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Alliance type, alliance experience and alliance management capability in high-technology ventures

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Abstract

We investigate a high-technology venture's alliance management capability. Thus, we develop a model that links differential demands of alliance type and the benefits of alliance experience to an observable outcome from a firm's alliance management capability. We test our model on a sample of 2226 R&D alliances entered into by 325 global biotechnology firms. We find that alliance type and alliance experience moderate the relationship between a high-technology venture's R&D alliances and its new product development. These results provide empirical evidence for the existence of an alliance management capability and its heterogeneous distribution across firms.

Keywords: Strategic alliances; New product development; Alliance management capability; Dynamic capabilities; Biotechnology industry

1. Executive summary

Building on the recent theoretical notion that a firm's alliance management capability can be a source of competitive advantage [Dyer, J.H., Singh, H., 1998. The relational view: cooperative strategy and sources of interorganizational competitive advantage. Acad. Manage. Rev. 23, 660–679; Ireland, R.D., Hitt, M.A., Vaidyanath, D., 2002. Alliance

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management as a source of competitive advantage. J. Manage. 28, 413–446], we empirically investigate the effect of *alliance-specific* and *firm-level* factors on a high-technology venture's *alliance management capability*. We define alliance management capability as *a firm's ability to effectively manage multiple alliances*.

To test the effect of alliance type on alliance management capability, we first establish that the relationship between a high-technology venture's R&D alliances and its new product development is inverted U-shaped, regardless of alliance type (i.e., upstream, horizontal and downstream alliances). Then, we posit that different alliance types place differential demands on a firm's alliance management capability due to the different types of partners involved and due to the different types of knowledge being transferred. Finally, we argue that firms build an alliance management capability through cumulative experience with strategic alliances over time. We test the effects of *alliance type* and *alliance experience* on alliance management capability by drawing on a sample of 2226 R&D alliances entered into by 325 global biotechnology firms in the 25-year period between 1973 and 1997.

We find that alliance type and alliance experience moderate the relationship between a high-technology venture's R&D alliances and its new product development. These results provide some preliminary empirical evidence for the existence of an alliance management capability. The results further highlight the relevance of alliance management capability for high-technology ventures since alliance experience appears to be a distinct construct, different from firm age and firm size. Taken together, these results underscore both the ability of a high-tech venture to create a competitive advantage based on its alliance management capability and the risks alliances pose if the firm's alliance activity exceeds its alliance management capability. Managers in high-tech ventures need to consider their current alliance portfolio as well as potential alliances within the context of their firm's alliance management capability.

2. Introduction

Strategic alliances are voluntary agreements between independent firms to develop and commercialize new products, technologies or services (Gulati, 1998). The use of strategic alliances has grown dramatically over the last two decades, particularly in high-technology industries (Hagedoorn, 1993). Commensurately, allying has become critical to the success of high-tech entrepreneurial ventures (Powell et al., 1996). Recently, scholars have proposed that firms differ systematically in their alliance management capability and that these differences may be a source of firm-level competitive advantage (Dyer and Singh, 1998; Ireland et al., 2002). Thus, understanding how *alliance-specific* and *firm-level* factors impact a firm's alliance management capability is an important, yet under researched, question, especially in the entrepreneurial context.

Prior research has provided empirical evidence that an entrepreneurial firm's strategic alliances enhance its rate of patenting (Shan et al., 1994), product innovation (George et al., 2002; Kelley and Rice, 2002), speed to initial public offering (IPO) (Stuart et al., 1999), market valuation at IPO (DeCarolis and Deeds, 1999) and foreign sales (Leiblein and Reuer, 2004). Other studies have generally endorsed a positive effect of alliances on entrepreneurial firm performance, but cautioned that there may exist diminishing returns to extensive allying

(Deeds and Hill, 1996). Some researchers have moved beyond general alliance experience and shown that alliance experience with the same partner over time positively impacted the alliance performance of subsequent alliances between these two partners (Zollo et al., 2002), and that firms with alliance experiences in similar technological fields were less likely to engage in post-formation governance changes in a subsequent alliance (Reuer et al., 2002).[2] When focusing on established firms rather than high-tech ventures, alliance experience has also been shown to result in higher stock market value creation (Anand and Khanna, 2000), enhanced new product development (Rothaermel, 2001a) and in the establishment of a dedicated alliance function, which in turn positively impacted alliance performance (Kale et al., 2002).

While prior research has clearly provided some evidence for the existence of firm-level alliance experience effects, empirical research that investigates factors impacting a firm's alliance management capability is scarce, mainly due to methodological obstacles. We argue that, if an alliance management capability indeed exists, it must have tangible benefits to be the basis for a firm-level competitive advantage (Godfrey and Hill, 1995). One such tangible benefit of a firm's alliance management capability is the firm's ability to productively manage its alliances, which in turn should positively impact its performance. Accordingly, we define *alliance management capability* as *a firm's ability to effectively manage multiple alliances*.

To empirically explore the construct of alliance management capability, we first establish that the relationship between a high-technology venture's alliances and its new product development is inverted U-shaped. In particular, we demonstrate that an inverted U-shaped relationship holds not only for a high-tech ventures total portfolio of alliances but also for individual alliance types (i.e., upstream, horizontal and downstream alliances). This is a precursory step to empirically establish that a firm's level of alliance management capability can be proxied by the point of diminishing total returns in the relationship between a firm's alliances and its new product development.

We then turn to the determinants of a firm's alliance management capability. We develop the notion that the *alliance type* and the firm's *alliance experience* moderate the relationship between firm allying and new product development. In particular, we suggest that different types of alliances demand different amounts of a high-tech venture's alliance management capability. Moreover, we propose that an alliance management capability is built through accumulated alliance experience over time. Firms with greater alliance experience should be able to productively manage a larger number of alliances. We test these hypotheses on a sample of 2226 R&D alliances entered into by 325 global biotechnology firms in the 25-year period between 1973 and 1997.

3. Alliance management capability

The management of alliances is a difficult organizational activity due to the complexities and uncertainties inherent in managing projects across organizational boundaries. It is not surprising, therefore, that most alliances fail or do not live up to expectations (Kogut, 1989). Yet, the ability to manage alliances effectively has been

[2] For an insightful review of the alliance literature in entrepreneurship, see Hoang and Bostjan (2003).

suggested to be a firm-level dynamic capability that enables a firm to "integrate, build and reconfigure internal and external competences to address rapidly changing environments" in order to create "innovative forms of competitive advantage given path dependencies and market positions" (Teece et al., 1997, p. 516). This is one reason why recent theoretical work has emphasized that superior alliance management can contribute to a firm-level competitive advantage (Dyer and Singh, 1998; Ireland et al., 2002).

