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FIRM AND ENVIRONMENTAL INFLUENCES ON THE MODE AND SEQUENCE OF FOREIGN RESEARCH AND DEVELOPMENT ACTIVITIES

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This paper develops an explanation for the mode and sequence of entry that firms select for their international research and development activities. The hypotheses are based on the internalization and evolutionary theory perspectives. I first hypothesize that there is a sequence to the mode of foreign research and development activities initiated. I then discuss two firm capabilities and alternatives which might cause firms to omit parts of the sequence. The context of the study is the foreign research and development activities of incumbents and recent entrants to the Japanese pharmaceutical industry. The results indicate intriguing differences between the motivations of established firms and new entrants in establishing foreign research and development activities. © 1998 John Wiley & Sons, Ltd.

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INTRODUCTION

There is increasing interest in the evolving role of firms' international research and development (R&D) activities. While there has been much descriptive work (De Meyer, 1992; Pearce and Singh, 1992a), the phenomenon has received little conceptual development. In particular, there is no broad-based explanation for the mode of entry that firms select for their international R&D activities. This paper develops a model using firm-level factors to explain the entry mode and sequence of international R&D activities. I draw on internalization and evolutionary theory perspectives to develop this model. I test the model's predications in the context of established and recent entrant firms in the Japanese pharmaceutical industry that have undertaken overseas research and development activities in the United States and Europe.

While much has been written about the mode of foreign market entry, past work has focused primarily on the sale of goods and services. Even the works which have focused on the internationalization of R&D have emphasized the influence of overseas production on the decentralization of R&D (Ronstadt, 1977; Pearce and Singh, 1992b). These earlier studies have generally followed product life cycle theory as developed by Vernon (1966). This theory maintains that multinational firms usually undertake overseas R&D activities in order to adapt their products and processes to local markets. This perspective was perhaps appropriate for stable industry environments, but it is less suited to current environments in which firms face many challenges that require competitive response. These challenges include increasing foreign competition and intensifying domestic competition. It appears that firms in many industries now undertake overseas R&D activities as a response to increased competition in their home markets and

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throughout the world, rather than as a support function for existing sales operations in a host market. Hamel and Prahalad (1985) argue that global strategy increasingly requires foreign research presence. Bartlett and Ghoshal (1989) have identified an innovation in multinational corporations which they describe as a 'globally linked' approach. In this approach, a firm identifies geographically dispersed sources of competitive resources and then links them through its activities in order to gain competitive advantages. International R&D activities contribute such globally linked competitive advantages. A missing piece of the literature, though, is a description of the form the firms' R&D activities take in order to obtain the dispersed sources of competitive ability.

BACKGROUND

A large body of work addresses foreign entry mode. Although most of this research discusses sales and production, some implications of the arguments apply to research entry. This prior research emphasizes that entry modes differ in terms of the degree of control that a firm has over its foreign activities. On the one hand, wholly owned subsidiaries provide the firm with substantial control of foreign operations. On the other hand, collaborative ventures provide less autonomous control by a firm. Two sets of perspectives—internalization theory and evolutionary theory—offer particularly relevant perspectives to explore the question of foreign research entry.

Internalization theory focuses on ownership of firm-specific advantages that firms can transfer to another country for economic benefit.[1] The theory stresses intangible assets, such as firm knowledge concerning technical or marketing activities (Hennart, 1982; Dunning, 1988). According to this view of foreign direct investment, firms with higher degrees of intangible knowledge will undertake entry modes that provide firms with greater degrees of control. Transaction cost theory (Williamson, 1975, 1985; Teece, 1976) offers an overarching perspective for the internalization view. Transaction cost analyses of foreign entry modes argue that firms which use transaction-specific assets for their foreign activities will undertake entry modes that provide greater degrees of control (Anderson and Gatignon, 1987; Gatignon and Anderson, 1988; Hennart, 1991; Kim and Hwang, 1992). The internalization view emphasizes incentives to choose entry modes that protect the value of a firm's knowledge from opportunistic behavior by a partner. While undoubtedly a partial explanation for foreign R&D entry modes, the opportunism perspective is not an encompassing explanation for cases in which firms undertake foreign research in order to acquire new knowledge, rather than to apply existing knowledge. The appropriability of new knowledge clearly is a factor in such cases but firms must consider how the entry mode will affect their ability to learn, as well as how the mode will protect the value of what the firm learns.

Evolutionary theory provides a complementary view to internalization theory. In counterpoint to the perspectives that emphasize protecting the value of knowledge, Kogut (1988) and Kogut and Zander (1993) explain entry modes in terms of adding to the knowledge of the firm. They argue that this is an evolutionary theory of the multinational firm in that firms accumulate knowledge over time by following sequential entry processes that combine their domstic knowledge with what they learn in foreign markets. In this view, firms initially will tend to undertake lower control activities until they learn enough to take greater control of their foreign activities. At a general level, evolutionary economic theory (Nelson and Winter, 1982) encompasses Kogut and Zander's (1993) evolutionary arguments concerning the choice and sequence of entry modes. A fundamental tenet of the evolutionary economics model is that firms' preexisting organizational routines strongly influence their actions. These organizational routines form the basis of a firm's capabilities. Winter (1990: 283) identified evolutionary theory's emphasis as being on the 'firm's role as a repository of productive competence.' When faced with a need for new capabilities, such as undertaking foreign research, firms tend to search in ways that are compatible

[1] The intellectual origin of internalization theory can be traced to Coase (1937). Scholars such as Hymer (1976) and Caves (1971) provided fundamental contributions. Williamson (1975) operationalized the theory as transaction cost economics, while the work of Dunning (1973), Buckley and Casson (1976), Teece (1976), Rugman (1981), Hennart (1982), and others is instrumental in developing the theory.

with their existing routines. Applying this view to foreign R&D entry modes suggests that one must consider both how a firm's existing capabilities and how its need for new capabilities influence the choice and sequence.

In this study, I draw on both the protection and the learning perspectives to analyze firms' foreign R&D entry modes. I categorize the organizational choices for a firm that undertakes foreign R&D into three basic types, including sponsored research, collaborative research, and controlled research. Sponsored research activities are those in which a firm funds research at a university or another firm for projects that do not involve company research staff. Firms usually target sponsored projects for discovery of a specific product or phenomenon, often with a specific project duration. Collaborative research projects involve the participation of a firm's employees in the foreign research activity, either through relocation to the foreign site or through undertaking dual tracks of research at home and abroad. Firms may undertake collaborative projects with either universities or other firms. I include joint ventures in the collaborative category. Controlled research activities are those for which the firm establishes ownership. Controlled activities can be the acquisition of a foreign facility or the establishment of a new facility. In these instances, the firm employs foreign researchers to work in these facilities and may also transfer scientists from its domestic operation to the foreign site. This three-part typology includes one form of wholly intrafirm activity and two forms of collaboration, where one collaboration mode involves organizational participation and the other involves only financial participation.

