	−80.259
	N	66	66	66	66	66	66	66	65	66

No statistical significant relationships were observed for the coordination instruments provided by Information Technology Platform Infrastructures.
Figure in () is standard errors.
Laboratory roles
SL: Adaptation of existing products and/or processes to make them more suitable to our markets and conditions.
LIL: To play a role in the development of new products for our distinctive markets.
IIL: To carry out basic research (not directly related to current products) as part of a wider MNE group-level research programme.
Notes*:*
a. Only statistical significant results are presented.
b. Laboratories that graded the role as either their only or predominant one.
c. For the classification of sector, see Table 5.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

might be an indication of increased dynamism in resource adaptation in times of increasing discontinuity in contextual and organizational parameters.

5. Conclusions

Globalization of R&D is a major topic within the business community, as well as for researchers and decision-makers (Gerybadze and Reger, 1999). The broad objective of our study was to investigate what are the suitable mechanisms employed for the coordination of international R&D in MNEs, and what are the relations between these coordination mechanisms and the strategic role of decentralized R&D labs. Grounded on recent developments in international management theory, we developed and analyzed a comprehensive framework with the aim to extend existing knowledge related to MNEs' coordination modes at the level of decentralized R&D activity.

In a nutshell, our study provides evidence suggesting that the use of specific coordination instruments is mainly explained by the distinctive roles of expatriate R&D and – to some extent – of functional-level characteristics, whilst factors characterizing the environment of the subsidiary or the country of HQs origin did not have such "predictive quality". This gives ground to attempts stretching the importance of decentralized labs' strategic mission as an influential force in determining coordination modes (e.g., Nobel and Birkinshaw, 1998; Asakawa, 2001). We emphasize that while formal hierarchical authority and structural mechanisms comprise efficient solutions for adaptation work, original product development tasks seem more difficult to be managed, since the coordination of LILs requires high levels of intra-firm arrangements and low levels of standardized procedures. No clear integration pattern for the regeneration and reinforcement of the group's core of scientific knowledge through pre-competitive

research (IIL role) has emerged from our study. In line with common suggestions, our work reveals that the use of coordination instruments depends also on units' size and years of operation.

5.1. Implications

Several insights for research, management and policy makers can be drawn from our findings. With regard to the implications for research, our study finds support for a contingency approach to examining coordination at the level of an MNE's functional unit. Specifically, the profile of integrating modes that have been used in the context of international R&D is related with a fit between the internal (structural and strategic) features of laboratories and the demands of their environment. As our results indicate, the more differentiated the output of the laboratory, the more difficult and complex it will be to coordinate its activities and more resources need to be devoted for that purpose. Further, we demonstrate the importance of adopting a systems approach to understand the coordination of decentralized R&D. MNEs utilize various mechanisms and instruments simultaneously, but with different levels of intensity so as to achieve effective integration of their dispersed R&D labs. But, even more important, the present research empirically shows the tendency of MNEs to keep the elements of knowledge-related competitiveness as hierarchical and integrated as possible. Thus, the "transnational configuration" of R&D that has gained considerable momentum in the literature recently (and especially in the late 1990s), is not confirmed from the evidence of this paper. These results sound a cautionary note to researchers in their examination of MNEs' integration process of decentralized technology strategies. In an attempt to explain the predominance of the centralized viewpoint and hierarchical relations, we highlight implications that are appropriate for subsidiary research in small countries. One could assert that the strategic significance of Greece is not that strong for MNEs that come to invest in that country. Thus, the adaptation of existing technologies (product or process) to local conditions is the primary aim of R&D subsidiaries in the local context (Manolopoulos et al., 2007). In this regard, tight corporate integration strategies are considered efficient so as to manage that motivation of R&D internationalization. However, since there are clear signs of interdependence of work in R&D labs in Greece with other parts of MNE networks, a transition from the "traditional paradigm" towards more dynamic and evolving integration patterns should be further investigated. Finally, the present work is one of the very few studies assessing coordination patterns of decentralized R&D activities in a European country and the sole empirical study investigating the relationship between different coordination instruments and some commonly studied FDI characteristics in the context of expatriate R&D located in Greece. It should be noted that much of the extant empirical work on globally dispersed R&D relates to US corporations, putting European (and Asian) firms aside or, has tended to concentrate on foreign-owned R&D in the US (Criscuolo et al., 2005).

With regard to implications for MNE managers, the evidence of our work indicates that the integration of technological resources and know-how generated by the MNE group appear to be determined mainly by functional — level characteristics, and especially by the strategic role of the labs. Since all three R&D types presented in our study are characterized by completely different sources of comparative advantage and contribute in unique ways to MNEs' competitive evolution, decentralized R&D can be best managed by tailoring the appropriate instruments to the distinctive mandate of labs. Consequently, a reciprocal coordination pattern should be established: management at headquarters have to ensure that they monitor the technological flows and outputs of their small country subsidiaries on a constant basis. Similarly, MNE subsidiary managers need also to closely monitor technological developments at headquarters; and, establish strong network relationships with their parents and MNE actors. As a result, international technology managers should be aware of the trade-off which has been frequently expounded in the literature on organizational design (Mintzberg, 1979; Sitkin et al., 1994) between formal coordination for the restricted routine adaptation of local R&D and the implementation of more flexible and informal coordination patterns for knowledge creation and innovation.