We suggest that an alliance management capability is a path dependent capability which is built over time through repeated engagements in strategic alliances (Levitt and March, 1988). Prior empirical work has produced some evidence that a firm's alliance experience positively affects its rate of patenting (Shan et al., 1994; Sampson, 2002), new product development (Deeds and Hill, 1996) and stock-market value created (Anand and Khanna, 2000). Others have recently focused our attention not only on alliance experience per se, but rather on how firms leverage their experience in developing an alliance capability (Kale et al., 2002).

If the capability to manage alliances is heterogeneously distributed across firms and difficult to imitate, a firm's alliance management capability has the potential to create a firm-level competitive advantage (Barney, 1991; Ireland et al., 2002). We suggest that a firm-level alliance management capability might be particularly salient for high-tech entrepreneurial firms. Said firms often need to rely on extensive interfirm cooperation in discovering, developing and commercializing new products (Powell et al., 1996), given the importance of resource access for new ventures (Alvarez and Barney, 2002; Alvarez and Busenitz, 2001). Successful new product development has been found to be especially critical for entrepreneurial firms in high-technology industries (Schoonhoven et al., 1990).

While prior research has provided some evidence for the existence of firm-level alliance experience effects (Anand and Khanna, 2000; Hoang and Rothaermel, 2005; Zollo et al., 2002), research that empirically investigates factors impacting a firm's alliance management capability is scarce due to considerable methodological barriers. Pioneering empirical work in the area of alliance capability has resorted to tracking changes in a firm's organizational structure, in particular "the creation of a separate, dedicated organizational unit charged with the responsibility to capture prior alliance experience" (Kale et al., 2002, p. 750), to proxy for an alliance management capability. These researchers found that firms with a dedicated alliance function achieved higher alliance performance as measured in managerial perception and stock market responses. While the creation of a dedicated alliance function that "coordinates all alliance-related activity within the organization and is charged with institutionalizing processes and systems to teach, share and leverage prior alliance-management experience and know-how throughout the company" (Dyer et al., 2001, p. 38) appears to be a reasonable approach to leverage alliance experience for large, multi-divisional firms that formed the sample in the Kale et al. (2002) study, it appears less likely to be a viable option for entrepreneurial ventures due to their endemic resource constraints.

Yet, measuring alliance management capability more directly appears to be an almost insurmountable task due to the inherent unobservability of capabilities. Godfrey and Hill (1995) argued that unobservable constructs lie at the core of a number of influential strategic management theories including the resource-based view of the firm, and by extension, the dynamic capabilities view. Given this serious challenge impeding empirical research, they suggested that "what scholars need to do is to theoretically identify what the observable consequences of unobservable resources [capabilities] are likely to be, and then go out and see whether such predictions have a correspondence in the empirical world. The analogy here is with quantum mechanics, which has been confirmed *not* by observing subatomic entities (since they are unobservable) but by observing the trail left by subatomic entities in the cloud chambers of linear accelerators" (Godfrey and Hill, 1995, p. 530).

Therefore, if an alliance management capability indeed exists, it must have tangible benefits to be the basis for a firm-level competitive advantage. When isolated properly in an empirical analysis, these tangible benefits can then be observed. One such tangible benefit of a firm's alliance management capability is that it enhances the firm's ability to manage effectively a larger number of alliances, an observable consequence of an unobservable alliance capability. We estimate this benefit by employing a novel measure to assess a firm's level of alliance management capability. In particular, we suggest that the *point of diminishing total returns* in the relationship between a firm's alliances and its new product development is reflective of a firm's maximum ability to manage alliances effectively.

Capabilities are path dependent and as such are constrained by the firm's past investments, prior experiences and current resource endowments (Dierickx and Cool, 1989). Given that history matters, there are limitations on any firm-level capability, including the number of alliances that a firm can manage productively. Therefore, declining performance is likely the observable outcome when a firm's activities exceed its finite capabilities. This observation enables us to leverage the point of diminishing returns in the relationship between allying and new product development as a proxy for a firm's alliance management capability. Accordingly, we first establish that the relationship between a firm's alliances and its new product development is inverted U-shaped, and that it holds regardless of alliance type, before discussing the effects of alliance type and alliance experience on a firm's alliance management capability.

3.1. Alliance type and new product development

Some researchers documented a positive relationship between an entrepreneurial firm's strategic alliances and firm performance (Shan et al., 1994). Yet, one must consider the fact that firms, especially new ventures, face limited managerial and financial resources. Thus, the relationship between the number of alliances into which a firm enters and its innovative output may eventually exhibit diminishing marginal returns and, possibly diminishing total returns beyond some point. In this vein, others demonstrated that there exist negative returns to high levels of alliance activity for high-technology ventures (Deeds and Hill, 1996).

There are several reasons for an inverted U-shaped relationship. In a classical Ricardian sense, the most productive alliances are entered first, leaving only less productive alliances for subsequent alliance formation. As the number of simultaneously managed alliances increases, managers are likely to be prone to information-processing overload, a problem that has been identified in a variety of managerial tasks (Hitt et al., 1997; Zahra et al., 2000). As firms enter more alliances, their transaction costs rise, possibly beyond a point where the gains from additional alliances are outweighed by their costs (Jones and Hill, 1988), resulting in a negative net effect for high levels of alliance activity.

While demonstrating both theoretically and empirically that there exists declining marginal and possibly declining total returns to the number of alliances a firm manages simultaneously, prior work has failed to generalize this relationship to different types of alliances. To investigate the relationship between alliance type and alliance management capability, we first need to establish that an inverted U-shaped relationship holds for different alliance types. Generalizing to different types of alliances is important since entrepreneurial firms tend to engage in alliances with different partners along the industry value chain (upstream, horizontal and downstream alliances), often reflective of the different types of knowledge being transferred in the alliances. This generalization lays the foundation for exploring the impact of alliance type on alliance management capability.

An entrepreneurial venture using R&D alliances within the new product development process has three distinct choices of partners differentiated by their position along the industry value chain (Baum et al., 2000). The firm can reach upstream in the product development process to tap into the basic, early stage research upon which a research project is based (*upstream alliances*). It can reach horizontally to other technology ventures to combine resources and technologies, which have reached the early stages of commercialization (*horizontal alliances*). The venture can also reach downstream to access the manufacturing, regulatory and marketing knowledge that is required to move from a commercially feasible technology to a marketable product (*downstream alliances*). Based on the arguments advanced above, we suggest that the total number of a high-technology venture's alliances and the number of the venture's alliances in each different alliance type are related to its new product development in a curvilinear, inverted U-shaped manner.