Each of the three forms of foreign research has advantages and difficulties concerning protection and learning. Sponsored research generally has the lowest cost and requires the least knowledge of the local environment, but also will tend to provide the least return because the firm may learn the least and will be unable to protect all the benefits of the research conducted on its behalf (Hagedoorn, 1993; Harrigan, 1985). At the other end of the continuum, controlled research offers the greatest protection and the greatest potential learning, but also requires the greatest commitment of money and effort as well as the greatest knowledge of the local environment in order to realize the potential learning. Collaborative research, which lies between the market and the firm, offers a mid-ground position in terms of protection and learning.

I have excluded licensing from the typology of entry modes for R&D. The primary reason is that firms usually form licensing arrangements to sell or obtain a specific product, rather than to undertake R&D activities. A licensee generally lacks control of spin-off opportunities because licensors attach restrictive conditions on their sale of technology, such as geographically or byproduct application (Odagiri and Goto, 1993).

In summary, several theoretical perspectives offer relevant arguments concerning international R&D entry modes. Internalization theory stresses the need to choose a mode that protects the value of knowledge, while evolutionary theory emphasizes the importance of obtaining new knowledge. For the purpose of this paper, I have categorized foreign research modes as sponsored, collaborative, and controlled, which vary in terms of protection and learning opportunities. In the next section, I develop hypotheses regarding the sequence of sponsored, collaborative, and controlled research activities that firms will tend to undertake outside their home country.

HYPOTHESES

The hypotheses address two primary issues. I first discuss how sponsored, collaborative, and controlled foreign research activities provide a sequence of increasing intensity of commitment, learning, and protection. I then discuss two factors and alternatives that might cause firms to skip parts of the sequence.

Firms have strong incentives to undertake controlled research activities, due to both protection and learning factors. Controlled research offers greater protection for the value of research than do sponsored or collaborative research. Moreover, controlled research activities offer firms the greatest opportunity to influence the ongoing direction of research as new results unfold. If learning about new environments is a major factor for foreign research, however, many firms will be unable to jump directly to controlled research activities when they begin to undertake foreign R&D because the dual burden of a new activity and a new geographic locale would be too large.

I start by emphasizing the learning-based per-

spective on initial international expansion. Firms undertaking an international R&D activity are interested in learning about the subject of the specific research activity. In order to be effective at this learning firms need to have some understanding of the nature of the research process as well as the national context in which the research takes place.

The learning perspective suggests that many firms will follow a sequence of increasing intensity in undertaking R&D activities abroad, instead of initially undertaking controlled research. That is, firms are likely to establish at least one sponsored research activity first, followed by one or more collaborative projects which, in turn, are followed by a controlled research activity. Stopford and Wells (1972) argue that lack of familiarity with a location will lead a firm to undertake less controlled entry modes. According to Mitchell, Shaver, and Yeung (1994), sequential entry allows a firm to learn about its new environment gradually. Such a sequential expansion of a firm's activities after the initial entry into a country is 'an expression of the evolutionary acquisition and recombination of knowledge' (Kogut and Zander, 1993: 640). Only once a firm gains substantial knowledge of the local environment and begins to generate research results does the need to protect the value of research dominate the incentives to learn from locally based entities.

Sponsored research provides an initial step in which firms begin to learn about the research environment in a new country. Relevant issues that a firm must learn before undertaking its own research include scientific norms, the geographic location of specific research capabilities, and the strengths and weaknesses of specific research institutions. The overarching issue is that each country has its own national innovation system that a firm must understand before it can undertake deep learning concerning specific products and processes (Nelson, 1993). Consistent with this view, sponsoring foreign R&D can also be thought of as an option that the firm might exercise if the sponsored research develops valuable results (Arora and Gambardella, 1994).

The second stage in the sequence, collaborative research, adds an organizational dimension to the research activity. Once a firm learns enough about the foreign research environment through sponsored research, it will often wish to undertake hands-on research activity. The tacit nature of R&D means that companies will often need an organizational presence in order to learn how to do research in a particular scientific area. Only by being involved can a firm gain a deep understanding of the strengths and weaknesses and areas of opportunity that a technology offers (Nelson and Rosenberg, 1993). Collaboration with a firm or university in a foreign location offers an initial means of undertaking hands-on research in an environment that a firm understands only imperfectly. The collaboration stage also adds an organizational dimension to the options perspective, in the sense that a firm may need to undertake hands-on activity in order to realize the value of its option for tacit technology. That is, unlike a financial option in which a buyer simply cashes in his or her valuable option, a research option will often require that the firm undertake direct participation in the next stage of development if it wishes to realize the value of the option.

Finally, controlled research requires the greatest financial and managerial commitment of the three modes (Hagedoorn, 1993), along with the greatest knowledge of the local environment. I expect many firms to undertake controlled research only once they have gained a reasonable understanding of the foreign research environment by first undertaking sponsored and collaborative research. That is, many firms will increase their level of investment and involvement in a foreign R&D activity only as they learn more about the environmental context, scientific viability, and market potential of technological areas. Undertaking controlled research will then provide the firm with the ability to direct future development and to protect the results of what the firm is learning in the foreign location.

> *Hypothesis 1: Firms will tend to undertake foreign R&D activities in a sequence of sponsored, collaborative, and controlled research activities.*

Although I expect that learning issues will lead many firms to follow the sponsored, collaborative, and controlled sequence of research activities, I also expect that the existing possession of scientific knowledge capabilities will influence some firms to undertake activities out of sequence. I focus on two types of scientific knowledge capabilities: domestic research skills and comple-

mentary technical skills. Both types of capabilities are relevant to foreign research expansion. Domestic research skills provide linkages to the traditional knowledge base of an industry, while complementary technical skills provide linkages to emerging technological opportunities. Together, the two sets of capabilities are most relevant in cases where an industry is faced with new technological opportunities, while existing technological bases remain valuable. This context is true of many industries, including the pharmaceutical industry that is the focus of my empirical analysis.

The possession of particularly strong domestic R&D capabilities may influence firms to established controlled foreign R&D activities out of sequence. In part, this prediction draws from learning issues. Firms which have strong domestic research capabilities in the relevant market area have a particularly deep understanding of the tacit aspects of that research (Teece, 1976). The presence of strong in-house research may allow firms to be more effective at evaluating international research opportunities. Their experience means that they may have skills required to be directly involved in the research, through collaboration or control, even though the research is conducted in a new environment. Moreover, firms with strong domestic research capabilities would have the absorptive capacity required to transfer knowledge from the foreign environment to their domestic operations. Cohen and Levinthal (1990) argue that firms with increased absorptive capacity will tend to be proactive and exploit opportunities present in the environment. Gambardella (1992) has shown that firms with better in-house scientific research are more effective at exploiting external scientific information. In addition, a firm with strong R&D capabilities would be likely to believe itself competent to collaborate or manage such a facility anywhere in the world due to a belief in the commonality of the scientific community throughout the world.

