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Alliance Activity as a Dynamic Capability in the Face of a Discontinuous Technological Change

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Using a dynamic capabilities lens, this study examines how technological and complementary capabilities affect firms' abilities to enter emerging technologies. The empirical evidence from a sample of pharmaceutical firms entering the new biotech fields indicates that both technological and complementary capabilities potentially affect firms' entry into emerging technologies and entry mode. However, the results also show that capabilities in the traditional technology and the emerging technology have different effects. Firms with capabilities in the emerging technology are more likely to enter new technological fields and more likely to use internal development in doing so. Complementary capabilities also increase the rate of entry into emerging technological fields. However, capabilities in traditional technology are found to be unrelated to the propensity to enter new fields, and to the choice of entry mode. These results are consistent with insights from the literature on dynamic capabilities and evolutionary theory. We examine the implications of these results for literatures on strategic alliances and technological competition.

Key words: interfirm alliances; technological discontinuity; dynamic capabilities
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There has been a considerable amount of research in the past few years on how firms cope with technological change (Christensen 1997, Henderson and Clark 1990, Hill and Rothaermel 2003, Vassolo et al. 2004). Several propositions now reside in this literature. First, firms require the appropriate technological capabilities to compete (Barney 1986, Prahalad and Hamel 1990); thus there is a need to update capabilities whenever technological change occurs (Eisenhardt and Martin 2000). Second, there is a great deal of variance in the ability of firms to develop these new technological capabilities (Agarwal et al. 2002, Dierickx and Cool 1989, Helfat and Lieberman 2002). Firms are constrained internally in generating new capabilities due to organizational inertia and path dependence (Cyert and March 1963), so firms that possess capabilities in the traditional technology may not be able to develop capabilities in the emerging technology with ease (Cohen and Levinthal 1990, Nelson and Winter 1982).

However, constraints in building new capabilities do not necessarily imply that disadvantaged firms may never be able to compete effectively. Less-endowed firms can potentially access a new technology through markets for partnering or corporate control (Anand 2004, Helfat et al. 2007). While transactional problems often limit the possibility of discrete trade in capabilities (Capron et al. 1998, Dierickx and Cool 1989), acquisitions require considerable commitment of resources and can involve accumulation of unwanted assets (Hennart and Reddy 1997, Reuer and Koza 2000). Therefore, interfirm alliances, often with start-up firms, have been seen as a possible mechanism to alleviate such problems (e.g., Arora and Gambardella 1990, Harrison et al. 2001, Penner-Hahn 1998, Rothaermel 2001, Stuart and Podolny 1996, Vassolo et al. 2004). Such alliance activity permits less-endowed firms to pursue new technologies that would otherwise be beyond their reach.

Several empirical studies have demonstrated that alliances are associated with innovation and new products at the firm-level (e.g., Rothaermel and Deeds 2004, Shan et al. 1994), but it is not clear if they are a suitable choice for firms lacking in appropriate capabilities. To understand if and how firms that are less technologically endowed can overcome their handicap through alliances, we explore how owned capabilities in the traditional or emerging technology and complementary capabilities influence the entry decision and entry mode choice into emerging technological fields, and refer to the notion of dynamic capabilities. Dynamic capabilities are the antecedent organizational and strategic routines by which managers alter their source base to generate new value-creating strategies (Eisenhardt and Martin 2000, Helfat et al. 2007). In this perspective, the ability of the firm to create and manage new alliances in order to enter emerging technological fields in the presence of discontinuous technological change is considered a dynamic capability. It is suggested that dynamic capabilities are linked with firm entry mode by aiming at changing a firm's existing bundle of resources and competencies to fit emerging technological fields, which in turn affect entry and mode choice (Helfat et al. 2007).

To shed light on these issues and test our hypotheses, we study the case of U.S. and European pharmaceutical firms responding to the biotech revolution from the 1980s through the end of the 1990s.[1] Biotechnology is a departure from the conventional chemistry-based drug discovery approaches and represents a technological discontinuity (Anand et al. 2009, Shan et al. 1994). There is considerable heterogeneity among pharmaceutical firms' biotech capabilities. For example, while U.S. and European pharmaceutical firms are generally in a symmetrical position in their traditional chemistry-based business, most of the biotech start-ups have been traditionally located in the United States. Furthermore, pharmaceutical firms have often used alliances with biotech firms to build new competencies. Consequently, we believe that this context represents a good natural experiment to study the responses of pharmaceutical firms to the emergence of biotech. To test the hypotheses, we rely on data from these firms' entry into biotech from 1989 to 1999. We estimate a Heckman probit model to estimate two probit equations jointly, one entailing the probability of entry and the other the probability of entry through alliance versus internal development. The estimation of the Heckman probit model allowed us to disentangle the effect of technological and complementary capabilities on the two decisions (entry and mode of entry), accounting for their potential interdependencies.

Our study has several implications. First, we confirm that firms with superior and appropriate capabilities are more likely to enter emerging technological fields. Existing capabilities unrelated to the emerging technology are found to be irrelevant or even detrimental. Second, and more interesting, we are also able to show that the use of alliances permits technologically disadvantaged firms to catch up in terms of assessing emerging technologies. However, we find that such entry is more likely when the firms possess some complementary capabilities. The capability to create and manage alliances may be an effective dynamic capability for playing technological catch-up, but only in the presence of complementary firm capabilities. Our analysis then sheds new light on the reasons that may hinder the effectiveness of an alliance for the acquisition of a new technology.

The rest of this paper is organized as follows. In the next section we review the relevant literature and formulate our hypotheses. In the following sections, we present, respectively, the methods and the results. In the final section, we discuss the results and their implications and draw our conclusions.

Literature Review and Hypotheses

Dynamic Capabilities

According to the resource-based view (RBV), firms in the same industry perform differently because, even in equilibrium, they differ in terms of the resources and capabilities they control (Amit and Schoemaker 1993, Barney 1986, Penrose 1959, Peteraf 1993, Wernerfelt 1984). Early explanations of why firms had differential stocks of resources and capabilities included luck or superior information about the expected value of resources (Barney 1986). More recently, strategy scholars have begun to acknowledge explicitly the importance of dynamic processes, including the acquisition, development, and maintenance of differential bundles of resources and capabilities over time (e.g., Dierickx and Cool 1989, Galunic and Eisenhardt 2001, Henderson and Cockburn 1994, Iansiti and Clark 1994, Kogut and Zander 1992, Szulanski 1996, Zander and Kogut 1995). These routines help the firm integrate (e.g., Helfat and Raubitschek 2000), reconfigure (e.g., Hargadon and Sutton 1997), or develop and release new resources (e.g., Henderson and Cockburn 1994, Sull 1999).

In particular, the dynamic capability construct in this study refers to "the capacity of an organization to purposefully create, extend, or modify its resource base" (Helfat et al. 2007, p. 4). This definition captures many of the critical features of dynamic capabilities, especially as both are related to the resource base of an organization and as distinguished from operational capabilities (Winter 2003). Yet, while strategic management research has uncovered the characteristics of capabilities that permit sustainable competitive advantage (e.g., Amit and Schoemaker 1993, Barney 1991, Peteraf 1993), little is known about the ways in which dynamic capabilities affect the emergence of different intraindustry firm entry modes.

The literature on dynamic capabilities has addressed the fundamental question of how firms develop the skills that allow them to compete and gain an enduring competitive advantage. We note also that prior researchers have studied established firms in diverse industries, allowing for a test of the key propositions of the dynamic capability view. The literature shows that established firms benefit from having dynamic capabilities in crafting new business and corporate strategies (Bowman and Ambrosini 2003), entering new market arenas (King and Tucci 2002), completing successful mergers (Anand 2004), and overcoming inertia and introducing innovative programs that stimulate strategic change (Repenning and Sterman 2002). In this study, we investigate the effect of different types of technological and complementary capabilities on the likelihood and mode of entry into emerging technological fields.