The study provides also challenging insights for public policy. Since our findings provide evidence that original development work (part of MNEs' innovation decentralisation) is at significant levels (23% of R&D subsidiaries in Greece are involved in the production of innovative products), policy makers can increase the quality and absorption capacity of domestic technological infrastructure by establishing appropriate coordination channels with those MNEs that are characterized by a solid record of technological innovation and output, with the explicit aim of attracting high-technology companies and secure access to foreign knowledge. Such a challenge for public policy occurs at a point in which other recent studies question the relevance of policy initiatives seeking to support local interaction and collaboration (e.g., Alecke et al., 2006; Bode, 2004).

5.2. Limitations and future research directions

Results should be considered in the light of several limitations. Of particular concern is the fact that evidence is mainly focused on exploring the demand-side factors of decentralized in-house R&D operations and is limited to R&D laboratories located in Greece. However, the received wisdom in the management of MNEs suggests that the use of coordination mechanisms is also affected by the different economic, legal, political and cultural environment of the individual countries. Although we could expect similar findings for middle-income peripheral European countries (where MNEs show a strong tendency for hierarchical control, e.g., Manea and Pearce, 2004), we should be very cautious in generalizing the results to more advanced economies. Another major limitation of the current research is its cross-sectional (rather than longitudinal) nature. In line with the majority of studies that relate to the coordination concerns of decentralized R&D (with some notable exceptions, like for example the work of Asakawa in 2001), we also present a static representation of the context and mechanisms employed in managing geographically dispersed R&D activities, without taking sufficient account of the dynamic organizational and institutional arrangements. As a result, we cannot assess how coordination mechanisms evolve over time. However, as MNEs move simultaneously towards the globalization

of their technology strategies and the effective leverage of host-country capacities, it can be arguably hypothesized that the strategic positioning of these labs would change throughout the whole internationalization process. Subsequently, the evolving positioning of R&D labs would require different administrative mechanisms so as to effectively encapsulate theses changes. To further corroborate, according to Asakawa (2001), a shift in the role of overseas labs would affect the nature of headquarters — subsidiary relationship, and, as a result, would impact on the application of different appropriate coordination techniques. Thus, it is highly anticipated that different suitable mechanisms are effective in the different stages of *development* of an R&D facility; an issue which is not considered here. Moreover, decentralized R&D plays an important role in the strategic evolution of multinationals; providing a crucial basis for the differentiation of subsidiary roles. To that end, we feel that any complete study on the coordination mechanisms used in foreign R&D should incorporate the range of subsidiaries' varied mandates. Finally, according to the construct of the research we investigate coordination mechanisms individually rather in combination, whereas organizational designs and coordination mechanisms usually coexist in complex and unique ways.

The limitations of this study guide suggestions for future research. The generalizability of our findings would be strengthened if similar studies were carried out in other small countries with dissimilar levels of economic and technological development. Similarly, comparison of datasets involving R&D configuration in small and large countries would illuminate whether the two country categories indeed produce different results. An evolutionary approach on international R&D configuration could be achieved by relating coordination mechanisms to the evolutionary process of the units in different development stages. Further, extensions of the research reported in this paper could include examination of other variables likely to affect the use of specific coordination instruments, such as the roles of foreign subsidiaries, their export propensity and their mode of entrance in the local market. In addition, there is a need for further investigations to address different research configurations of this sort and the effect on R&D performance. Thus, a more holistic investigation of the topic would require the impact of the usage of different coordination mechanisms on R&D output. Such approach might include different indicators for R&D performance (such as new products, patents, etc.), dependent on the role of laboratory.

Appendix A. Sample by industries and country of HQ origin

Sector	Total sample	Number of respondents	Number of useable responses with R&D	Response rate
Automobiles and transport equipment	19	12	0	63.16%
Chemicals	18	11	5	61.11%
Electronics and IT	15	10	6	66.67%
Food and beverages	47	29	18	61.70%
Manufacturing	62	31	15	50.00%
Miscellaneous[a]	19	9	3	47.37%
Other manufacturing[b]	34	9	6	26.47%
Pharmaceuticals	31	16	10	51.61%
Services	51	11	2	21.57%
Textiles	19	6	1	31.58%
Total	*315*	*144*	*66*	*45.71%*
HQs country of location	Total sample	Number of respondents	Number of useable responses with R&D	Response rate
EU Countries	129	61	29	47.29%
Other European countries[c]	78	33	13	42.31%
Asia Pacific Rim[d]	46	18	8	39.13%
US	62	32	16	51.61%
Total	*315*	*144*	*66*	*45.71%*

Notes:
[a]Miscellaneous includes agribusiness, equipments for bakery, home equipment.
[b]Other manufacturing includes tobacco, paper and forest products, heating and air conditioning and office machinery.
[c]Includes subsidiaries from Switzerland, Cyprus, Liechtenstein, Luxembourg and Russia.
[d]Includes Canada.
Source: Authors' survey.

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