The protection logic also applies here. Firms with a well-developed R&D capability are likely to have developed proprietary knowledge. Much of the literature on entry mode has discussed the hazards of transferring knowledge across organizational boundaries. Stopford and Wells (1972), Gatignon and Anderson (1988), and Gomes-Casseres (1989) have shown that greater R&D intensity leads to full ownership of subsidiaries in the case of U.S. firms. Thus, firms with a high degree of R&D capability may also be worried about reverse flow of information in the case of a collaborative foreign R&D activity. This fear of exposing their proprietary information could drive firms to establish collaborative or controlled activities, rather than risk leakage through sponsorships. For both learning and protection reasons, therefore, I expect firms with strong domestic research capabilities to be most likely to establish controlled foreign R&D facilities out of sequence.

Firms that possess strong complementary technical skills also may be likely to undertake foreign research activities out of sequence. Complementary technical skills consist of technological knowledge in fields closely related to the scientific area that a firm might explore through an international R&D activity. A firm which judges itself to possess relevant technical skills may believe that it knows enough to establish collaborative or controlled foreign R&D activities without first sponsoring foreign research activity. Strength in a particular process skill may drive firms to seek products that utilize that process. Teece (1986) argues that firms which already control the specialized complementary assets necessary for commercialization of a technology will be able to maximize their return on their R&D investment. Teece (1986) recommends that firms target technology areas for which they already control the specialized complementary assets necessary for commercialization of the technology. Firms targeting particular technology areas in order to acquire products would need to be certain of being able to protect the value of research, which would be more assured through the establishment of a collaborative or controlled research activity than through sponsorship.

> *Hypothesis 2: The greater a firm's scientific knowledge capabilities in the relevant market area, the more likely the firm is to undertake a foreign collaborative or controlled research activity before undertaking a sponsored research activity.*

There are alternative explanations for disruption of the sequence of entry mode. One factor which could disrupt the sequence is the timing of the firm's initial R&D activity. Another factor which could disrupt the sequence is the firm's preexisting knowledge of the foreign market. Either of

these factors could influence firms to undertake international R&D activities out of sequence.

The time that a firm first undertakes foreign R&D activities may affect the sequence of research modes. In almost all industries in economically developed countries, several national competitors might engage in foreign R&D. If a firm is among the first of the national firms within an industry to undertake foreign R&D, which I refer to as an early entrant, it may be more likely to follow the sequence of sponsored, collaborative, and controlled. However, the later a firm is to undertake its first international R&D activity, relative to its national competitors, the more likely the firm will start at a later point in the sequence of entry. There are two reasons for this disruption of the sequence of entry. The first reason is that a later entrant will have the advantage of learning from its predecessors (Mitchell *et al*., 1994), which is the result of spillovers from previous entrants (Shaver, 1994). Later entrants also might feel more competitive pressure to establish international R&D activities due to issues of competition, legitimacy, and imitation, creating a bandwagon effect in which firms rush to undertake hands-on international research activities (Knickerbocker, 1973; Graham, 1978). These later firms see that the earlier entrants have progressed to collaborative or even controlled research activities and may believe it necessary to establish international R&D activities that are further along in the sequence in order to remain competitive in the industry. Later entering firms may feel the need to expand internationally most intensely where competition in their home market is increasing (Graham, 1990).

Firms with previous foreign market knowledge might establish collaborative or controlled R&D activities earlier than sponsored activities. Firms obtain foreign market knowledge by participating in the market through a sales subsidiary or export activity (Ronstadt, 1977). Such firms might perceive their specific market knowledge as lessening the barriers to foreign R&D.

In summary, the hypotheses address the sequence of entry mode for foreign research activities. Hypothesis 1 predicts a common sequence of sponsored, collaborative, and controlled activities. Hypothesis 2 argues that firms with strong scientific knowledge capabilities will often expand out of sequence. Alternative explanations argue that the timing of the firm's entry into international R&D or the firm's market knowledge will induce the firm to expand their activities out of sequence. I now turn to the empirical context of the study.

THE INDUSTRY CONTEXT

I chose the Japanese pharmaceutical industry to test the hypotheses. The use of a single industry and country allows a detailed understanding of the companies involved in the industry. Firms in the pharmaceutical industry depend on intensive R&D activities in order to maintain competitiveness as do firms in industries like electronics, chemicals, communications, and aircraft manufacture.

Pharmaceuticals is considered a high-technology industry. For example, U.S. pharmaceutical companies spent an average of 16 percent of sales on R&D early in the 1990s (Japanese Pharmaceutical Manufacturers Association, 1992). The pharmaceutical industry also has recently experienced substantial change in its R&D activities due to the increasing applicability of biotechnology. This technological change has necessitated the acquisition of new research skills by pharmaceutical firms. These skills can be acquired in several ways: through sponsored research, collaboration such as joint ventures, or through establishment of wholly owned research facilities. Therefore, the pharmaceutical industry provides many of the triggers for international research and an ideal opportunity to test the hypotheses I developed above.

The Japanese pharmaceutical industry is the specific context in which I test the hypotheses. In addition to enjoying the general features of the pharmaceutical industry, the Japanese pharmaceutical industry only recently experienced pressures to expand abroad. The Japanese domestic pharmaceutical market is the second largest single-country market in the world after the United States. The size of this market meant that Japanese pharmaceutical firms generally did not feel pressure to expand abroad until the 1980s. At that time, the pressure in the domestic market increased due to two factors (Reich, 1990; Mitchell, Roehl, and Slattery, 1995). First, government restrictions on the entry of foreign firms began to be lifted during the late 1970s. Second, the government introduced price controls for pharma-

ceuticals starting in the 1980s in order to decrease national expenditures on health. The government allocated higher prices to newer drugs in order to encourage pharmaceutical innovation. These two factors placed pressure on pharmaceutical firms to seek markets and technology outside Japan starting in the early 1980s.

In addition to the recent beginning of internationalization of the Japanese pharmaceutical industry, the number of firms in the industry makes this empirical context appropriate for my study. The industry is neither too concentrated nor extremely diffuse. The top four domestic firms accounted for 25 percent of sales in the Japanese market in 1991. The top 31 domestic firms, by sales revenue, accounted for 70 percent of sales in 1980 and 85 percent of sales in 1991.

Complementary technical skills are relevant in the empirical context of the Japanese pharmaceutical industry because biotechnological developments have affected the firms' R&D environment. During the 1960s and 1970s, several molecular biology discoveries changed the nature of drug discovery for all pharmaceutical firms. Previously, firms had experimented with compounds that they hoped would have a desired physiological effect. Large groups of organic chemists synthesized minor variants on a common root structure, which required the testing of hundreds of compounds in order to discover the most effective compound. With biotechnological techniques, a therapeutic protein can be synthesized through the manipulation of genetic structure of cells. The technical skills required for synthesizing compounds through biotechnology are very different from the chemical methods that had previously been used (Pisano, 1990).