Core and Complementary Capabilities

Prior research has employed various classifications of resources and capabilities, particularly within the RBV in strategic management. For instance, Barney (1991) divided resource and capabilities into three broad categories: physical, human, and organizational. Subsequent research has distinguished more finely between resources and capabilities (Amit and Schoemaker 1993). In our analysis of entry, it proves helpful to organize these general sorts of resources and capabilities into core versus complementary. The distinction between core and complementary activities exists within many strands in the technology literature. Several authors have used different terms to describe the general concepts. For instance, Thompson (1967) distinguished between core activities at the focus of a firm's attention and peripheral activities that extend beyond the boundaries of the firm but affect the firm's activities. In parallel, Richardson (1972) distinguished between similar and complementary activities. Richardson defined similar activities as the bundle of routines that a firm is most familiar with and monitors most closely, and defined complementary activities as those activities essential to the overall commercialization process that do not fall within the specialized set of a firm's routines. Teece drew a distinction between core and complementary assets (or resources and capabilities). Core resources refer to knowledge that fundamentally underlies and is required to create a product or service, including core technological knowledge (Teece 1986) and knowledge of customer needs (Helfat and Raubitschek 2000). Cleland and Bursic (1992) distinguished between core technology that firms require to make a product or service and complementary technology that supports the product or the service. Similarly, Henderson and Clark (1990) distinguished between core product technologies and complementary technologies, while identifying linkages among components as key foci of change. Others such as Argyres (1996) and Anand and Singh (1997), meanwhile, distinguished between changes that deepen a firm's existing knowledge and changes that broaden a firm's existing capabilities.

We draw on the common strands of thinking among these studies. We use the concept of core activities as technological capabilities for our study. Core capabilities are the set of routines involving physical assets, knowledge, and competencies that are intrinsic to the engineering and manufacturing of a product—for example, technological skills (Mitchell 1992). In times of discontinuous technological change, it is also useful to further distinguish between the different kinds of core capabilities, recognizing that there are core capabilities in the traditional technology as well as core capabilities in the emerging technology.

Complementary resources and capabilities are those required to profit from core knowledge, and thus comprise the set of routines involving physical assets, knowledge, and competencies that contribute to the production of or enhance the commercial utility of a product (Mitchell 1992). In this paper, we focus on those complementary capabilities that allow the firm to combine and integrate its core capabilities to develop new potentially viable products (similar to the petroleum refining-based technological knowledge in Helfat 1997). This definition, therefore, does not involve the complementary capabilities related to marketing, commercial, and distribution activities.

To illustrate, in the context of the pharmaceutical industry, incumbents have a stock of core capabilities in the traditional technology based on organic chemistry. They may also have core capabilities in the emerging technology, which is based on molecular biology and biochemistry. Finally, they may also possess complementary capabilities for converting their core capabilities into viable commercial products. Helfat (1997) took a similar approach, but in the context of the petroleum industry facing the two shocks in the 1970s. Helfat (1997) identified two types of core capabilities (in conventional technology and in less-developed technology) and two types of complementary capabilities (refining-based technological knowledge and commercial assets). In an industry in which products are undergoing technological change, complementary capabilities may provide the cushion to support continued sales while a firm uses its technical resources to catch up to product innovators.

Core Technological Capabilities and Entry into an Emerging Technological Field. Penrose (1959) proposed that the nature of firms' preentry capabilities determines the direction of expansion as firms grow, an approach also taken by recent evolutionary economic theory (Anand and Singh 1997, Kim and Kogut 1996, Helfat and Lieberman 2002). Thus, firms tend to enter industries that have resource requirements similar to the firms' preentry resource and capability profiles. Studies of large manufacturing firms in various settings have found that the greater the similarity of firms' preentry technological and marketing resources to the resource requirements of individual industries, the greater is the likelihood of entry (Anand 2004, Chang 1997, Merino and Rodriguez 1997, Montgomery and Hariharan 1991, Silverman 1999).

These studies suggest that firms match their preentry resources and capabilities to the required resource profile of industries when making entry choices. According to this logic, entrants strive to redeploy preentry resources and capabilities to the demands of the entered industry in an effort to obtain economies of scope (Panzar and

Willig 1981), and hence competitive advantage. Entry choices depend not only on the relevance of preentry resources and capabilities, but also on the degree of similarity between the preentry resources of firms and the required resource profiles of markets (Anand 2004). These results apply to both core and complementary capabilities. This study focuses on entry into emerging technological fields, which are related to firms' existing capabilities.

Consequently, for the firm's decision to enter into an emerging technological field, an important factor is the capabilities possessed by the firm. Yet, since new technologies can substantially alter the principles by which business is conducted or by which the product achieves its functionality (Dewar and Dutton 1986, Wind and Mahajan 1997), acquiring necessary new capabilities is important. It must determine whether its existing resources will be valuable in the changed industry, whether they must be complemented with new capabilities, or whether they must be abandoned (Anand and Singh 1997).

While all potential entrants are attracted by the high growth potential in the emerging technological fields (Aaker and Day 1986, Day and Schoemaker 2000), firms with capabilities related to the emerging technology are more likely to enter not only to preempt, but also to avoid being preempted by rivals that also may possess relevant capabilities (Lieberman and Montgomery 1988; Mitchell 1989, 1992). Firms that already possess capabilities in the emerging technology have competitive advantages over other firms, and are more likely to enter the emerging field. However, the appropriate technological capability is not the only such capability required to create a competitive advantage in the emerging technological field. The technological capability needs to be complemented with other capabilities in order to generate superior performance. Other sources of competitive advantage may include downstream and complementary capabilities such as marketing, sales, product testing, and obtaining regulatory approval, as well as financial and manufacturing capabilities. So increases in a single capability will exhibit diminishing returns unless such increases are accompanied by commensurate increases in other capabilities. This is analogous to diminishing returns to a single factor of production in an industrial or agricultural setting. Furthermore, the combination of these capabilities provides economies of scope up to a certain point, beyond which these economies are exhausted. Moreover, even in the case when the scope economies generated by complementary assets are not fully exploited, there is a limit to the rate at which any firm can grow, a limit provided by the capacities of its existing management (Penrose 1959). Consequently, while technological capability in the emerging technology accelerates entry, we expect to see a plateuing of this benefit beyond a certain point due to alternative sources of diminishing returns.

Hypothesis 1 (H1). *Capabilities in an emerging technology will increase the likelihood of entry into new fields of that emerging technology, but at a decreasing rate.*

Now, what is the impact of the capabilities in the traditional technology possessed by firms on their entry behavior? Many industry entrants possess none of the new technical skills required when an emerging technological field initially develops. It must acquire those skills externally through alliances or acquisitions or internally by hiring new personnel to develop the capabilities. However, there can be conflicts between capabilities in traditional and emerging technologies for industry incumbents (Mitchell 1989, 1992). Incumbent firms may fail to enter new market niches because experience can lead to habitual routines and inertia (Cyert and March 1963, Nelson and Winter 1982) that reinforce existing practices and impede adaptation (Gersick 1989, Hackman 1990). These routines may take the form of organizational structures that further impede change (Hlavacek and Thompson 1973). As a result, the inertia of current practice can overwhelm concerted efforts to change (Hannan and Freeman 1984). Nelson and Winter (1982) argued that experience with particular operating routines restricts an organization's ability to produce other products or to acquire new resources. Similarly, Greve (1996) argued that experience in one industry market niche can lead to investments and psychological commitments to a set way of doing things that then impedes entry into another market niche. Therefore, we expect that the capabilities in the traditional technology should not increase the likelihood of entry into new fields of the emerging technology.

Effect of Core Technological Capabilities on Mode of Entry (*Alliances*). Past research identifies different ways that firms acquire new capabilities when technological change affects their businesses, including internal development and alliances with other firms (e.g., Mitchell and Singh 1992, Pisano 1990, Teece 1986, Williamson 1991). Firms can enter an emerging technological field through internal development or by forming relationships with other organizations. External relationships included equity-based associations, such as joint ventures and direct investment, and nonequity associations, such as technology licensing, technology exchanges, testing agreements, and research contracts. This section argues that internal and interorganizational methods of acquiring capabilities vary with the types of their existing capabilities.

An extensive literature has discussed many sources of advantages for internal development over external arrangements for emerging technology. Two basic types of advantages of internal development are at the core of the discussions: mitigating risks of opportunistic behavior, and building on tacit organizational routines. In part, internal development protects a firm from opportunistic behavior by a partner in an external research relationship, including both reducing inadvertent leakage of proprietary information to a partner and guarding against active opportunism by a partner (Pisano 1990, Teece 1986, Williamson 1975). Moreover and often more important from a dynamic capabilities perspective, technology development typically involves the communication of tacit knowledge. The members of a firm often have a common code of communication for discussing tacit knowledge and developing new capabilities (Arrow 1974, Nelson and Winter 1977, Zhao and Anand 2009). Such codes often intertwine in the form of cumulative tacit organizational routines that span external organizational boundaries only with difficulty (Kogut and Zander 1996). By contrast, people working within a single business unit can often exchange and develop tacit information owing to their common understanding of the business's routines (Cohen and Levinthal 1990), while people working within a multiproduct firm may be able to build on a common technology and develop applications in different product areas (Argyres 1996).