Hypothesis 1. The relationship between a high-technology venture's total number of alliances and its new product development is inverted U-shaped (H1). An inverted U-shaped relationship holds regardless of alliance type, i.e., for upstream (H1a), horizontal (H1b) and downstream (H1c) alliances.

3.2. Alliance type and alliance management capability

Firms generally face the challenge of managing different types of alliances that are likely to make differential demands on the firm's alliance management capability. Such differential demands on a firm's alliance management capability stem primarily from two factors: the different *types of partners* involved in the firm's alliances and the different *types of knowledge* being transferred through the alliances. We first discuss a biotechnology firm's different alliance partners along the industry value chain before discussing the implications of the different types of knowledge being transferred in these alliances.

3.2.1. Different types of partners

When studying different types of partners involved in R&D alliances, Lane and Lubatkin (1998) found that the ability of a pharmaceutical firm to learn from an alliance with a biotechnology firm was determined by the relative characteristics of the two partners involved in the alliance. In particular, the ability of the pharma firm to learn from the biotech firm depended on the similarity of both firms' dominant logics, knowledge bases, as well as their organizational structures and compensation policies. The greater the similarities in these areas, the more effective the knowledge transfer, even if the knowledge was more tacit in nature.

A biotechnology venture generally faces three *different types of partners* along the industry value chain (Baum et al., 2000). Upstream alliances are entered with research universities or other non-profit research institutions, horizontal alliances are partnerships with other biotechnology firms, and downstream alliances are generally entered into with established pharmaceutical companies. These three different types of partners differ substantially along the dimensions identified by Lane and Lubatkin (1998). For example, most research universities are large public institutions dominated by bureaucratic structures, whose primary obligation is the creation and dissemination of knowledge. Private research universities tend to follow the same philosophy. Biotechnology firms are generally entrepreneurial start-ups and often face resource constraints. Moreover, while the biotech's focus is primarily on R&D, the fact that they are for-profit entities often results in proprietary treatment of the knowledge created and allows for substantially different compensation plans compared to universities, most notably stock options. Finally, pharmaceutical companies are large, established firms, with significant resources and clearly structured processes and procedures for their organizational activities.

Extending Lane and Lubatkin's (1998) findings to the three different types of partners a biotechnology firm faces would suggest that alliances with universities and other research institutions would require the greatest amount of a biotechnology firm's alliance management capability since the difference between non-profit and for-profit institutions tend to be more fundamental than differences among various types of for-profit institutions. While research universities are increasing their commercial involvement (Thursby and Thursby, 2002), they often appear ill-prepared to transact with commercial entities (Bowie, 1994; DiGregorio and Shane, 2003).

It appears that alliances with other biotechnology firms would require the least amount of a biotech's alliance management capability since two biotechs are most likely to be more similar than biotech–university or biotech–pharma pairings along the dimensions highlighted by Lane and Lubatkin (1998). Yet, we suggest that a biotech's alliances with a pharmaceutical company may actually require less of a biotech's alliance management capability since many, if not most, large pharmaceutical companies have institutionalized processes and devote considerable resources to facilitate alliances with biotechnology partners, often centralized in a dedicated alliance function (Dyer et al., 2001). Pharmaceutical companies generally expend significant resources to manage their alliances with biotechnology firms since these alliances are critical to adapt to the radical innovation introduced by this new technology (Hill and Rothaermel, 2003). In turn, this should require commensurably less of their biotechnology partner's alliance management capability.

For example, the pharmaceutical company Eli Lilly has a clearly established alliance management process executed through their Office of Alliance Management (Gueth et al., 2001). Lilly's alliance management prescribes that each alliance is managed by a three-person team: alliance champion, alliance leader and alliance manager. The alliance champion is a senior executive responsible for high-level support and oversight. The alliance leader has the technical expertise and knowledge needed for the specific area and is responsible for the day-to-day management of the alliance. The alliance manager, positioned within the Office of Alliance Management, serves as an alliance process resource and business integrator between the two alliance partners, and provides alliance training and development, as well as diagnostic tools, etc.

Clearly, different types of alliance partners demand different amounts of a biotechnology firm's alliance management capability. We suggest that alliances with the pharmaceutical companies demand the least amount, while alliances with universities demand the largest amount, and that alliances with other biotechnology firms demand a moderate amount. Taken together, we argue that there exists a pecking order of demand on a high-tech venture's alliance management capability based on the type of partner, with upstream partners demanding the most, while downstream partners demanding the least.

3.2.2. Different types of knowledge

We suggest that the pecking order of demand on a high-tech venture's alliance management capability based on the type of partner corresponds to the differences in the alliance capability required to manage the *different types of knowledge* that are being transferred in different alliances along the industry value chain. Biotechnology ventures are positioned as intermediaries in the industry value chain, taking on a dual role of knowledge transformation and commercialization (Rothaermel and Deeds, 2004). First, biotechnology firms transform the basic scientific knowledge discovered by universities and non-profits research institutions into viable products. The dependence of biotechnology firms on basic science is evidenced by the high number of citations to scientific journals included in their patents (McMillan et al., 2000). Second, biotechnology firms then commercialize new products, generally in conjunction with established pharmaceutical companies, which manage the new products through the regulatory process and distribute them through their dedicated sales divisions.

The resource-based perspective has emphasized that tacitness, ambiguity and complexity are barriers to competitive imitation because they impede organizational learning (Barney, 1991; Reed and DeFillippi, 1990). It has also been shown that these same knowledge characteristics influence the difficulty of knowledge transfer between parent and subsidiary (Szulanski, 1996), as well as knowledge transfer in strategic alliances (Simonin, 1999). R&D alliances are complex organizational forms involving the transfer of knowledge between firms under an incomplete contract. This fact implies that it is costly to acquire and assimilate the knowledge and information needed to manage possible contingencies (Jensen and Meckling, 1992). These knowledge acquisition costs increase commensurately with the level of tacitness, ambiguity and complexity inherent in alliances.

We follow Reed and DeFillippi's (1990) definition of *tacitness* as the non-codifiable accumulation of skills and know-how that results from learning-by-doing. Causal ambiguity is the ambiguity about the nature of the causal connections between actions and results (Lippman and Rumelt, 1982). In this case, we are concerned about *knowledge* *ambiguity*, which we adapt from Simonin (1999), and define as a lack of understanding about the logical links between the knowledge and the desired outcome of a commercially viable product. *Complexity* refers to the number of interdependent routines, individuals, technologies, skill sets and resources linked to a particular knowledge asset (Reed and DeFillippi, 1990). More complex knowledge assets are more difficult to transfer and thus require more of a firm's alliance management capability.