Biotechnology represents a radical change in the technological environment of established pharmaceutical firms. Nonetheless, biotechnology has conflicting effects on the traditional skills of pharmaceutical firms. In Tushman and Anderson's (1986) terminology, biotechnology is 'competence destroying' in terms of R&D capabilities. By contrast, however, biotechnology is 'competence enhancing' in terms of commercialization capabilities, because biotechnology can be used to develop a myriad of products which can be sold through the usual pharmaceutical channels (Mitchell, 1989). The enhancement of commercialization capabilities provides strong incentives for established pharmaceutical companies to undertake biotechnology research.

Japanese firms faced strong incentives to undertake international research if they wished to develop biotechnology-based skills. Although many Japanese firms had strong capabilities in processes that are relevant to biotechnology, such as fermentation, most of the early product advances occurred outside Japan. Scientists working in Great Britain provided the intellectual development of molecular biology (Nelson, 1993). Researchers in the United States have undertaken much subsequent work in biotechnology (National Research Council, 1992). Both countries continue to be leaders in the field of biotechnology. Thus, Japanese firms wishing to obtain competence in biotechnology needed to seek expertise abroad, especially in the United States and Western Europe. Moreover, because the primary locations of the knowledge were stable countries, the firms could chose entry modes independent of any issues of country risk (Vernon, 1985; Kobrin, 1982). Instead, differences in the firms' capabilities are more likely to explain differences in modes.

The development of biotechnology also expands the empirical base for the study, by raising the distinction between established Japanese pharmaceutical companies and recent entrants to the industry. The possibilities of biotechnology have induced a number of other players to enter the pharmaceutical market. In Japan, textile, food, brewing, and even steel companies entered the pharmaceutical industry during the 1970s and early 1980s and started exploring biotechnology, often undertaking research outside Japan. For some of these diversifying companies, entry to the pharmaceutical industry represented an extension of their skills with fermentation, which is the process by which many biotechnological products are produced (Watanabe, 1986). The food and brewing companies have a long experience in fermentation through the production of sake, beer, and other alcohol products. For other recent entrants, without fermentation skills, biotechnology is a technological tool for diversification into new, higher value-added product areas (National Research Council, 1992). Although biotechnology has applications in many sectors, including agriculture, industrial chemicals, electronics, energy, and environmental treatment, health care is by far the largest market segment for biotechnology applications. Therefore, the relevant sample for the study includes both the established Japanese pharmaceutical

companies and many recent entrants to the industry.

In summary, the Japanese pharmaceutical industry provides an appropriate context for testing hypotheses related to the internationalization of R&D for four reasons. First, the pharmaceutical industry is a high-technology industry that depends heavily on the outcome of R&D activities. Second, Japanese pharmaceutical firms faced increasing pressures during the 1980s to become globally competitive, which both provides an opportunity for the study and limits the relevant time frame. Third, the Japanese pharmaceutical industry is sufficiently diffuse to provide a large enough sample for this study. Fourth, recent changes in the technology necessary for pharmaceutical discovery requires a response from firms involved in the industry and create incentives for new firms to enter the industry. The combination of increasing competition and a changing technology base is a powerful incentive for firms to reach out for technology outside national borders. This work explores the question of how the incentives affected the international research entry mode choices of different firms.

I believe that the framework I have developed can help explain the actions of firms from other countries and industries. Using the Japanese pharmaceutical industry as a research context may seem to limit the generalizability of the research. However, most of the previous research on internationalization has focused on the actions of the U.S. firms (Sakakibara and Westney, 1992). It may be that it is the U.S. context which is unique and that the Japanese case is more similar to that experienced by European firms due to their similar market sizes and other factors such as technological capabilities (Reed, 1993). Certainly, many Japanese and European firms are pursuing internationalization of R&D. Over 50 percent of the 250 foreign-owned R&D facilities in the United States at the end of 1992 were established in the last 5 years. R&D spending by foreign-owned companies in the United States nearly doubled between 1987 and 1990, increasing from $6.5 billion to $11.3 billion (Serapio and Dalton, 1993). This included 250 R&D facilities owned by 100 foreign parent companies from Japan, Germany, Britain, France, and South Korea. Japanese firms are certainly appropriate objects of study since they have led this trend, accounting for 60 percent of these activities. In addition, pharmaceutical firms from many countries have invested in R&D in the United States. The majority of the European research activities in the United States have been focused on biotechnology (63% of 95 facilities). While these activities may be a small fraction of the total R&D spending in the United States, the phenomenon clearly has growing importance. I expect this framework to be generalizable to other industry and country contexts.

METHODS

This section includes descriptions of the sample, data sources, variable definitions, and statistical methods I use to test the hypotheses.

Sample and data sources

I collected the data on firms involved in the Japanese pharmaceutical industry for the time period 1980–92 (Penner-Hahn, 1995). The year 1980 is an appropriate starting point for the study since that is the beginning of a period of substantial technical, regulatory, and competitive change for the Japanese pharmaceutical industry. Targeted firms include the top 31 domestic Japanese pharmaceutical firms by sales in 1980, together with 35 recent entrants to the Japanese pharmaceutical industry. I exclude European and U.S. pharmaceutical firm subsidiaries with Japanese pharmaceutical sales from the sample. I planned to include the top 30 firms in the sample but settled on 31 firms because the 30th and 31st firms had about the same sales. The 31 firms in the sample account for 85 percent of pharmaceutical sales in Japan in 1991. The firms that are included are the major ethical pharmaceutical manufacturers in Japan. Of the 31 pharmaceutical firms included in the study, 20 established at least one foreign R&D activity during the study period. To my knowledge, the sample includes all of the foreign pharmaceutical R&D activities undertaken by Japanese firms during this period.