This relationship is further reinforced by the learning perspective. The possession of particularly strong capabilities in the emerging technology may influence firms to enter through internal development into emerging technological fields due to the tacit nature of their capabilities (Kogut and Zander 1996). Their capabilities imply that they may have skills required to be directly involved in the development of new capabilities through internal development, even though the emerging field may be immersed in a new environment. Cohen and Levinthal (1990) argued that firms with increased absorptive capacity will tend to be proactive and exploit opportunities present in the environment. Gambardella (1992) showed that firms with better internal development research are more effective at exploiting external scientific information.

Furthermore, studies on relative advantage also support the notion that firms with specific advantages will enter through internal development rather than through external mechanisms (Anand and Delios 2002). Similarly, Kogut and Chang (1991) reported that technology acquisition by relatively weaker Japanese firms occurred via joint ventures. Hence, we expect that the choice of entry mode will be driven in part by the relative technological advantages. When the entrants have relative disadvantages, they are likely to use alliance for entry; otherwise, they would use internal development for entry as argued above.

Furthermore, firms with well-developed capabilities in the emerging technology are likely to have developed proprietary knowledge, which often needs to be protected from exposure to other firms. Firms with a high degree of technological capability may also be worried about reverse flow of information in the case of a collaborative technological activity. This fear of exposing their proprietary information could also drive firms to establish internal development rather than alliance activities.

On the other hand, alliances can serve as substitute for innovations (Hitt et al. 1990, Penner-Hahn 1998, Rosenkopf and Almeida 2003) and allow firms to undertake substantial expansions of resources that might be difficult to develop internally (Karim and Mitchell 2000). They can also allow quick entry into a market (Biggadike 1979, Hennart and Park 1993). An alliance is a means to acquire capabilities that are lacking (Grant and Baden-Fuller 2004), or to access and combine resources in order to create new capabilities (Hamel 1991, Hamel and Prahalad 1994, Prahalad and Hamel 1990, Ring and Van de Ven 1992). Alliances can strengthen the capability base of a firm (Hamel 1991, Kogut 1988). They are also a way to share the risk, to diminish uncertainty, and to benefit from reversibility (Balakrishnan and Wernerfelt 1986, Hagedoorn 1993, Parkhe 1993).

For all the interrelated reasons based on learning, protection, and relative advantage, we expect firms with strong capabilities in the emerging technology to be most likely to establish internal development entry into an emerging technological field rather than to establish alliance with a partner. In contrast, when the potential partner has a relative technological advantage, the entrants may prefer alliances for entry.

But similar to the diminishing returns logic in the previous hypothesis, since we are focusing on a single capability, we also expect diminishing returns and a leveling off of the effect of technological capabilities on entry mode. These capabilities provide beneficial economies of scope only up to certain point since, as discussed earlier; there is a limit to the rate at which any firm can grow, which is imposed by the availability of managerial resources (Penrose 1959). Consequently, while strong capability in the emerging technology encourages entry through internal development, we expect to see a plateauing of this benefit beyond a certain point.

Based on the above arguments for the use of internal development and alliances as modes of entry into new technological domains, we conclude with the following hypothesis.

Hypothesis 2 (H2). *Capabilities in an emerging technology will increase the propensity to enter new fields of that emerging technology by internal development rather than by alliances, but at a decreasing rate.*

As discussed previously, capabilities in the traditional technology may not be an advantage for entry into the emerging technological field. The nature of underlying routines in traditional technology may be quite distinct, so that new capabilities do not necessarily build on traditional capabilities. In this sense, the relationship between capabilities in traditional and in emerging technology is "path breaking" rather than "path dependent" (Karim and Mitchell 2000). Based on our above review of knowledge-based arguments, firms with capabilities in traditional technology may not have an advantage in pursuing entry into emerging technological fields through internal development relative to alliances. Therefore, they should not increase the propensity to enter new fields of the emerging technology by internal development rather than alliances.

Effect of Complementary Capabilities. Previous research on firms' ability to appropriate gains from innovation or technological capabilities has often focused on complementary capabilities. For example, (Teece 1986, p. 288) argued, "The successful commercialization of innovations requires that the know-how in question be utilized in conjunction with other capabilities or assets. Services such as marketing, competing manufacturing and after sales support are almost always needed. These services are often obtained from complementary assets which are specialized.... In some cases, as when the innovation is systemic, the complementary assets may be other parts of a system."

Helfat and Lieberman (2002) integrated the concepts of complementary assets and dynamic capabilities to define the complementary resources and capabilities as those required to profit from core knowledge, including finance, manufacturing, marketing, sales, and distribution. Firms lacking these capabilities are likely to fail, while firms that have these complementary capabilities but lack technological capabilities can sometimes succeed at the innovating firm's expense (Chesbrough and Teece 1996, Zucker and Darby 1997). If a firm has proprietary access to the specialized complementary capabilities necessary for the commercial exploitation of an innovation, then that firm has a distinct advantage (Teece 1986). The commercialization of the CAT scanner provides a compelling example. The innovator, EMI, lost to the follower, GE Medical Systems, because of a lack of specialized complementary capabilities.

Other empirical work has also pointed to complementary capabilities in explaining firm entry into newly emerging technological subfields (Mitchell 1989). For example, complementary capabilities buffered incumbents in the typesetter industry from the consequences of radical technological change (Tripsas 1997), and led to extensive interfirm cooperation between incumbents and new entrants (Rothaermel 2001). In addition, Rothaermel and Hill (2005) found that the performance implications of a technological change for incumbents are determined in part by the impact of the change on downstream, complementary capabilities needed to commercialize the new technology. Thus, complementary capabilities not only enhance technological capabilities, but also promote all performance.

However, once again, the effect of any single capability is likely to plateau off beyond a certain range owing to diminishing marginal returns to any single capability. The benefits from economies of scope provided by complementary capabilities will taper off without a commensurate rise in the level of all other capabilities, leading to a prediction of a nonlinear relationship. This account suggests the following hypothesis.

Hypothesis 3A (H3A). *Complementary capabilities will increase the likelihood of entry into new fields of an emerging technology, but at a decreasing rate.*

We now turn to the relationship between complementary capabilities and mode of entry. Teece (1986) argued that the ownership of complementary assets determines who will benefit from that innovation. Incumbents with competencies in manufacturing or marketing are often well positioned to benefit from technological change, even if it is radical in nature. He posited that the fully integrated incumbent is the firm best positioned to benefit from innovation through exploitation of existing complementary assets.

However, dynamic networks can allow firms to focus on their core competencies through partnering with other firms along the industry value chain. Interfirm networks can improve an incumbent's access to emerging technologies, increase opportunities for organizational learning, and enable rapid adaptation to market and technology shifts (Gulati 1998). In addition, alliances may allow firms to generate relational rents that they would not be able to generate in isolation (Dyer and Singh 1998). In their study of strategic alliances in the computer industry, Mohr and Spekman (1994) found that a network strategy can lead to a competitive advantage.

Therefore, alliances have been regarded by scholars inspired by the resource- and competence-based views as an effective mechanism allowing the combination of the technological capabilities of innovative firms with the complementary capabilities possessed by other firms so as to obtain synergistic gains (Das and Teng 2000, Grant and Baden Fuller 2004, Kogut 1988). The "combination of complementary capabilities" motive for alliance formation is particularly pertinent for new technology-based firms, especially if they have been founded to exploit commercially a major technological innovation (Eisenhardt and Schoonhoven 1996, Gans and Stern 2003). In fact, such firms possess distinctive technological competencies relating to a new product, process, or service idea that need to be used in conjunction with other specialized assets in order to generate economic returns, i.e., to gain access to the market and to capital, in particular when forward integration is difficult and capital is scarce (Pisano 1991). In addition, new entrants may be further motivated to cooperate with those that possess complementary capabilities since alliances can bestow legitimacy and positive reputational effects (Stuart et al. 1999).