Taken together, the demands of an alliance on a firm's alliance management capability are likely to increase commensurately with the levels of tacitness, ambiguity and complexity involved in the knowledge exchanged in the alliance. The level of tacitness, ambiguity and complexity of any alliance, in turn, depends on the knowledge and activities being shared across boundaries in the alliance during different stages of the new product development process.

Upstream alliances with universities and other research institutions are generally characterized by high uncertainty and frequently involve the transfer of tacit, ambiguous and complex knowledge of uncertain value. The goal of upstream alliances is to embody leading-edge scientific discoveries into the biotechnology firm's products or processes (George et al., 2002). The knowledge at the center of these alliances is generally new, with the partners having little or no experience with advancing this type of basic knowledge into a viable prototype product or new process. The high level of knowledge ambiguity surrounding basic scientific research places commensurately high demands on a firm's alliance management capability. The value and potential of the knowledge involved in these alliances is evolving, and thus requires continuous monitoring and re-evaluation. The actual form of the product or application to a specific disease is rather unclear in early stage product creation. This leaves biotechnology ventures engaged in alliances with a university partner, whose basic values and priorities are distinctively different and potentially in direct conflict with the biotechnology venture's need for secrecy and protection of intellectual property (McMillan et al., 2000). Yet, to overcome the challenges of early product development due to the tacitness, ambiguity and complexity involved in the knowledge of interest, the alliance partners frequently place research personnel into each other's laboratory. Given these circumstances, upstream research alliances pose a significant demand on a biotechnology firm's alliance management capability since biotechnology firms success depends on commercializing the ambiguous, uncertain, tacit knowledge transmitted through alliances with research universities and other non-profit research organizations.

Horizontal alliances in the R&D process are formed with other biotech firms in a similar position in the industry value chain and are generally motivated by the desire to combine complementary technologies or to create economies of scale. In contrast to upstream alliances, the knowledge assets being combined in horizontal alliances are generally closer to commercialization and therefore better understood. In addition, the partners in a horizontal alliance generally have experience with the knowledge involved in the alliances. The application may be new, but the knowledge bases being combined are more familiar. The increased level of development implies that the transfer of assets in horizontal alliances involves relatively lower levels of tacitness, ambiguity and complexity than does the transfer of assets in upstream alliances. Thus, horizontal alliances tend to be less demanding of the firm's alliance management capability compared to upstream alliances. Biotechnology firms both receive and transmit knowledge in horizontal alliances.

Downstream alliances are generally formed with pharmaceutical firms that provide manufacturing capabilities, regulatory know-how, market knowledge and access. Downstream alliances focus on complementarities among the allied partners as they exchange knowledge that tends to be more explicit, and thus codifiable (Teece, 1992). Generally, the biotechnology firms transmit knowledge to the pharma companies as the biotechs focus on drug discovery and development, while the pharmaceutical firms leverage their expertise in clinical trials, regulatory management, and drug distribution (Rothaermel, 2001a). Prior research has shown that most alliances between small biotechnology firms and large pharmaceutical companies were initiated when the new drug candidate was ready to enter clinical trials (Pisano and Mang, 1993). A new drug that has moved through pre-clinical testing has undergone substantial development indicating that the levels of tacitness, ambiguity and complexity in the alliance should be reduced in downstream alliances. This in turn implies that downstream alliances should absorb less of a firm's alliance management capability than either horizontal or upstream alliances.

Hypothesis 2. Different alliance types demand different levels of a high-technology venture's alliance management capability, with upstream alliances demanding the largest amount, downstream alliances demanding the least amount and horizontal alliances demanding a moderate amount.

3.3. Alliance experience and alliance management capability

Building on the experience curve literature (Levitt and March, 1988), we suggest that a firm's alliance management capability is built through repeated engagements in alliances over time. Traditionally, experience effects, due to their roots in operations research, referred to systematic unit-cost reductions that occur over accumulated production volume (Yelle, 1979). Most experience benefits appear to be based on learning-by-doing through repeated engagements in the focal activity (Lieberman, 1984). While the majority of empirical studies have documented learning-by-doing effects in the manufacturing sector (Dutton and Thomas, 1984), there is also evidence that learning effects appear to play an important role in service industries (Darr et al., 1995). Luft et al. (1979), for example, found that more experienced health care providers of complex procedures like heart surgeries performed significantly better in terms of a lower mortality rate than less experienced providers.

Repeated engagements in strategic alliances allow the firm to create codified routines, policies and procedures as well as tacit knowledge with respect to the entire range of alliance management, beginning with partner selection and alliance formation to alliance management and finally alliance termination. High-technology start-ups with greater alliance experience tended to be more innovative (Shan et al., 1994). Learning effects have also been found to play out in repeated joint venturing since the stock market responded more positively to alliance announcements by firms with prior alliance experience, especially if the joint venture contained an R&D component (Anand and Khanna, 2000). While most empirical research on alliance experience has focused on this more general kind of alliance experience, others have also found significant learning-by-doing effects for repeated partnering with the same partner over time. Zollo et al. (2002) showed that prior partner-specific experience increased the performance of subsequent alliances with the same partner, in particular, if these alliances were organized in a contractual fashion.

Repeated alliance engagements over time appear to contribute to the build-up of an alliance management capability, which the firm can then leverage to enhance the performance in subsequent alliances (Dyer and Singh, 1998; Ireland et al., 2002). While we argue that a firm-level alliance management capability is built through repeated engagements in alliances, this does not imply that entrepreneurial start-ups are unable to accumulate alliance experience in any meaningful fashion. The definition of alliance management capability as a firm's ability to effectively manage multiple alliances implies that entrepreneurial ventures may accrue alliance experience through entering several alliances early on, in a more or less simultaneous fashion.[3] Taken together, we suggest that a firm's cumulative alliance experience moderates the relationship between firm allying and performance. All else being equal, a firm with greater alliance experience should be able to manage a larger number of alliances effectively.

Hypothesis 3. A high-technology venture's alliance experience moderates the relationship between strategic alliances and new product development in such a fashion that a more experienced firm is able to manage a larger number of alliances.