I selected recent entrants to the pharmaceutical industry on the basis of industry analyses by Yano Keizai Research Institute, Toyo Keizai, the Pharmaceutical Industry Forum, and others which indicated that these firms had either started pharmaceutical research or had pharmaceutical products for sale. The new entrants include tex-

Table 1. Year of establishment of initial foreign R&D activity for pharmaceutical and new entrant firms

	Pharmaceutical firms	New entrant firms
1980	Green Cross (cn)	
1981		Toray (sp)
1982	Daiichi (sp)	Kirin (co)
	Kyowa Hakko (sp)	
	Otsuka (cn)	
	Shionogi (co)	
	Yamanouchi (co)	
	Yoshitomi (sp)	
1983	Fujisawa (co)	
1984	Tanabe (co)	Suntory (sp)
1986	Takeda (co)	Asahi Breweries (sp)
		Nitto Boseki (cn)
1987	Chugai (sp)	Mitsubishi Kasei (sp)
	Eisai (cn)	Nissin Foods (cn)
		Snow Brand (co)
		Teijin (sp)
1988	Meiji Seika (co)	Ajinomoto (sp)
		Morinaga Milk (sp)
		NKK (sp)
1989	Dainippon (co)	Hitachi Chemical (sp)
	Ono (co)	Shiseido (sp)
	SSPharmaceutical (co)	
	Sumitomo Seiyaku (sp)	
	Taiho (cn)	
1990	Sankyo (cn)	Japan Tobacco (sp)
1991	Mochida (co)	Kanebo (co)
		Nippon Mining (co)

(sp) indicates a sponsored activity; (co) indicates a collaborative activity; (cn) indicates a controlled activity.

tile, food, beverage, chemical, and steel firms. Most of these firms entered the pharmaceutical industry during the 1970s, although most introduced their first products only recently. In a survey of these recent entrants, Tanaka (1992) found that the majority of the companies identified application of technology as a main motive for entering the pharmaceutical industry. Seventeen of the 35 recent entrant firms had established at least one foreign R&D activity by the end of the study period. The sample includes all recent entrants to the Japanese pharmaceutical industry that I was able to identify through the multiple sources I consulted.

I consider the established pharmaceutical firms and recent entrants separately in my analysis. The firms in the two groups are likely to possess very different capabilities and objectives. The established pharmaceutical firms are the traditional pharmaceutical firms, which we would expect to be stronger in drug development skills. Some, but not all, of the pharmaceutical firms have strength in fermentation given their involvement in the production of antibiotics. We would expect some of the new entrant firms to have strong skills in fermentation given their historic involvement in liquor, soy sauce or milk products. The new entrant firms would be less likely to have skills in drug development given that the pharmaceutical industry is a relatively new area of activity for them. Many other differences between the two groups of firms will influence their efforts to establish foreign R&D activities. The pharmaceutical firms are generally smaller than the new entrants, which tend to be large diversified firms. Almost all the pharmaceutical firms are one-industry firms while, by contrast, most recent entrants are large diversified firms. The new entrants to the pharmaceutical industry have very different motivations for their R&D activities when compared to the traditional pharmaceutical firms. New entrants, which are

entering a new industry, are seeking diversification opportunities through their pharmaceutical activities. The established firms are familiar with the pharmaceutical industry and are defending their pharmaceutical position. The pharmaceutical firms are familiar with the industry, while the new entrants must learn about the industry while also learning about new R&D areas. Although some of these differences can be measured directly, many differences are impossible to capture directly. Therefore, I have considered the two groups separately in my analysis.

I collected data for this study from several sources. The principal sources for information concerning entry and motivation are interviews with selected Japanese pharmaceutical firms regarding their foreign R&D activities and a survey sent to the remaining members of the sample. The interviews took place in Japan during May and June of 1993. At that time, a team of researchers interviewed 15 Japanese established and recent entrant pharmaceutical firms. In most cases, the company employees we interviewed were members of the R&D strategy staff or the equivalent. Prior to the interviews, we sent the firms summaries of their foreign R&D activity, which we obtained from public sources. The interviewers verified the accuracy of the activity reports and obtained information on any missing activities. The interviews also provided the study team with information regarding the companies' R&D strategies and general philosophies.

I sent the remaining Japanese established and recent entrant pharmaceutical firms a summary of their foreign R&D activities, again obtained from public sources, and asked for confirmation of these activities. The archival search resulted in a data base of approximately 115 foreign R&D activities undertaken by the firms in the sample. I sent the summary and request for confirmation to the Vice President for Pharmaceutical Research and Development at each firm. I contacted the established pharmaceutical firms through their representative with the Japanese Pharmaceutical Manufacturers Association (JPMA). I contacted the recent entrant firms using the address provided in the *Japan Company Handbook*. The publication *Japanese Overseas Investment: A Complete Listing by Firms and Countries 1992/93* was the primary source of information on the firms' foreign R&D activities. I supplemented the information obtained through the interviews and surveys with secondary data from industry guides, industry research studies, government reports, corporate annual reports, and on-line data bases. The industry guides used include the *Japan Company Handbook* and the Japan Pharmaceutical Manufacturers' *Data Book 1992*. LEXIS/NEXIS was the primary data base used to obtain business articles from international newspapers and journals.

Variables and statistical methods

The dependent variable for this study is a measure of the mode of foreign R&D activity that was initiated by an individual firm during the period 1980–92. No firms began foreign research activities before this period. I categorized the foreign R&D activities as sponsored, collaborative, or controlled based on their characteristics as described previously. For the purposes of this study, I defined R&D as any activities needed to synthesize, formulate, and test a pharmaceutical product prior to human clinical trials. I excluded clinical activity undertaken for the purposes of conducting human trials from the analysis, because this type of activity is generally focused on preparing a specific drug for a particular market. Human clinical trial activity is thus much closer to a marketing activity than a research activity. In addition, the motivation for human clinical trials is more one of complying with government regulations rather than acquiring new knowledge. This study focused on the acquisition of knowledge which would aid in the creation of new pharmaceuticals.

I defined independent variables for scientific knowledge capability as domestic research capability measured by drug patents or complementary technical skills measured by fermentation patents to test Hypothesis 2. Table 2 reports summary statistics.

I based the measures of domestic research capability and complementary technical skills on patent classifications taken from the U.S. patents granted to each firm. Patent examiners at the U.S. Patent and Trademark Office assign patent classes. The examiners assign each patent a primary patent class and subclass, based on the information that the patent applicant provides. Technological and functional principles are the primary basis for patent classes, rather than products and industries, which makes patent classes