The firms with complementary capabilities, on the other hand, often prefer to ally with new technological entrants in order to internalize the new technology and thus maximize the value of their real options, particularly in environments of high uncertainty (Vassolo et al. 2004). Thus, complementary capabilities form the basis for a specialization-based division of labor in commercializing a radical new technology (Teece 1992). Alliances driven by access to complementary capabilities should be positively associated with the new product development by incumbent firms since they allow incumbents to commercialize the innovative output developed by new entrants. Even when alliances are also motivated by learning (Powell et al. 1996), firms with complementary capabilities are likely to be seen as attractive and worthy partners. And, as in previous hypotheses, we expect a diminishing marginal effect in this relationship. Therefore, based on the notion that strategic alliances are driven by complementarities and intent to learn, we propose the following hypothesis.

Hypothesis 3B (H3B). *Complementary capabilities will increase the propensity to enter new fields of the emerging technology by alliances rather than internal development, but at a decreasing rate.*

Research Methods

The U.S. and European Biotech Industry Context

The pharmaceutical-biotech industries offer the appropriate empirical context to test the hypotheses because

(1) Biotechnology refers to a technique that comes from a scientific advance: the advent of molecular genetics and recombinant DNA. The emergence of modern biotechnology represents a technological discontinuity that has challenged the traditional pharmaceutical industry. As Shan et al. (1994) indicated, biotechnology includes innovations that are foreign to established firms, whose technological tradition is built around traditional organic chemistry. In particular, biotechnology, building on the advances on disciplines such as molecular biology and biochemistry, has introduced at least three main changes in the pharmaceutical research: (i) new modes of drug synthesis, (ii) new knowledge about the underlying biological mechanisms of disease, and (iii) new design and screening methodologies that have facilitated the search for drugs based on biological information (Pisano 2006).

(2) Large incumbents pursue multiple exploratory investments in order to overcome the technological discontinuity imposed by the evolution of biotechnology (Vassolo et al. 2004).

(3) There is great deal of heterogeneity among pharmaceutical firms in terms of their biotech-related competencies and complementary capabilities.

(4) Technology-seeking alliances between these pharmaceutical incumbents and biotech start-ups are commonly observed, with many empirical studies referring to them (e.g., Powell et al. 1996, Rothaermel 2001, Rothaermel and Deeds 2004, Shan et al. 1994).

(5) In addition, the pharmaceutical and biotech contexts have been used before in studies on technological competences (Henderson and Clark 1990, McGrath and Nerkar 2004, Penner-Hahn 1998).

(6) Biotechnology research involves many kinds of technological domains, which we refer to as "technological fields" throughout the paper. There were 143 such biotech fields classified by BioScan in 1999, relating to ongoing research regarding different diseases.

Thus, we believe this context provides a natural setting to test our hypotheses regarding the role of capabilities and alliances under technological discontinuity.

Data

We test the above hypotheses using data on pharmaceutical firms' decisions regarding biotech R&D investments. To analyze the map of R&D investment, we track information about internal development (i.e., inhouse) investments, alliances, and acquisitions. The main source of information about technological investment is BioScan. BioScan captures R&D investments information by technological field, six times a year. Examples of these technological fields are AIDS therapeutics, bones therapeutics, and vaccines. Some of these classifications are received directly from firms themselves through means of a survey. In other cases, firm profiles were tagged by the BioScan editorial staff based on information from company press releases and websites.

The information regarding equity agreements and acquisitions were gathered from different databases, including Recombinant Capital, North Carolina Biotechnology Industry databases, Ernst & Young Biotechnology Industry Reports, Predicast F&S Index of Corporate Change, Lexis-Nexis, Dow Jones News Service, SEC Schedule 13D filings, and pharmaceutical firms annual reports.

Data collected include all biotech entry decisions made by the 19 largest worldwide pharmaceutical firms (hereafter, "firms") between the years 1989 and 1999. The starting point of this period relates to the first year of complete information provided by BioScan, while the ending period relates to the appearance of the first commercial products derived from biotech. Therefore, by the end of this period the level of uncertainty regarding these investments started to substantially decrease. These 19 firms come from several different countries, including England, France, Germany, Switzerland, and the United States. The final sample includes 876 total entries, of which 393 were in house and 483 were through alliances. We excluded acquisitions from our sample because we had just two entries through outright acquisitions. In fact, the acquisitions normally followed alliances once a firm had already entered the technological field.

Method

To test our hypotheses, we estimated a Heckman probit model, which allowed us to jointly estimate two probit equations, one entailing the probability of entry and the other the probability of entry through alliance versus internal development.[2] In particular, the model is as follows:

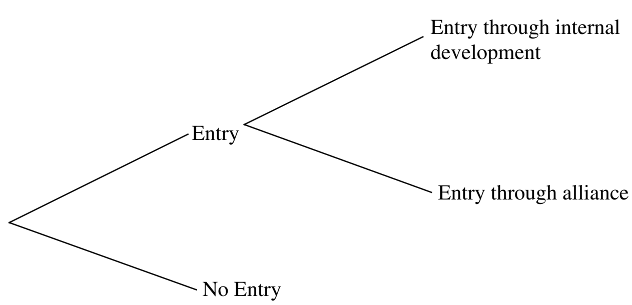
$$y_1^* = x_1\beta_1 + \varepsilon_1; \quad y_1 = 1 \quad \text{if } y_1^* > 0, \quad 0 \text{ otherwise},$$
$$y_2^* = x_2\beta_2 + \varepsilon_2; \quad y_2 = 1 \quad \text{if } y_2^* > 0, \quad 0 \text{ otherwise}, \quad (1)$$
$$\text{Corr}(\varepsilon_1, \varepsilon_2) = \rho,$$

where $y_2 = 1$ in case of entry through alliance and 0 in case of entry through internal development and $y_1 = 1$ in case of entry, and 0 in case of no entry. Given the structure of the model, three types of observations are present in the sample: no entry, entry through alliance, and entry through internal development (see Figure 1). The log-likelihood function is then based on the probabilities of the three types of observation (see Greene 2003, pp. 713–714). The choice of this model allowed us to analyze the decisions on entry and entry mode jointly, accounting in this way for potential interdependencies between the two kinds of decisions.

Dependent Variables

Our study deals with two different dependent variables, corresponding to the different hypotheses and the different equations reported in Expression (1). In H1 and H3A, the analysis involves the likelihood of entry. In this case, the dependent variable of the first equation in Model (1) is set equal to 1 if firm i entered the emerging technological field j between 1989 and 1999 through either alliance or internal development, and 0 otherwise. We recognize a firm i entering the emerging technological field j through *internal development* when, based on the data of BioScan, the firm was not present in technological field j in year $t-1$ and was present in technological field j in year t. Similarly, we recognize a firm i entering the emerging technological field j through *alliance* if the database BioScan reports an alliance of firm i in the emerging technological field j in year $t-1$.

Figure 1 Firms' Decisions Within the Heckman Probit Model



Regarding H2 and H3B, the analysis involves mode of entry, and in particular the decision to enter through alliance instead of internal development. Accordingly, the dependent variable of the second equation of Model (1) is coded 1 if firm i entered the emerging technological field j through alliance and 0 if entry occurred through internal development. Entry through alliance and entry through internal development are defined as above.

Independent Variables

To test our hypotheses, we include several measures of firms' capabilities. We build these measures using patent data and follow a consolidated approach (e.g., Narin et al. 1987, Patel and Pavitt 1997). In pharmaceutics and biotechnology, patents are highly relevant because they represent a key mechanism to appropriate returns from innovation (Gittelman and Kogut 2003). Therefore, in this industry, patent-based measures are not as affected by the potential problem of the low propensity to patent observed in other industries (Cohen et al. 2000). Our approach is very similar to that of Penner-Hahn (1998), who uses patents to measure research competences for Japanese pharmaceutical firms.

We gathered patent information from the NBER database, which reports all the patents granted by the U.S. Patent & Trademark Office (USPTO) from 1963 to 1999 (see Hall et al. 2002 for a detailed description). The U.S. Patent Classification System (USPC) is a system for organizing all U.S. patent documents into relatively small collections based on common subject matter, called patent classes. Patent classes have been considered a reasonable proxy for technological areas (e.g., Jaffe et al. 1993). Following Penner-Hahn (1998), we assign the patent classes defined by the USPTO to the three distinct sets of capabilities (technological capabilities in the traditional technology, technological capabilities in the emerging technology, and complementary capabilities). For each firm in the sample, we calculated three different patent stocks in 1988. The stocks represent different patent classes that approach different type of capabilities.