4. Methods

4.1. Data and sample

To test the hypotheses relating different alliance types to new product development and the effect of alliance type and alliance experience on alliance management capability, we chose the global biotechnology industry as the research setting. The scientific breakthroughs underlying biotechnology, such as genetic engineering and hybridoma technology, were accomplished in the mid-1970s. Subsequently, the first new biotechnology drugs reached the market for pharmaceuticals in the 1980s. This industry seems particularly suitable to test the notion of an alliance management capability since it exhibits the highest number of alliances among all high-technology industries (Hagedoorn, 1993). In the biotechnology industry, collaborative arrangements appear to be critical to firm performance since upwards of 70% of the top-10 selling drugs during the study period were commercialized through biotech–pharma collaborations (Ernst and Young Biotechnology Reports). This number, reflecting the collaborative intensity in this industry, would even be higher if one were to add the biotechnology firms' alliances with

[3] The empirical results presented below show that alliance experience is not significantly correlated with firm age ($r = 0.03$), and thus underscores the relevancy of alliance management capability as an entrepreneurial phenomenon.

universities that laid the foundation for many of these projects (Rothaermel and Deeds, 2004). Moreover, the biotechnology industry is characterized by a prolonged period of entrepreneurial activity due the drawn out product development process for new drugs (up to 15 years or more), and the complex, uncertain and costly nature of transforming basic science into commercializable drugs (upwards of US$500 million). Thus, the vast majority of biotechnology firms in the sample (95%) had no approved drugs on the market at the end of the study period (1997) and was burning substantial amounts of cash to finance ongoing R&D activities.

Biotechnology firms are clearly engaged in the *process of entrepreneurship*–the creation of new wealth through opportunity discovery, evaluation and exploitation (Shane and Venkataraman, 2000)–and this process extends to a considerable period of time. The prolonged time frame for new product development provides a window of opportunity for the examination of the entrepreneurial process and the emergence of a new industry. These characteristics make the biotechnology industry an excellent candidate for the study of entrepreneurship and entrepreneurial activity. While none of the prior empirical research has focused on the determinants of an alliance management capability in high-technology ventures, the substantial prior work situated in the biotechnology industry has investigated various aspects of other entrepreneurial phenomena (Deeds and Hill, 1996; George et al., 2002; Powell et al., 1996; Rothaermel and Deeds, 2004; Sørensen and Stuart, 2000; Stuart and Sorenson, 2003; Stuart et al., 1999).

To create the sample, we identified all biotechnology firms listed in the 1997 *BioScan* industry directory that were fully dedicated to human therapeutics. These are high-technology ventures that were founded to commercialize the new biotechnology. *BioScan* is a publicly available industry directory that provides comprehensive data about the worldwide biotechnology industry. The data contained in *BioScan* are cumulative in the sense that each subsequent issue includes the information of all prior versions. The sources for the *BioScan* data are company questionnaires, news releases, annual reports, SEC and FDA filings, journals and investment reports, among others. *BioScan* data are factual and objective in nature; it does not include any comparative or evaluative analyses. For example, *BioScan* lists qualitative information about each firm such as its new product development, number of employees, year of founding, whether the firm is public or private, whether the firm is a subsidiary or independent, etc. Moreover, *BioScan* provides detailed information about each firm's alliances, such as the focal firm's partners, the month and year when the alliance was entered, and whether the alliance is governed by an equity or contractual arrangement. An additional source of data for this study was the patent database maintained by the U.S. Patent and Trademark Office.

The biotechnology firms in this sample are engaged in the discovery, development and commercialization of therapeutics that are placed inside the human body (in vivo). Focusing on the in-vivo segment of biotechnology ensures a homogenous sample since firms engaged in this industry segment are exposed to extensive regulatory requirements (e.g., Food and Drug Administration [FDA] in the U.S. or European Medicines Evaluation Agency [EMEA]), which bring with them detailed reporting of products under development. Moreover, this industry demarcation reflects the uniqueness of the biotechnology segment in terms of its economic importance and potential, its regulatory environment and its consumer market (Powell et al., 1996).

We obtained a sample of 325 fully dedicated biotechnology firms that participated in 2226 R&D alliances between 1973 and 1997. We collected data on alliance activity since the inception of commercial biotechnology, and thus were able to attenuate the problem of left-censoring that is frequently observed in prior alliance studies.

4.2. Variables and measures

4.2.1. New product development

A biotechnology firm's new product development is the dependent variable of this study. We measured a biotechnology firm's new product development by its total number of new biotechnology products, which is the sum of products in development and products on the market, as of the end of the study period (1997). Using the number of products on the market as sole indicator for new product development was not feasible since the majority of the entrepreneurial firms in this study did not have any products on the market due to the protracted nature of the new product development and approval process in biopharmaceuticals. Moreover, it is important to emphasize that the drug product development process is beset with extreme uncertainty as more than 99% of all molecules screened do not make it into clinical trials (Ernst and Young Biotechnology Reports). We only count drugs that have entered clinical trials as being products in development. These products have overcome a major hurdle towards successful commercialization in the product development process. Focusing on products in development allows us to investigate the relationship between a biotechnology firm's alliances and its new product development (Hypothesis 1), which lays the foundation for testing the moderating effects of alliance type (Hypothesis 2) and alliance experience (Hypothesis 3) on alliance management capability. Thus, we submit that the sum of products in development and products on the market presents a reasonably proxy for a biotechnology firm's total new product development.

4.2.2. Alliance type

We proxied a biotechnology firm's alliances by the total number of its R&D alliances that the firm had entered into with any other partner along the industry value chain (*total alliances*). We then split the total number of alliances into three subcategories: upstream, horizontal and downstream alliances. We proxied a biotechnology firm's *upstream alliances* through alliances with non-profit organizations such as universities and other research institutions, *horizontal alliances* through alliances with other biotechnology firms and *downstream alliances* through alliances with pharmaceutical firms (Baum et al., 2000). While the *type of partner* is accurately reflected by this categorization, the *type of knowledge* transferred in these alliances represents a more rough, yet reasonable, approximation.

4.2.3. Alliance management capability

A firm's ability to manage its alliances has been highlighted as a dynamic capability, and thus should contribute to achieving a competitive advantage (Teece et al., 1997) through allowing the firm to manage a larger number of alliances productively. Yet, if a capability enables a firm to enhance its performance, what is the observable consequence if the firm exceeds its capability? Clearly, declining performance should result. We submit that the point of *diminishing total returns* (or inflection point) in the relationship between a critical firm activity and firm performance indicates the maximum level of the specific capability held by the firm at a certain point in time.