Table 2. Correlation matrix and descriptive statistics

Variables	Sponsored	Collaborative	Controlled	Drug patents	Fermentation patents	Foreign sales offices	Entry	R&D avg. expenditure	Export ratio	Size	Age
Pharmaceutical firms ($N = 20$)											
Sponsored	1.00	–0.58	–0.33	0.22	0.02	0.06	–0.21	0.24	0.55	0.28	0.28
Collaborative		1.00	–0.58	–0.11	0.22	0.10	0.19	–0.06	–0.18	–0.10	–0.47
Controlled			1.00	–0.10	–0.28	–0.18	–0.01	–0.17	–0.33	–0.16	0.27
Drug patents				1.00	0.49	0.45	0.12	0.97	0.38	0.95	0.28
Fermentation patents					1.00	0.70	0.01	0.51	0.53	0.58	–0.16
Foreign sales offices						1.00	–0.20	0.46	0.45	0.59	0.16
Entry year							1.00	0.08	–0.16	0.14	–0.05
R&D avg. expenditure								1.00	0.43	0.95	0.25
Export ratio									1.00	0.50	0.05
Size										1.00	0.33
Age											1.00
Descriptive statistics											
Mean	0.25	0.50	0.25	25.15	9.40	0.35	1986	7018.40	3.85	131,399	19 37
S.D.	0.44	0.51	0.44	27.60	10.21	0.49	3.51	7205.00	3.63	155,477	20.22
New entrant firms ($N = 17$)											
Sponsored	1.00	–0.75	–0.49	0.23	0.21	0.13	–0.05	0.32	0.18	0.20	0.12
Collaborative		1.00	–0.20	–0.12	–0.13	–0.10	0.12	–0.18	–0.13	–0.01	–0.12
Controlled			1.00	–0.18	–0.14	–0.07	–0.10	–0.23	–0.10	–0.28	–0.02
Drug patents				1.00	0.33	–0.12	0.08	0.06	0.14	–0.08	0.06
Fermentation patents					1.00	0.15	–0.01	0.00	–0.01	–0.09	–0.15
Foreign sales offices						1.00	–0.22	0.44	0.36	–0.20	–0.47
Entry year							1.00	–0.33	–0.02	0.15	0.47
R&D avg. expenditure								1.00	0.88	0.10	–0.49
Export ratio									1.00	0.01	–0.40
Size										1.00	0.30
Age											1.00
Descriptive statistics											
Mean	0.65	0.24	0.12	7.59	5.41	0.59	19 87	2633.24	8.82	600,109	19 37
S.D.	0.49	0.44	0.33	15.95	13.56	0.51	2.65	3707.32	10.54	663,435	20.14

useful for measuring a firm's technical skills. Griliches suggests that 'it is possible to use a firm's distribution of patenting by field to infer its position in "technological space" ' (1990: 1702). Jaffe (1986) grouped 328 patent classes into 49 categories, with which he then characterized the technological positions of the firms.

I measured the firms' domestic research competence by the number of patents categorized in the two drug classes of 424 and 514. The link between drug patents and research capability is quite direct, as one would expect that competence in R&D would result in patents for new drugs. Complications arise in the counting process because patents have multiple patent classes assigned to them, while a particular patent may use a single patent class more than once when combined with different subcategories. For each patent in this study, I counted a class only once regardless of the number of times it appeared. Similarly, I counted patents that appeared in both drug classes 424 and 514 only once. I based the counts on the patent class assigned to each patent received by the firms during the 1975–80 period. This time period is appropriate because the objective is to capture a measure of the skills possessed by the firms prior to the study period.

I used the count for the patent class for Molecular Biology and Biochemistry (435) to measure complementary technical skills. This patent class is of particular interest as it includes all patents related to fermentation. This study defines fermentation as a complementary technical skill due to its importance to the production of many biotechnological products (Pisano, 1990). In the cases where the Patent Office classified a patent in both a Drug classification (424 or 514) and the Molecular Biology (435) classification, I counted the patent only in the Molecular Biology classification. This affected 60 of the 1040 patents included in the study. A sensitivity analysis that counted the patents in both categories did not alter the results reported.

The CASSIS data base from the Patent and Trademark Office of the U.S. Department of Commerce contains the information of patent classes. The data base is available on compact disk in depository libraries around the United States. I copied the patents for each of the companies in the sample to disk and then used a Fortran program to obtain the patent classes for each of the patents.

Using U.S. patents to measure the technical skills of Japanese firms is appropriate because Japanese firms as well as firms of other nationalities systematically patent in the U.S. system. Japanese firms had the second largest percentage of U.S. patents granted, after U.S. firms, in 1986 (Wineberg, 1988). The United States represents the largest single market in the world for pharmaceutical products, so that most firms want to protect their rights with U.S. patents. In addition, the Japanese system is slow to grant patents, with 5–7 years median wait as opposed to 2–3 years in the United States (Dunphy, 1988). This provides even more incentive for Japanese firms to patent their drug discoveries in the United States. One firm in the sample had over 450 U.S. patents granted during the period studied. In addition, the pharmaceutical industry is one in which patents play an extremely important role in protecting the intellectual capital of firms. In this industry, more so than in many others, firms are likely to apply for patents when there is a development which may lead to a future product.

I define other variables to examine alternative explanations of disruptions to the sequence of R&D activities. These other variables include entry timing and foreign market knowledge measured by foreign sales offices and export ratios. I used the number of years after 1979 that a firm undertook its first foreign research activity as the entry timing variable. The first firm undertook its first activity in 1980. The last firm to begin foreign research in the sample initiated its research activity during 1991. I measured foreign market presence by whether a firm had a foreign sales office at the start of the study period, that is, prior to 1980. I collected this information from *Japanese Overseas Investment: A Complete Listing by Firms and Countries 1992/1993*. The purpose of the foreign sales office variable is to determine whether the prediction that R&D activities tend to follow marketing activities (Ronstadt, 1977), based on product life cycle theory, provides greater explanatory power than the research competence and competitive pressure predictions of this study. The variable will also help assess whether marketing activities provide sufficient environmental knowledge to allow firms to skip early stages in the research activity sequence. Where possible, I also recorded the firm's export sales ratio in 1980, which correlates moderately strongly with foreign sales offices.

In addition, I recorded several supplemental variables in order to gain information about the firms. I took the values of these supplemental variables from the beginning of the study period in order to avoid endogeneity with foreign research activities and because the values of most variables change only slightly from year to year during the study period. I measured average annual R&D expenditure, which correlated highly with drug patents for the established pharmaceutical firms. I measured firm size, based on sales revenue, which also correlated highly with drug patents. Finally, I measured firm age in years, which had moderate correlation with patents and size, especially among the established pharmaceutical companies.

I have discussed the data sample, data sources, and variable definitions of my empirical analysis. My sample includes 66 Japanese firms which are active in the pharmaceutical industry, 37 of which have undertaken foreign R&D activities. The data are primarily archival, supplemented by surveys and interviews. The dependent variables are the types of the first and subsequent foreign R&D activity that the firms undertook. The independent variables are the firm's domestic research capability, complementary technical skills, and time of first activity, plus the firm's foreign market presence.

RESULTS

I use nonparametric analysis to test the hypotheses. The sample size reduces from 66 firms to 37 when I include only the firms that undertook international R&D activities. The 37 firms include 20 established pharmaceutical firms and 17 recent entrants. The small numbers involved here preclude the use of complex statistical techniques.