The patent stocks were calculated through the perpetual inventory method as in Hall et al. (2005). For each firm, all the patents in a given patent class were added up from 1963 to 1988 and depreciated at a yearly rate of 15%. We chose the application year instead of the grant year of the patents for the calculation because the former should be more informative of the availability of a given capability within the firm.

In the case of the pharmaceutical industry, the traditional drug search process and the emerging biotechnological techniques relied on two distinct sets of core technological capabilities (Penner-Hahn 1998, Pisano 2006). The traditional process required the synthesis and the test of several hundred organic compounds, which involved strong capabilities in organic chemistry. In a biotechnological search, therapeutic proteins are synthesized through the manipulation of the genetic structure of cells, building on a distinct set of capabilities in molecular biology and biochemistry.

Based on this distinction and on the USPTO patent classes, the measure of *Capabilities in the traditional technology* was calculated as the stock of the patents in the USPTO classes from 532 to 570 entitled "Organic compounds." The patents in these classes signal strength of the firm in the organic chemistry. The measure of *Capabilities in the emerging technology* was calculated as the stock of the patents in the USPTO Class 435 entitled "Chemistry: Molecular Biology and Microbiology."[3]

To further validate our measures, we interviewed an expert from the biopharmaceutical industry. Specifically, our goal was to confirm that, in our context, the use of different patent classes as core and complementary capabilities was appropriate. The answer we received was that the capabilities of organic chemistry lie at the core of the traditional drug research process, requiring the search and screening of new chemical compounds, whereas biochemistry and, above all, molecular biology represent the basis for genetic manipulation in the biotechnological drug search process.[4] This confirms and reinforces our idea that patents in Classes 532–570 and 435 measure core technological capabilities underlying two alternative drug research processes.

Regarding *Complementary capabilities*, it should be noted that the process to discover and develop new drugs is inherently difficult, and it requires the integration of several distinct specialized technological capabilities (Pisano 2006). Consistent with the definition of complementary capabilities used in this paper, the measure of complementary capabilities should reflect the ability of the firm to combine its core capabilities in organic chemistry or biology and biochemistry into a new potentially marketable product. Accordingly, we measure this variable as the stock of patents in the USPTO Class 424, "Drug, bio-affecting, and body-treating compositions." This class mainly contains patents on new products (drugs; bio-affecting compositions capable of preventing, alleviating, treating, or curing abnormal and pathological conditions; and antibiotics) and processes for their use or preparation (see the USPTO *Manual of Classification*), signaling the ability of the firm to develop new products and processes from its existing core technological capabilities.[5]

Control Variables

This study uses a measure of organization size to control for the financial resource position: the natural logarithm of *total pharmaceutical annual sales* (US$ millions) in 1988, the year just before the start of the study period. Organizational size has been previously used as predictor of alliance formation (Burgers et al. 1993, Gulati 1995), since larger firms may be more able to establish more internal development projects and equity agreements. The values for these variables were taken from Compustat, Lexis-Nexis, Global Access, and the annual reports of the firms. For most of the cases, the information was available under U.S. accounting standards, ensuring the compatibility of the measure across countries. Different sources were used for early observations. In particular, substantial work was needed to get early observations for non-U.S. firms. In some cases, English versions of the annual reports were not available, so it was necessary to consult the originals in French or German.

We control for organizational innovation using the *number of therapeutic classes* which the pharmaceutical firm was investigating in 1988, since broader research scope indicates a higher commitment to innovation. The source of this information was BioScan.

We also control for the U.S. origin of the firms since the main innovations in biotechnology were achieved in the United States. Firms operating in the United States were then closer to the locus of the emerging technology, which could have made their entry into the new technological fields easier.

Finally, in the equation predicting the entry mode, we use a set of dummy variables to control for the entry year. In this way we control for the fact that the entry timing can affect firms' decisions on the entry mode.[6]

Descriptive Statistics and Correlations

Table 1 contains descriptive statistics and the Pearson correlation coefficients among the variables. As expected, the number of patents related to the emerging technology is much lower than the number of patents related to the traditional technology, suggesting that at the end of the 1980s the established firms were just beginning to explore the new disciplines underlying biotech. However, the relatively high standard deviation signals that the firms in the sample are relatively heterogeneous in their investment in the emerging technology.

The analysis of the correlation coefficients could raise some potential problems of multicollinearity, in particular the correlations between *Capabilities in the emerging technology*, *Capabilities in the traditional technology*, and *Complementary capabilities*. As expected, the three variables are positively but not perfectly correlated. Whereas this evidence is consistent with the idea that firms build their capabilities heterogeneously, but through correlated processes, especially the correlation

Table 1 Descriptive Statistics for the Sample

Variables	Mean	Median	Std. dev.	1	2	3	4	5	6
1. ln(*sales*)	8.46	8.59	0.84	1.00					
2. *Number of therapeutic classes*	10.16	10.00	3.97	0.67***	1.00				
3. *U.S. firms*	0.57	1.00	0.49	0.43***	0.24***	1.00			
4. *Capabilities in the emerging technology*	16.90	8.10	20.40	−0.25***	−0.04**	0.02	1.00		
5. *Capabilities in the traditional technology*	153.90	56.60	203.20	0.06***	0.01	−0.20***	0.24***	1.00	
6. *Complementary capabilities*	13.00	4.90	15.26	0.15***	−0.07***	0.32***	0.45***	0.62***	1.00

$^{**}p < 0.05$; $^{***}p < 0.01$.

of *Complementary capabilities* with the other two variables (0.45 and 0.62) can raise some concerns of multicollinearity. It also has to be remarked that ln(*sales*) and *Number of therapeutic classes* exhibit a high correlation coefficient (0.67).

We addressed these potential problems in several ways. First, we ran a factor analysis to check if the three variables measuring capabilities referred to three different constructs. We checked for the presence of a common factor analyzing together the pairs *Capabilities in the emerging technology–Capabilities in the traditional technology*, *Capabilities in the emerging technology-Complementary capabilities*, and *Capabilities in the traditional technology–Complementary capabilities*. None of these combinations had an eigenvalue greater than 1. This analysis confirmed that the three variables loaded on three distinct factors. Second, we calculated the variance inflation factor (VIF), which was below the critical value of 10 suggested by Neter et al. (1983, p. 392), suggesting that multicollinearity did not represent a very serious concern in this study. However, given the presence of high correlation among some variables, we also performed a likelihood ratio test comparing each regression with its nested counterpart to ensure that changes in coefficients' significance level were not due to multicollinearity, but rather to an overall improvement in the explanatory power of the model.

Table 2 Capabilities, Entries, and Entry Mode for Different Groups of Firms in the Sample

Firms with	Avg. number of entries per firm	Entries through alliance (%)
High capabilities in the emerging technology, high complementary capabilities	50.0	43.5
Low capabilities in the emerging technology, low complementary capabilities	39.9	55.0
High capabilities in the emerging technology, low complementary capabilities	43.0	45.6
Low capabilities in the emerging technology, high complementary capabilities	66.0	73.9

To make a final check on the fact that our variables measured distinct types of capabilities, we analyzed in a descriptive fashion whether firms with high (low) levels of both capabilities in the emerging technology and complementary capabilities behaved differently from firms with an imbalanced mix of these capabilities.[7] For each firm in the database, we standardized the values of *Capabilities in the emerging technology* and *Complementary capabilities*, and plotted the values of the two types of capabilities.[8] Based on that, we divided the 19 firms of our sample into four groups: (1) High capabilities in the emerging technology, high complementary capabilities (five firms); (2) Low capabilities in the emerging technology, low complementary capabilities (ten firms); (3) High capabilities in the emerging technology, low complementary capabilities (two firms); and (4) Low capabilities in the emerging technology, high complementary capabilities (two firms). For each of these groups, we then calculated the firm average number of entries and the percentage of these entries realized through alliances. The results are reported in Table 2. While not pretending to be statistically significant, they highlight some preliminary interesting evidence consistent with our hypotheses. First, firms with high capabilities in the emerging technology and high complementary capabilities are more likely to enter new therapeutic classes than are firms with low values of both capabilities (50 versus 39.9 average entries per firm). Moreover, the latter firms are more likely to enter through alliance (55% versus 43.5%). As expected, firms with high capabilities in the emerging technology and low complementary capabilities are positioned between the two extreme groups in terms of both entries and use of alliances. However, the most interesting result is regarding firms that have low capabilities in the emerging technology but high complementary capabilities. These firms appear to be very successful (highest average number of entries per firm, 66) and to enter mostly by alliance (73.9% of the cases). Firms with strong complementary capabilities, even in the presence of weaker capabilities in the emerging technology, seem to be strongly advantaged in pursuing new alliances to enter the new therapeutic classes.