Therefore, we suggest that one way to assess a firm's alliance management capability is by the number of alliances a firm is able to manage productively in a simultaneous fashion. Specifically, this capability is examined by assessing the point at which the addition of the next alliance at the margin is detrimental to firm performance since the hypothesized relationship between a firm's capability and firm performance is positive up to the point at which a firm exceeds that capability by taking on one too many projects, alliances, etc. Hence, the inflection point represents the maximum level of this capability and thus is the observable consequence of an unobservable capability (Godfrey and Hill, 1995). Accordingly, we proxied a firm's alliance management capability by the point of diminishing total returns in the functional relationship between a firm's number of alliances and firm performance, which herein is measured as new product development. The point of diminishing total returns represents the point at which a firm's next alliance has a negative impact on the firm's overall new product development, i.e., the total returns to allying are beginning to decline. This point is an observable consequence of a firm exceeding its capability to manage its alliances effectively.

It is very important to note that our proxy for alliance management capability is not concerned with the relative height of the functional relationship between a firm's alliances and its new product development across different alliance types, which depends on the differential contribution of the specific alliance type. When considering the performance implications of individual alliance types, one would clearly expect downstream alliances to have the strongest effect on new product development, while upstream alliances would have the weakest effect and horizontal alliances would have a moderate effect. This would be expected because of the differential theoretical proximity in the relationships between the different alliance types and new product development. In this study of alliance management capability, however, the critical point in the relationship between a firm's alliances and its new product development is to be found on the *horizontal* axis (representing the number of alliances) at which the relationship turns negative rather than on the *vertical* axis (representing new product development). Mathematically, this is the point where the slope of the function relating alliances to new product development is zero. The specific inflection point is an indication of the magnitude of a firm's alliance management capability beyond which it can no longer manage subsequent alliances productively. All else being equal, the later a firm reaches its inflection point, the more alliances it can manage simultaneously, and thus the greater its alliance management capability.

Based on the arguments presented above, we expect the respective point of diminishing returns to vary systematically across different alliance types due to differential demands on a firm's alliance management capability (Hypothesis 2). We suggested that upstream alliances generally place the greatest demands on a biotechnology firm's alliance management capability and should thus reach their point of diminishing total returns first, while downstream alliances require the least amount of a biotechnology firm's alliance management capability and should thus reach their point of diminishing returns last. The point of diminishing total returns for horizontal alliances, due to their moderate amount of alliance management capability required, should fall in between that of upstream and downstream alliances.

4.2.4. Alliance experience

We proxied a biotechnology firm's alliance experience by its alliance years, which is the cumulative sum of the alliance duration for each of the firm's alliances. For example, if a firm has formed three alliances over the study period, with the first alliance 3 years old, the second 6 years old and the third 8 years old, the firm's total cumulative alliance experience would be 17 years. This experience measure corresponds to the experience construct underlying the experience curve effect (Dutton and Thomas, 1984) since a firm-level alliance experience, such as forming, managing and exiting alliances, is accumulated through learning-by-doing over time (Levitt and March, 1988). This assumption also resonates with prior empirical research demonstrating a life cycle to individual alliances (Deeds and Hill, 1999; Deeds and Rothaermel, 2003).

Moreover, the alliance experience measure used in this study goes beyond that of simple alliance counts generally used in prior research (Anand and Khanna, 2000; Deeds and Hill, 1996; Hoang and Rothaermel, 2005; Kale et al., 2002; Rothaermel, 2001a; Rothaermel and Deeds, 2004; Sampson, 2002; Shan et al., 1994; Zollo et al., 2002). We are able to differentiate, for example, between five alliances that were entered 1 year ago and five alliances that were entered 4 years ago. Applying the traditional measure of raw alliance counts as a proxy for alliance experience, this example would have been coded indiscriminately as an experience of five alliances for both observations. On the other hand, applying our more fine grained measure of alliance years as a proxy for alliance experience, the first observation would have been coded as an experience of 5 alliance years and the second observation as one of 20 alliance years. We submit that an alliance experience measure of alliance counts weighted by alliance time enables us to conduct a more subtle analysis of an alliance experience effect on alliance management capability.

To test the moderating effect of firm alliance experience on the relationship between firm allying and new product development (Hypothesis 3), we split the sample along the mean of alliance experience.[4] This approach is indicated to test the moderating impact of alliance experience on the hypothesized *curvilinear* relationship between allying and new product development. In particular, this allows us to investigate if a significant difference in the respective points of diminishing total returns exists. We suggest that a difference in the respective inflection points to allying is reflective of a differential firm-level alliance management capability resulting from different levels of alliance experience.

Two requirements must be fulfilled when using a split sample approach to test for moderation (Green, 1978). First, the two sub-samples must be significantly different along the variables of interest. Second, the variances of the key variables in the two sub-samples

[4] Prior to splitting the sample, we established a positive and significant impact of alliance experience on new product development ($p<0.05$). Moreover, adding the alliance experience variable resulted in a significant better model fit ($\Delta\chi^2=8.51$, $df=1$, $p<0.01$). These results enhanced our confidence in applying a split sample approach to test Hypothesis 3. A recent example of a split sample approach is found in Eisenhardt and Tabrizi (1995) when studying product innovation in the computer industry.

must be equal (i.e., not significantly different). We tested these requirements for the alliance experience variable since this was the decision criterion used to split the sample, and for the new product development variable since this is the dependent variable of the study. Applying a *t*-test, we find that the two sub-samples are significantly different with respect to their alliance experience and new product development (in both cases at $p<0.001$). Moreover, applying a variance ratio test revealed that the variances for the two sub-samples are not significantly different along alliance experience or new product development.

4.3. Control variables

To isolate the effect of a high-technology venture's alliances on its new product development, we controlled for a number of possible confounding effects including a firm's size, age, innovativeness and technological diversity. We further controlled whether the firm was public, a subsidiary or a U.S. firm. We also included the governance structure and the age of the alliances as control variables.

Firm size is a critical control variable when attempting to isolate the moderating effect of alliance experience on the relationship between allying and new product development. We controlled for firm size by using the number of employees as a proxy. Using the number of employees as a proxy for firm size is the preferred measure in this industry since many biotechnology firms do not yet have positive revenues that would allow the use of more traditional size measures like market share. Moreover, the assets of dedicated biotechnology firms are largely intangible, which rules out total assets as a proxy for firm size.

Firm age is a second critical control variable in isolating the moderating impact of alliance experience on the relationship between firm allying and new product development. We measured a biotechnology firm's age by its age since founding. All new biotechnology firms in this sample are fully dedicated biotechnology firms, thus calculating their age since incorporation is appropriate (Sørensen and Stuart, 2000).