Hypothesis 1 predicted that firms will tend to undertake foreign research in a sequence of sponsored, collaborative, and controlled research activities. Tables 3a–c report the actual sequences. Contrary to the prediction, most pharmaceutical firms do not follow the strict predicted sequence. Table 3a shows that 15 of 20 established pharmaceutical companies that undertook foreign research began with either collaborative (10 cases) or controlled (5 cases) activities first, rather than with sponsored research (5 cases). Table 3b shows that among the five established pharmaceutical firms that began with sponsored foreign research, two undertook no other subsequent forms of research activity, while two next undertook collaborative relationships and one jumped directly to controlled activities. Some support for a modified sequence does appear in Table 3c, which reports the second type of activity given that the first was collaborative. Of the 10 established pharmaceutical firms that established collaborative activities first, five had no further activities or only additional collaborative activities, two established sponsored activities subsequently, and three moved on to controlled activities. This means that 8 of the 10 firms remained in the modified sequence, which is a statistically significant result ($p = 0.055$) using a binomial test (Wonnacott and Wonnacott, 1977). Thus, the results reject the overall sequence for established pharmaceutical companies, but provide moderate support for an intermediate sequence that begins with collaboration and proceeds to controlled activities.

By contrast to the results concerning established pharmaceutical firms, Tables 3a–c provide greater support for Hypothesis 1 with respect to recent entrants to the industry. Table 3a shows that recent entrants are more likely to begin with sponsored research, which occurred in 11 of 17 cases (65%), while four began with collaboration, and only two began immediately with controlled research. Table 3b shows that the sequence for the firms that began with sponsored research is mixed thereafter, with two of the 11 undertaking collaborative research next, four jumping directly to controlled activities as a next step, and five undertaking no additional forms of research activity. In the modified sequence reported in Table 3c, of the four recent entrants that began with collaborative activities, one next undertook controlled activities and the other three undertook no other forms of research activities. Thus, there is some support for the initial sponsorship stage in the sequence for recent entrants to the industry and for sequential expansion by firms that initially undertake collaborative research.

Three general conclusions concerning research sequences stand out in the tables. First, few firms jumped directly to controlled research (only 7 of 37 = 19%; Table 3a). Second, most established pharmaceutical firms that undertook foreign research were able to take an immediate organizational presence, most often through collabo-

Table 3a. Mode of initial foreign R&D activity

Type of firm	Number of firms in sample	Number of firms with international R&D activities	Number of firms with sponsored activity as first activity	Number of firms with collaborative activity as first activity	Number of controlled activity as first activities
Pharmaceutical	31	20	5	10	5
New entrants	35	17	11	4	2
Total	66	37	16	14	7

Table 3b. Second type of entry given that first entry was sponsored (column 3, Table 1)

Type of firm	Number of firms	No other type of entry (either no new entry or only additional sponsored activities)	Collaborative	Controlled
Pharmaceutical	5	2	2	1
New entrants	11	5	2	4
Total	16	7	4	5

Table 3c. Second type of entry given that first entry was collaborative (column 4 of Table 1)

Type of firm	Number of firms	No other type of entry (either no new entry or only additional collaborative activities)	Sponsored	Controlled
Pharmaceutical	10	5	2	3
New entrants	4	3	0	1
Total	14	8	2	4

rative relationships, while many recent entrants to the industry needed to begin with sponsored research. Third, many of the firms that expanded after beginning with an initial sponsorship entry jumped directly to controlled research (five of nine = 56%; Table 3b). These conclusions have intriguing implications for understanding the differing pressures between learning and protection.

The results offer a revised interpretation of the learning argument concerning foreign R&D. That is, few firms possess enough knowledge of another country's research environment to jump directly to controlled research as a first activity. However, firms with established presence in an industry often possess enough relevant knowledge to pick foreign partners with which to undertake initial collaborative research. Firms with little industry experience, however, are more likely to need an initial period of sponsoring research. This suggests that knowledge of the industry and the technology often dominates knowledge of the broader national environment in explaining initial entry modes. After an initial sponsorship or collaborative activity, moreover, many firms move to controlled research. Thus, once firms gain initial knowledge of the research environment, concern for controlling research and protecting proprietary rights often comes to the fore. Nonetheless, it is notable that less than half of the firms that have undertaken foreign research activities in the sample had advanced to controlled activities by the end of the study period (16 of 37 = 43%; Tables 3a–c). Clearly, the learning opportunities that sponsorship and collaboration provide offer strong incentives for foreign research.

These results echo Pisano's (1989) results in

his study of the biotechnology industry. He noted that in the early years of the industry virtually all biotechnological innovation took place through collaborative arrangements between biotechnology firms and established pharmaceutical firms. These arrangements were collaborative initially because of the complementary nature of the skills provided by biotechnological firms and the pharmaceutical firms. Due to transactions costs associated with these collaborative efforts and the organizational history of established firms, however, vertical integration became more likely. Pisano's results suggested that firms with more previous R&D experience in the relevant biotechnology were more likely to internalize new biotechnology R&D projects. There is some indication that we are seeing some of this internalization as some of the Japanese pharmaceutical firms move to controlled research activities.

Hypothesis 2 predicted that firms with strong scientific knowledge capabilities would often undertake a foreign collaborative or controlled research activity before undertaking a sponsored research activity. Domestic research capability is the first measure of scientific knowledge capabilities. The results in Table 4a provide moderate support for this prediction for established pharmaceutical firms with respect to domestic R&D skills. Among firms with the greatest number of drug patents, only one of seven (14%) began with sponsored research. By contrast, among firms with low to medium numbers of drug patents, 4 of 13 (31%) began with sponsored research. Thus, although few established pharmaceutical companies began with sponsored research, the results also show that the firms that did begin with sponsored research rarely had strong domestic research capabilities.

The results in Table 4b provide no support for Hypothesis 2 with respect to recent entrants to the pharmaceutical industry. As Table 3a reported earlier, most such firms began with sponsored research. Among those that began with collaborative or controlled research, there is no relationship with greater numbers of drug patents. I will discuss the contrast between the results for the established pharmaceutical firms and the recent entrants after presenting the other results.

Complementary technical skills are the second measure of scientific knowledge capabilities. Hypothesis 2 predicted that firms with strong scientific knowledge capabilities would establish a collaborative or controlled foreign R&D activity first. Table 5a provides moderate support for the prediction with respect to complementary technical skills. The table shows that initial entry via sponsorship declines markedly from low ($2/3 = 67\%$) to medium ($1/5 = 20\%$) fermentation patents, and then declines slightly further to the high fermentation patent category ($2/12 = 17\%$). Thus, firms with stronger complementary technical skills were more likely to establish collaborative or controlled foreign research activities first.

The results in Table 5b provide no support for Hypothesis 2 for recent entrants to the pharmaceutical industry with regard to complementary technical skills. As Table 3a reported earlier, most such firms began with sponsored research. As in the case of drug patents, there is no relationship between greater numbers of fermentation patents and initial collaborative or controlled research.

Alternative explanations for the sequence of entry predicted that firms that started their foreign R&D activities later in the study period would be more likely to establish collaborative or controlled

Table 4a. Pharmaceutical firms mode of foreign R&D by drug patents

	Total number of firms	No foreign R&D	Foreign R&D	Sponsored foreign R&D	Collaborative foreign R&D	Controlled foreign R&D
Low drug patents	11	8	3	0	2	1
Med. drug patents	12	2	10	4	4	2
High drug patents	8	1	7	1	4	2

Note: Drug patent categories were determined by ranking the firms by number of patents and breaking the sample at logical break points. Low patents were 0–3 drug patents, medium were 6–19 and high were 21–118 during the period 1975–80.