Results

Table 3 presents the results. For ease of presentation, we are not presenting the information regarding the year variables. Because the nonlinearity of the probit distribution can create problems in the interpretation of the coefficients, following the suggestion of Hoetker (2007), we also present the marginal effects calculated at the mean of all the independent variables (Table 4). For the variables of theoretical interest, we observe that both the sign and the statistical significance of the marginal effects are consistent with the coefficients reported in Table 3.

In Model 1, which includes only the control variables, it appears that firm sales matter for the likelihood of entry. The dummy for the U.S. firms has a negative sign, probably suggesting that U.S. firms had already started entering the new fields before 1989, whereas European

Table 3 Results of the Heckman Probit Model

	Model 1	Model 2	Model 3	Model 4	Model 5
Entry					
ln(*sales*)	0.12***	0.16***	0.11*	0.15***	0.03
	(0.05)	(0.05)	(0.06)	(0.05)	(0.06)
Number of therapeutic classes	−0.000	−0.006	0.009	−0.002	0.043***
	(0.009)	(0.009)	(0.011)	(0.010)	(0.013)
U.S. firms	−0.30***	−0.31***	−0.43***	−0.34***	−0.68***
	(0.06)	(0.06)	(0.08)	(0.08)	(0.10)
Capabilities in the emerging technology		0.0026**	0.026***	0.002	0.025***
		(0.0014)	(0.010)	(0.002)	(0.10)
Capabilities in the emerging technology^2			−0.0003***		−0.0004***
			(0.0001)		(0.0001)
Capabilities in the traditional technology		0.0005***	−0.0008	0.0004*	−0.0031***
		(0.0001)	(0.0007)	(0.0002)	(0.0010)
Capabilities in the traditional technology^2			0.000001		0.000003**
			(0.000001)		(0.000001)
Complementary capabilities				0.003	0.058***
				(0.004)	(0.001)
Complementary capabilities^2					−0.0009***
					(0.0001)
Constant	−1.30***	−1.62***	−1.31***	−1.55***	−0.95**
	(0.33)	(0.38)	(0.42)	(0.39)	(0.48)
Alliance vs. internal development					
ln(*sales*)	0.06	0.02	0.07	0.02	0.06
	(0.07)	(0.07)	(0.08)	(0.08)	(0.09)
Number of therapeutic classes	−0.024**	−0.020*	−0.038***	−0.015	−0.027*
	(0.011)	(0.011)	(0.013)	(0.013)	(0.016)
U.S. firms	0.10	0.12	0.29***	0.07	0.08
	(0.08)	(0.08)	(0.10)	(0.11)	(0.14)
Capabilities in the emerging technology		−0.0024	−0.029***	−0.003	−0.017
		(0.0020)	(0.011)	(0.002)	(0.012)
Capabilities in the emerging technology^2			0.0004**		0.0002
			(0.0002)		(0.0002)
Capabilities in the traditional technology		−0.0003**	0.0007	−0.0004*	−0.0010
		(0.0002)	(0.0008)	(0.0002)	(0.0012)
Capabilities in the traditional technology^2			−0.000001		0.000001
			(0.000001)		(0.000001)
Complementary capabilities				−0.0004	0.12
				(0.0004)	(0.14)
Complementary capabilities^2					−0.00005
					(0.00020)
Constant	0.33	0.60	0.39	0.61	0.37
	(0.49)	(0.55)	(0.60)	(0.58)	(0.67)
Total observations	2,408	2,408	2,408	2,408	2,408
Censored obs. (no entry)	1,532	1,532	1,532	1,532	1,532
Uncensored obs. (entry)	876	876	876	876	876
ρ	−0.985	−0.985	−0.984	−0.981	−0.980
Log-likelihood	−2,002.3	−2,001.7	−1,996.7	−2,000.1	−1,960.84
Log-likelihood ratio test		22.05***	10.04**	3.05	78.62***

Notes. A full set of year dummies is included in the entry mode equation. Standard errors appear in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 4 Marginal Effects of the Independent Variables Calculated at Their Mean Values from the Heckman Probit Model

	Model 2	Model 3	Model 4	Model 5
Entry				
Capabilities in the emerging technology	0.00097**	0.0099***	0.00072	0.0095***
	(0.00055)	(0.0036)	(0.00063)	(0.0037)
Capabilities in the emerging technology^2		−0.00013**		−0.00015***
		(0.00005)		(0.00005)
Capabilities in the traditional technology	0.00018***	−0.00028	0.00014*	−0.0012***
	(0.00005)	(0.00028)	(0.00008)	(0.0004)
Capabilities in the traditional technology^2		0.0000001		0.000001**
		(0.0000001)		(0.000000)
Complementary capabilities			0.00094	0.0217***
			(0.00124)	(0.0038)
Complementary capabilities^2				−0.0003
				(0.0001)
Alliance vs. internal development				
Capabilities in the emerging technology	−0.00054	−0.0068**	−0.00063	−0.00041
	(0.00044)	(0.0027)	(0.00043)	(0.00029)
Capabilities in the emerging technology^2		0.00001*		0.00005
		(0.00000)		(0.00004)
Capabilities in the traditional technology	−0.00006**	0.0002	−0.00008*	−0.00002
	(0.00004)	(0.0002)	(0.00005)	(0.00003)
Capabilities in the traditional technology^2		−0.0000001		0.0000001
		(0.0000001)		(0.0000001)
Complementary capabilities			0.00070	0.00283
			(0.00082)	(0.00387)
Complementary capabilities^2				−0.00001
				(0.00005)

firms tried to catch up in the period 1989–1999. The second equation shows that sales are not relevant in the choice between an alliance and internal development.

Model 2 includes the linear terms of the capabilities in the emerging and the traditional technologies. Model 3 includes both the linear and the square terms. Since the Heckman regression simultaneously estimates entry and mode of entry, Models 2 and 3 jointly test H1 and H2. In Model 2, where we consider only the linear relationships, we have mixed results. Both capabilities increase entry likelihood, whereas only *Capabilities in the traditional technology* negatively affect the likelihood of an alliance over internal development. When we introduce the square terms (Model 3), however, we obtain results perfectly consistent with our hypotheses. The first-order coefficient of *Capabilities in the emerging technology* is positive (0.026, marginal effect 0.0099) and significant at the 1% level, whereas the second-order coefficient is negative (−0.0003, marginal effect −0.00013), and significant at the 1% level. This suggests, in line with H1, that those technological capabilities that a firm has built in the new technology make entry into a new technological field more likely, but at a decreasing rate (H1). On the contrary, *Capabilities in the traditional technology* do not exhibit a statistically significant effect on the likelihood of entry.

Regarding the entry mode, *Capabilities in the emerging technology* favor internal development over alliances, supporting H2. In fact, they negatively affect the likelihood of an alliance (the coefficient of the first-order term is equal to −0.029 and is significant at the 1% level, the marginal effect is −0.0068 and significant at the 5% level) but at a decreasing rate (the coefficient of the second-order term is 0.0004 and significant at the 5% level, the marginal effect is 0.00001 and is significant at the 10% level). On the other hand, *Capabilities in the traditional technology* do not significantly affect the entry mode, as neither the first-order nor the second-order coefficients is statistically significant.

The likelihood ratio test is significant for Models 2 and 3 regarding the closest nested model ($p < 0.001$ and $p < 0.01$, respectively). This confirms that the significance levels for the individual coefficients increase the overall significance of the model and that they are not driven by multicollinearity effects.

Model 4 assesses the effect of *Complementary capabilities* on entry and entry mode and Model 5 also includes the square terms. When we consider only the linear effects of the three types of capabilities (Model 4), we obtain only weak results. In Model 5, where the square terms are introduced, we obtain clearer evidence, especially for the equation explaining the likelihood of entry. The coefficients of the *Capabilities in the* *emerging technology*, as in Model 4, confirm again H1. *Capabilities in the traditional technology* reduce the likelihood of entry at a decreasing rate. The effect of *Complementary capabilities* on the likelihood of entry is positive and decreasing, fully supporting H3A. In fact, the coefficient of the first-order term is positive (0.058, marginal effect 0.0217), while the coefficient of the second-order term is negative (−0.0009, marginal effect −0.0003). Both the coefficients and marginal effects are highly significant ($p < 0.001$).