We controlled for a biotech firm's *innovativeness* by including a count variable of its patents received between 1991 and 1995. In the biotechnology industry, patent counts as a proxy for innovativeness may be preferred over patent citation measures since citations occur over time and thus are biased towards older patents. This bias would be potentially accentuated in this high-technology sample since most biotechnology firms are recent start-ups that did not have an opportunity to accrue many patent citations (DeCarolis and Deeds, 1999). Prior research has shown that a firm's raw patent count is highly correlated with the quality of its patents (Stuart, 2000). We applied a 5-year window to attenuate annual fluctuations. This enabled us to capture a firm's innovativeness more effectively since most firms in the sample do not receive many patents per year, if any. Such a time window is consistent with prior research proxying a firm's innovativeness (Stuart and Podolny, 1996; Ahuja, 2000).[5]

We further controlled for the ownership status of the firm (1 = *public firm*) and whether the firm was a subsidiary or independent (1 = *subsidiary*). We also included an indicator variable (1 = *U.S. firm*) to capture institutional and cultural differences. Moreover,

[5] The results presented below remained robust to variations in the time window.

biotechnology is characterized by many different technology trajectories. To control for each firm's degree of *technological diversity*, we included a count variable representing the number of distinct biotechnology subfields in which the firm participated.

Strategic alliances are ongoing cooperative relationships between independent firms that are governed either by contractual agreements or by equity. Non-equity alliances are much more frequent, although equity alliances are considered to be stronger ties. We included a ratio of a firm's equity alliances over its total alliances to control for a firm's preference for *equity versus non-equity alliances* and its potential impact on new product development. Finally, we controlled for the *average age of a firm's alliances* (in months) since older alliances are more likely to yield new product development than younger alliances.

4.4. Model specification

We standardized the variables to reduce potential multicollinearity and to enhance the interpretability of the results. Following Aiken and West (1991), we standardized the variables contained in the interaction terms prior to creating the cross products. Standardization improves the robustness of the analysis without degrading the quality of the data. Further, we explicitly assessed potential multicollinearity in all models, and found that the variance inflation factors were well below the suggested cut-off point of 10 (Kleinbaum et al., 1988).

The dependent variable, number of new products, is a count variable taking on discrete non-negative integer values, including zero. We applied the following specification of a Poisson regression model to test our hypotheses (Greene, 1997):

$$E\left(\mathrm{NPD}_i/X_i\right) = e^{\beta X_i},$$

where NPD_i is the number of new products by firm i and X_i is a vector of regressors containing the independent and control variables described above. To obtain consistent and robust standard errors that are corrected for over dispersion, we employed a general linear model (GLM) estimation technique (Gourieroux et al., 1984).[6]

5. Results

Table 1 presents the means, standard deviations and bivariate correlations. The average biotechnology firm in this sample has a total of 6 new products, holds 5 patents, has 162 employees, competes in 6 different biotechnology subfields and is 10 years old. Moreover, 69% of the firms are public, 8% are subsidiaries and 78% are U.S. firms. The average firm has entered about 7 alliances, of which 4% are structured as equity alliances. It is important to note that, while the average firm is only 10 years old, it has accumulated 22 years of alliance experience. Noteworthy is also the discriminant validity of the measures.

[6] We also checked the robustness of our findings presented below by additionally applying a negative binomial regression model. The results were consistent.

Table 1
Descriptive statistics and correlation matrix

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. New product development	6.34	4.97																	
2. Firm size	161.17	573.19	0.55																
3. Firm age	9.61	4.62	0.32	0.23															
4. Firm innovativeness	4.88	13.95	0.50	0.70	0.35														
5. Public	0.69	0.46	0.19	0.09	0.17	0.10													
6. Subsidiary	0.08	0.27	−0.04	0.00	0.05	−0.03	−0.18												
7. U.S. firm	0.78	0.42	0.07	0.06	0.01	0.10	0.11	−0.04											
8. Technological diversity	6.23	4.71	0.39	0.40	0.27	0.41	0.06	0.03	0.04										
9. Equity ratio	0.04	0.12	0.08	0.03	−0.03	0.02	−0.03	−0.05	0.05	0.01									
10. Age upstream alliances	21.93	28.12	0.15	0.07	0.13	0.12	0.06	0.03	0.09	0.19	−0.03								
11. Upstream alliances	1.61	2.31	0.18	0.08	−0.03	0.01	0.08	−0.06	0.07	0.17	0.00	0.50							
12. Age horizontal alliances	25.19	26.68	0.09	0.06	0.22	0.06	0.00	0.12	−0.01	0.19	−0.09	0.22	0.10						
13. Horizontal alliances	2.24	3.44	0.58	0.75	0.28	0.69	0.05	0.04	0.07	0.44	0.02	0.17	0.17	0.22					
14. Age downstream alliances	29.21	28.63	0.19	0.08	0.37	0.13	0.09	0.13	0.01	0.03	−0.08	0.10	−0.04	0.25	0.11				
15. Downstream alliances	2.99	3.57	0.53	0.43	0.33	0.53	0.22	0.01	0.10	0.42	0.00	0.12	0.05	0.17	0.55	0.25			
16. Age total alliances	35.75	23.20	0.04	0.03	0.32	0.06	0.00	0.18	−0.03	0.08	−0.12	0.39	0.10	0.50	0.02	0.60	0.09		
17. Total alliances	6.85	6.86	0.63	0.63	0.30	0.63	0.16	0.01	0.11	0.49	0.01	0.31	0.45	0.23	0.85	0.18	0.81	0.09	
18. Alliance experience (years)	21.65	29.36	0.27	0.17	0.03	0.22	0.13	−0.08	0.04	0.26	0.13	0.13	0.20	−0.04	0.22	−0.13	0.36	−0.35	0.37

$N = 325$.

The correlations between alliance experience and firm age ($r = 0.03$) or firm size ($r = 0.17$) are well below the suggested cut-off point of $r = 0.70$ (Cohen et al., 2003). This is pertinent since it emphasizes alliance experience as a distinct construct relevant for entrepreneurial ventures.