Table 4b. New entrants mode of foreign R&D activity by drug patents

	Total number of firms	No foreign R&D	Foreign R&D	Sponsored foreign R&D	Collaborative foreign R&D	Controlled foreign R&D
Low drug patents	20	11	9	6	1	2
Med. drug patents	7	4	3	1	2	0
High drug patents	8	3	5	4	1	0

Note: The patent categories were determined by ranking the firms by number of drug patents and breaking the sample at logical break points; for this table, low patents were 0 patents, medium were 1–4 and high were 8–64 during the period 1975–80.

Table 5a. Pharmaceutical firms mode of foreign R&D by fermentation patents

	Total number of firms	No foreign R&D	Foreign R&D	Sponsored foreign R&D	Collaborative foreign R&D	Controlled foreign R&D
Low patents	9	6	3	2	0	1
Medium patents	9	4	5	1	3	1
High patents	13	1	12	2	7	3

Note: The fermentation patent categories were determined by ranking the firms by number of patents and breaking the sample into thirds unless thre was no significant difference between the firms on either side of the break point. In this table, low patents corresponds to 0 patents, medium to 1–3 patents and high to 5–39 patents.

Table 5b. New entrants mode of foreign R&D activity by fermentation patents

	Total number of firms	No foreign R&D	Foreign R&D	Sponsored foreign R&D	Collaborative foreign R&D	Controlled foreign R&D
Low patents	17	10	7	4	2	1
Medium patents	10	3	7	5	1	1
High patents	8	5	3	2	1	0

Note: The patent categories were determined by ranking the firms by number of patents and breaking the sample into thirds unless there was no significant difference between the firms on either side of the break point. In this table, low patents corresponds to 0 patents, medium to 1–3 patents and high to 7–56 patents.

activities first. Table 1 provides moderate support for the prediction with respect to established pharmaceutical firms. During the first 3 years, 4 of 7 (57%) cases involved collaborative or controlled research, compared with 11 of 13 (85%) cases during the last 9 years of the study period. The results in Table 1 do not support the prediction for recent entrants, however, as there is no increasing tendency toward collaborative or controlled research among these firms.

The second alternative explanation predicted that firms with experience in the foreign market would be more likely to establish collaborative or controlled activities out of sequence. The correlations in Table 2 do not support such a prediction. In fact, the correlations in Table 2 indicate that pharmaceutical firms with higher export ratios were more likely to establish sponsored international R&D activities.

Comparing the results concerning Hypothesis 2 with respect to established pharmaceutical firms and recent entrants provides useful insights con-

cerning the importance of environmental knowledge. Established pharmaceutical firms are somewhat more likely to undertake initial collaborative or controlled research if they have strong domestic research capabilities and complementary technical skills, and if they are later to initiate foreign research. Thus, their own strength, along with the competitive threats and learning opportunities that other firms create, appear to influence the choices of the established firms. By contrast, the research capabilities, complementary technical skills, and entry timing had no influence on initial entry mode choices by recent entrants to the pharmaceutical industry. Instead, at all skill levels and throughout the study period, most recent entrants preferred sponsorships as their first foreign research activity. The comparison again speaks to the importance of the differential knowledge of the industry environment held by established firms and recent entrants. The differential capabilities and prior expansion by competitors likely influence the established firms most strongly because the established firms have enough understanding of the pharmaceutical industry environment to be able to take those factors into account. For the recent entrants, by contrast, the lack of knowledge of the industry environment is the dominant factor. Only once they obtain more knowledge of the pharmaceutical research environment can most firms begin to consider collaborative or controlled research activities.

There is another factor that might affect the new entrant firm's choice of entry mode. In addition to their lack of knowledge of the industry environment there is also the fact that potential partners will be unfamiliar with the new entrant companies. Prospective partners may be reluctant to enter into collaborative arrangements with unknown quantities such as the new entrants. Once the new entrants have demonstrated their commitment and perhaps their capabilities in the new technological area, they may become more attractive to firms seeking partnerships beyond the purely financial.

Sensitivity analysis concerning the influence of foreign sales offices on the choice of initial research mode reinforces the implications concerning the importance of knowledge of the research environment. I found little or no difference in initial foreign research mode based on the presence of foreign sales offices, either among established pharmaceutical firms or recent entrants. This null result suggests that knowledge of the research environment is a more important factor than knowledge of the market environment in its influence on foreign research activities.

DISCUSSION

The analysis of mode and sequence of establishment of foreign R&D activities by Japanese firms offered mixed support for the hypotheses developed in this work. There is some evidence of a sequence of modes used by the firms establishing foreign R&D activities. However, this sequence may not start with the initial step of sponsored research as is demonstrated by the pharmaceutical firms. Instead, the majority of the pharmaceutical firms initiated foreign R&D with collaborative arrangements.

The results suggest two other hypotheses. One is, that firms that enter a new technological regime, complementary to their existing business, will be more likely to initially establish collaborative foreign R&D activities than other types of activities. A collaborative arrangement is the most organizationally interdependent arrangement which firms will enter into if they see a longer-term benefit to be derived from the activity (Hagedoorn, 1993). Pisano (1990) found that firms that were more dependent on pharmaceutical sales were more likely to internalize biotechnology R&D. Pisano's analysis included multiple biotechnology projects for each firm, not just the initial activity, so it is possible that the sum of all current and future biotechnology projects for firms in my sample could indicate a propensity to internalize. I argue that when the technology is both new and closely related to the firm's traditional activity, the firm is more likely to initiate a collaborative venture.

In contrast to the traditional pharmaceutical firms, the new entrants to the pharmaceutical industry appeared to be far more likely to establish sponsored activities initially. This may be explained by the fact that new entrant firms would be less dependent on pharmaceutical sales than traditional pharmaceutical firms. It may also indicate a fundamentally different motivation for entering into an international R&D activity. New entrants to the pharmaceutical industry are looking for growth opportunities by applying existing

skills to new lines of business. This closely follows Penrose's (1959) argument that firms often grow by using intangible skills in new businesses. These business opportunities present themselves as a result of the new entrant firm's activities in the markets where the complementary technical opportunities emerge.

In this paper I have explored the question of entry mode and sequence in international R&D activities. My study has broadened the discussion of foreign R&D entry modes to include the impact of a firm's existing capabilities and its knowledge of the industry environment on its choice of entry mode and sequence. The analysis of both incumbents and new entrants in the pharmaceutical industry demonstrates how their different capabilities and levels of industry knowledge influence their choice of entry mode. This finding has implications for understanding the motivations of the various players in an industry as well as for participants in R&D seeking funding and/or partners.

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