The effect on entry mode is less clear. The coefficients of *Complementary capabilities* are in line with H3B, but they are not statistically significant. The coefficients of *Capabilities in the emerging technology* have the same sign as in Model 4, but they lose statistical significance. *Capabilities in the traditional technology* still do not significantly impact the entry mode.

The likelihood ratio test is not significant in Model 4, which is consistent with the lack of significance of *Complementary capabilities* in the linear terms. The likelihood ratio test in Model 5 is significant ($p < 0.001$), suggesting that the inclusion of complementary capabilities in the model enhances its explanatory power.

Robustness Checks

In this section, we test the robustness of our results to two issues that could be potentially important: analysis of subperiods and alternative measurement of complementary capabilities. We address each of them in turn.

Subperiod Analysis. In our overall analysis, we observe entries during a period of 11 years (1989–1999). However, most entries occurred in the first few years after 1988: there were almost twice as many entries per year during 1989–1993 (107 entries per year) compared with 1994–1999 (57 entries per year). This may signal that the industry evolution would reveal qualitatively distinct patterns across these subperiods. To address this concern, we divided our sample into two subperiods (1989–1993 and 1994–1999). Additionally, we calculated the independent variables at the beginning of each period (1988 and 1993, respectively) so the independent and dependent variables are better matched in terms of their time of observation. We then ran our full model separately for these two subperiods. We had 533 entries in the period 1989–1993 and 343 in the period 1994–1999. The decision to divide the sample into only two subperiods was due to the need to ensure a large enough number of entries for each subperiods. Moreover, it is reasonable to assume that the stock of capabilities needs a longer interval to be significantly modified. Indeed, this approach is in line with the analysis of Stuart and Podolny (1996), where the authors measure the technological position of the sample firms at regular intervals of five years. The results of the subperiod analysis are reported in Table 5.

Table 5 Results of the Heckman Probit Model (Full Model) for Two Subperiods (1989–1993 and 1994–1999)

	1989–1993	1994–1999
Entry		
ln(*sales*)	0.01	0.18***
	(0.07)	(0.06)
Number of therapeutic classes	0.04***	0.008
	(0.01)	(0.005)
U.S. firms	−0.69***	0.42
	(0.12)	(0.38)
Capabilities in the emerging technology	0.036***	−0.012
	(0.010)	(0.010)
Capabilities in the emerging technology^2	−0.0005***	0.0001
	(0.0002)	(0.0001)
Capabilities in the traditional technology	−0.002*	−0.004***
	(0.001)	(0.001)
Capabilities in the traditional technology^2	0.000001	0.000005***
	(0.000001)	(0.000001)
Complementary capabilities	0.036***	0.057***
	(0.011)	(0.017)
Complementary capabilities^2	−0.0005***	−0.0007***
	(0.0002)	(0.0013)
Constant	−1.22***	−2.64***
	(0.53)	(0.52)
Alliance vs. internal development		
ln(*sales*)	0.17	0.34
	(0.17)	(0.35)
Number of therapeutic classes	0.019	0.008
	(0.046)	(0.005)
U.S. firms	−1.28	0.42
	(0.94)	(0.38)
Capabilities in the emerging technology	0.002	0.001
	(0.034)	(0.030)
Capabilities in the emerging technology^2	−0.00001	−0.00000
	(0.00049)	(0.00001)
Capabilities in the traditional technology	−0.008*	0.004
	(0.005)	(0.006)
Capabilities in the emerging technology^2	0.000001*	−0.000000
	(0.000000)	(0.000001)
Complementary capabilities	0.134*	−0.060
	(0.072)	(0.084)
Complementary capabilities^2	−0.0017*	0.0009
	(0.0010)	(0.0011)
Constant	−0.98	−0.75
	(2.22)	(5.09)
Total observations	2,408	1,875
Censored obs. (no entry)	1,875	1,532
Uncensored obs. (entry)	533	343
ρ	−0.421	−0.006
Log-likelihood	−1,539.1	−993.9

Results for the first period (1989–1993) substantially confirm those obtained for the whole sample. However, we have an additional important result. The coefficients of *Complementary capabilities* in the entry mode equation confirm H3A and H3B and are statistically significant at the 10% level (the coefficients were not significant for the whole sample). This means that in the immediate years following the technological discontinuity created by the emergence of biotechnology, *Complementary capabilities* do increase the likelihood of choosing an alliance as entry mode, but at a decreasing rate. Indeed, this result is consistent with the descriptive evidence presented in Table 2. For the second period (1994–1999), in the entry equation *Complementary capabilities* have the same effect as in the previous period, while the coefficients of the *Capabilities in the emerging technology* lose statistical significance. This result could signal that the heterogeneity of capabilities in the emerging technology matter more in the period that just follows the emergence of the new technology. However, the loss of statistical significance of the effect could also be due to the reduction in the number of total observations and entries. In terms of the entry mode equation, all the coefficients lose statistical significance. We attribute this evidence to the fact that the entry mode equation is strongly affected by the reduction in the number of entries. (Please recall that in the entry mode equation only observations where entry occurs are included.)

Alternative Measurement of Complementary Capabilities. Complementary capabilities are a broad construct that can be measured in different ways. We have chosen a measure based on patents consistent with our theoretical construct, which refers to technological complementary capabilities rather than to marketing and commercial capabilities. However, market-related complementary capabilities could be as important as technology-related ones. For this reason, we calculated an alternative measure of complementary capabilities based on market data, which we refer to as *Complementary market capabilities*. For this purpose, we referred to the data on the presence of the firm in the different market segments as reported in the *Physicians' Desk Reference* (PDR). PDR identifies markets where firms sell existing products; based on this information we were able to compute the number of markets in which the firm is present. The market classification in PDR is simple and straightforward. Such classification replicates the Food and Drug Administration's "therapeutic treatment" taxonomy, including, for example, Alzheimer's disease, antihypertensives, blood modifiers, ophthalmics, respiratory agents, skin rash treatment, antidandruff shampoo, and so on. Considering all industry firms, PDR identifies 278 markets where these firms were found to conduct sales activities. Our measure of *Complementary market capabilities* is the number of market segments in which each firm was present. The intuition is that the higher the number of market segments a firm has reached, the stronger is its capability to commercialize new products, based on both the traditional and the emerging technologies. We find that this new variable is highly correlated with our measure of *Complementary capabilities* based on patents ($\rho = 0.69$). Moreover, when we introduce this new variable in our regression models, we obtain very similar results to that reported in the paper, as you can notice from Table 6. These observations provide us with a robustness check on the effect of complementary capabilities and enhance our confidence in the corresponding substantive results.

Table 6 Results of the Heckman Probit Model (Full Model) with an Alternative Measure of Complementary Capabilities

	Model 5
Entry	
ln(*sales*)	0.20***
	(0.06)
Number of therapeutic classes	−0.015
	(0.012)
U.S. firms	−0.40***
	(0.08)
Capabilities in the emerging technology	0.0167*
	(0.0097)
Capabilities in the emerging technology^2	−0.0002
	(0.0001)
Capabilities in the traditional technology	−0.0005
	(0.0007)
Capabilities in the traditional technology^2	−0.0000001
	(0.0000001)
Complementary market capabilities	0.0372***
	(0.0066)
Complementary market capabilities^2	−0.0008
	(0.0001)
Constant	−2.00***
	(0.45)
Alliance vs. internal development	
ln(*sales*)	0.35***
	(0.32)
Number of therapeutic classes	−0.015
	(0.012)
U.S. firms	0.14
	(0.54)
Capabilities in the emerging technology	−0.056**
	(0.022)
Capabilities in the emerging technology^2	0.0009***
	(0.0002)
Capabilities in the traditional technology	−0.0003
	(0.0013)
Capabilities in the traditional technology^2	0.0000001
	(0.0000001)
Complementary market capabilities	0.0568
	(0.0566)
Complementary market capabilities^2	−0.0010
	(0.0011)
Constant	−2.13
	(4.44)
Total observations	2,408
Censored obs. (no entry)	1,532
Uncensored obs. (entry)	876
ρ	−0.094
Log-likelihood	−2094.7

Discussion and Conclusions

This paper investigates how the capability of a firm to form alliances helps overcome technological gaps. In doing so, it is the first study to jointly examine the firms' decision to enter new domains as well as to examine their entry modes; this examination is accomplished with the estimation of a two-stage Heckman probit model. Our results show that firms with stronger technological capabilities in an emerging technology are more likely to enter emerging technological fields and that they tend to prefer internal development. On the other hand, firms possessing weaker technological capabilities in the emerging technology are less likely to enter new technological fields but more likely to recur to alliances. Complementary capabilities positively impact, ceteris paribus, the likelihood of entry whereas their effect on the entry mode is less clear. Capabilities in the traditional technology not only do not increase the likelihood of entry, but also might have a negative effect.

These results have several implications for the literature on technological change and dynamic capabilities. They confirm the anecdotal findings and the theoretical predictions of some studies on radical technological change (e.g., Christensen 1997, Hill and Rothaermel 2003). Firms that have an advantage in the emerging technology are more likely to enter new technological fields. Capabilities in the traditional technology not only do not matter, but can become "competency traps" (Levitt and March 1988). Anand and Singh (1997, p. 115) suggested that the ability of firms to redeploy their capabilities into new businesses are a function of the "fungibility" of these capabilities and the "business-specific nature of their routines." Our results reveal that the technology-specific nature of the routines overwhelms any sources of fungibility. Interestingly, Anand and Singh (1997) investigated the consequences of a changing market with technological capabilities intact. Our study complements it by capturing the impact of a changing technology with market capabilities intact yet reaches similar broad conclusions in this regard.

Furthermore, our results provide a possible explanation for the heterogeneity that is observed in the incumbents' capability to enter an emerging technology. Given firms' technological capabilities, complementary capabilities play an important role, allowing firms to manage the transition from the traditional to the new technology more effectively. Complementary capabilities offer firms facing a discontinuity to undertake an engage in a give-and-take exchange with other firms with different capability profiles.

Our study also sheds light on a very interesting question regarding the role of alliances as a means for obtaining new capabilities. As Mesquita et al. (2008) asked, is it possible for firms to obtain a competitive advantage from their alliances? In other words, is it ever possible for firms with a competitive disadvantage to catch up by using interfirm alliances? Such a question has fundamental implications for RBV as well as for dynamic capabilities literatures. In terms of the former, answering such a question provides insight into the trade-off between possessing core capabilities internally and accessing them through alliances. In terms of dynamic capabilities, such an answer would help in gauging the extent to which dynamic capabilities can help overcome a weak position, specifically with alliances.

We show that firms that already possess an advantage in emerging technologies may not need to rely on alliance formation for their entries into new domains. But more interesting, we find that firms lacking in capabilities for emerging technologies can sometimes use alliances effectively, especially in a period closely following a technological discontinuity. To achieve this, they should possess a requisite amount of complementary capabilities. Therefore, the dynamic capability to create and manage alliances can be considered as an effective strategy to deal with the technological gap created by a discontinuous technological change. Our study shows that alliances are used by firms to play catch-up, but only under certain conditions. By disaggregating firms' capabilities into traditional, emerging, and complementary, we are able to establish some boundary conditions for the use of alliances as a form of dynamic capability.

Whether and when alliances can help less-competent firms is not only an interesting question from the perspective of understanding competitive positions of firms, but also a question that relates to fundamental implications of evolutionary theory. On the one hand, stickiness in firm capabilities implies that firms are constrained in developing new capabilities internally, so are likely to search for such capabilities externally, which suggests the use of alliances. On the other hand, firms are also constrained in assimilating new capabilities that are sourced externally due to their limited absorptive capacity, bounded rationality, and causal ambiguity. This suggests that firms may be handicapped even while pursuing alliances. In other words, these are two distinct perspectives on whether alliances can help firms break out of path dependence. Our results offer qualified support for the use of alliances to seek new capabilities. Even if firms lack core capabilities, their complementary capabilities can serve as a bridge to seek external capabilities through alliances.

In the framework of Makadok and Barney (2001), the alliance-based strategies in our study represent an instance of "resource picking," while internal development may be considered as a case of "capability development." As firms seek attractive opportunities, both of these mechanisms can be seen as distinct forms of dynamic capabilities. However, our study suggests that the use of resource picking is not independent of capabilities developed by firms. When firms possess capabilities in technology and complementary activities, they tend to prefer the capability-development mechanism. The resource-picking mechanism seems to be emphasized when the firms' capabilities are irrelevant or deficient. Future research should also examine more directly whether the resource-picking mechanism is intrinsically more risky than the capability-development approach.

Regarding the empirical analysis, we have jointly estimated the likelihood of entry and the likelihood of entry through alliance using a two-step Heckman probit. This allowed us to disentangle the effect of technological and complementary capabilities on the two decisions (entry and mode of entry), accounting for their potential interdependencies. In fact, the decision to enter a new technological field might be intertwined with the decision regarding the entry mode. Analyzing only entry mode, independently from the entry decision, would have led to possibly biased results, since the factors affecting entry may not be the same affecting entry mode.

We also have to acknowledge some limitations of this study. One of the most important is that our results do not allow any conclusion about the effective ability of a firm to internalize a technology after the alliance. A technologically disadvantaged firm, in fact, could access a new technology through an alliance, but then may not be able to internalize it due to the lack of absorptive capacity (Cohen and Levinthal 1990). The internalization capability could be important to explain firms' dynamic capability to manage alliances for technology acquisition (Iansiti and Clark 1994). Further research on this line could analyze the effect of this capability on firms' ability to overcome technological gaps.

To conclude, this study empirically demonstrates the capability-based determinants of interfirm variance in entry into new technological domains. Different kinds of capabilities differently impact the entry decision. While the capabilities in emerging technology as well as complementary capabilities are drivers of entry into new technological domains, competence in traditional technology is irrelevant. Even more important, we have highlighted the impact of firm deficiencies on the choice to enter new technological domains through alliances. Since different kinds of capabilities impact the use of alliances differently, our study offers insights into the conditions under which alliances may be seen as a dynamic capability.

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Endnotes

[1]This study follows the Helfat and Lieberman (2002) to define a market narrowly in terms of a specific type of product or service at a particular level of technological development or state of the art in business practice.

[2]See, for example, Van de Ven and Prag (1981) for an application of the model to consumers' choices on health insurance and Boyes et al. (1989) for an application to the analysis of credit default.

[3]The fact that patents in Class 435 are at the core of a distinct drug search process is confirmed by the fact that many subclasses of Class 435 are clearly related to genetic manipulation—for example, Subclass 4: "Measuring or testing process involving enzymes or micro-organism; composition or test strip therefore; process of forming such composition or test strip" or Subclass 41: "Micro-organism, tissue cell culture or enzyme using process to synthesize a desired chemical compound or composition."

[4]This claim is supported also by the technical literature on drug development. For example, Ohlstein et al. (2000), comparing different drug development methods, said about medical chemistry (p. 182), "Organic synthesis is, and is likely to be for some time, the cornerstone upon which medicinal chemistry is built." As regards biotechnology, instead, they added (p. 187), "The development of proteins as drugs has been the principal focus of the biotechnology industry as well as a component of the drug pipeline of several larger pharmaceutical firms for some time" (i.e., the development of proteins falls under patent Class 435 within the USPTO classification system).

[5]Penner-Hahn (1998) used the same classes to calculate different variables. This difference is mostly due to the different research design of her study. Penner-Hahn analyzed the internationalization of R&D activities of Japanese pharmaceutical firms. She considered patents in Classes 424 and 514 (later integrated in Class 424) as "domestic research competence," while patents in Class 435 (Molecular Biology and Biochemistry) were seen as a platform (complementary capability) to access foreign R&D activities. Our research design, instead, aims to analyze whether the possession of competencies in the traditional technology (Classes 532–570) and the emerging technology (Class 435), at the core of two alternative drug search processes, affects the likelihood and the mode of entry into new therapeutic classes. In this perspective, the ability of a firm to obtain patents on new drugs (Class 424) should signal its ability to combine its core technologies to enter new therapeutic classes, independently of the nature of the core technological capabilities mobilized in the drug search progress.

[6]We did not introduce year dummies in the entry equation for a statistical reason. In the entry mode equation we only have the observations for which we registered an entry. The year dummies control if the entry year had an effect on the decision regarding the entry mode. In the entry equation, instead, we have many observations for which there was no entry. For these observations, we cannot create a dummy variable for the entry year because there was no entry. If we calculate the

dummy variables only for the observations for which we had an entry, the full set of year dummies perfectly explains the dependent variable (entry), and the model cannot be estimated.

[7]We thank an anonymous referee for suggesting this further analysis of the data.

[8]We do not report the graph in the paper for reasons of space, but it is available from the authors upon request.

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