The entrepreneurial profile of this sample is further highlighted by focusing on the following descriptive statistics. The median age of the biotech firms in this sample is 9 years, while the median firm size is 60 employees. Applying traditional categorizations for entrepreneurial firms, we find the following: Out of the 325 biotech firms in the sample, 209 (64%) are 10 years old or younger, while 232 (71%) firms have no more than 100 employees. Yet, new ventures in the life sciences tend to be older than entrepreneurial ventures in other industries due the protracted nature of the new product development process. As a case in point, 308 biotech firms (95%) in the sample did not have a single drug on the market. The important point in considering the entrepreneurial nature of the firms in this sample is that all of them were directly involved in the process of entrepreneurship defined as recognizing, evaluating and exploiting opportunities to create new wealth (Shane and Venkataraman, 2000). Thus, while a few firms in the sample might not fit the typical profile of an entrepreneurial firm when applying a simple age classification, all of the firms in the sample are engaged in the *entrepreneurial process*. In sum, we submit that the sample can reasonably be viewed as entrepreneurial high-tech in nature.

The 325 biotechnology firms entered a total of 2226 R&D alliances. These alliances split into 524 (23%) upstream alliances, 729 (33%) horizontal alliances and 973 (44%) downstream alliances. At the industry level, the biotechnology firms engaged in downstream alliances at a significantly greater rate than horizontal alliances and, in turn, used horizontal alliances at a significantly greater frequency than upstream alliances (all differences at $p < 0.001$). Accordingly, this distinction also holds true at the firm level. The average biotechnology firm uses downstream alliances (2.99) at a significant greater frequency than horizontal alliances (2.24) and horizontal alliances at a significant greater frequency than upstream alliances (1.61, again all differences at $p < 0.001$).

Table 2 depicts the descriptive statistics for the low and high alliance experience sub-samples. As anticipated, the firms in the two sub-samples differ significantly along several dimensions including new product development and alliance experience. Yet, we also find that there are many younger firms among the high-experience sub-sample (about one half of the firms are 10 years or younger), which indicates that accumulated alliance experience appears to be quite relevant for entrepreneurial start-ups.

Table 3 presents the regression results for testing Hypotheses 1 and 2. Model 1 is the baseline model and includes the control variables only. Each subsequent model provides a significant improvement over the baseline model. Model 2 evaluates the impact of a high-technology ventures total number of alliances. Models 3–5 assess the effect of the individual alliance type on a high-technology venture's new product development in isolation, while model 6 represents the fully specified model assessing the effect of each individual alliance type on new product development while controlling for alternate alliance types and other potentially confounding factors.

Hypothesis 1 states that the relationship between a high-technology venture's total number of alliances and its new product development is inverted U-shaped, and that this

Table 2
Descriptive statistics for low and high alliance experience sub-samples

Variable	High alliance experience sub-sample ($N=94$)				Low alliance experience sub-sample ($N=231$)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
New product development	9.07	6.62	1	29	7.63	5.93	1	29
Firm size	355.74	1029.21	4	7500	81.99	112.84	3	1300
Firm age	11.72	4.77	1	27	8.74	4.28	1	25
Firm innovativeness	9.44	23.14	0	155	3.03	6.76	0	55
Public	0.80	0.40	0	1	0.65	0.48	0	1
Subsidiary	0.11	0.31	0	1	0.06	0.25	0	1
U.S. firm	0.80	0.40	0	1	0.77	0.42	0	1
Technological diversity	8.10	5.59	2	26	5.47	4.08	1	33
Equity ratio	0.03	0.08	0	0.44	0.04	0.13	0	1
Age total alliances	49.13	23.26	18.00	174.00	30.30	20.89	2.00	159.00
Total alliances	13.50	9.24	2	58	4.14	2.53	1	16
Alliance experience (years)	51.50	40.62	21.75	229.82	9.51	5.93	0.17	21.42

relationship holds regardless of alliance type, i.e., for upstream (Hypothesis 1a), horizontal (Hypothesis 1b) and downstream alliances (Hypothesis 1c). The results obtained in model 2 support Hypothesis 1, while models 3–5 each provide individual support for Hypothesis 1a–c since the linear term of the respective alliance type is positive and significant in each case, while the squared term of the respective alliance type is negative and significant in each case (albeit at $p<0.10$ for upstream alliances). The results for the individual alliance types remain robust in model 6, when assessing the effect of each alliance type on new product development, while controlling for the other alliance types (the squared term for downstream alliances is significant at $p<0.10$, however). Overall, the findings provide broad support for Hypothesis 1 (H1 and H1a–c) suggesting that the relationship between alliances and new product development is inverted U-shaped, regardless of alliance type.

Hypothesis 2 predicts that different alliance types demand different levels of a high-technology venture's alliance management capability, with upstream alliances demanding the largest amount, downstream alliances demanding the least amount, and horizontal alliances demanding a moderate amount. To test this hypothesis, we determined the respective point of diminishing total returns for each alliance type on a firm's new product development. As a reflection of differential demands on a venture's alliance management capability, upstream alliances should reach their respective point of diminishing returns first, followed by horizontal alliances, which in turn should be followed by downstream alliances. To calculate the respective inflection points, we took the partial derivatives with respect to each alliance type (in model 6). We find the inflection point increases from 2.36 for upstream alliances to 3.65 for horizontal alliances and finally to 6.01 for downstream alliances. All else being equal, a high-technology firm's alliance management capability increases by a total of more than 150% when comparing a firm's inflection point for its upstream versus its downstream alliances.

Additionally, we applied a Wald-type test to the fully specified model (model 6) to test whether the respective differences in inflection points are significantly different. We find

Table 3
Results of GLM Poisson regression predicting new product development

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	1.7896*** (0.0362)	1.8097*** (0.0353)	1.8079*** (0.0403)	1.8143*** (0.0357)	1.7981*** (0.0356)	1.8455*** (0.0410)
Firm size	0.0769** (0.0271)	0.0294 (0.0263)	0.0694** (0.0268)	0.0524† (0.0333)	0.0637** (0.0280)	0.0443† (0.0338)
Firm age	0.1231*** (0.0368)	0.0968** (0.0367)	0.1312*** (0.0370)	0.0921** (0.0364)	0.0750* (0.0390)	0.0630* (0.0385)
Firm innovativeness	0.0329 (0.0321)	0.0623† (0.0459)	0.0423† (0.0309)	0.0652† (0.0463)	0.0013 (0.0353)	0.0454 (0.0500)
Public	0.1096** (0.0390)	0.0721* (0.0367)	0.1014** (0.0386)	0.1089** (0.0373)	0.0677* (0.0385)	0.0728* (0.0374)
Subsidiary	−0.0147 (0.0373)	−0.0220 (0.0353)	−0.0096 (0.0369)	−0.0244 (0.0362)	−0.0336 (0.0363)	−0.0306 (0.0357)
U.S. firm	0.0173 (0.0367)	−0.0024 (0.0343)	0.0113 (0.0364)	0.0087 (0.0351)	0.0116 (0.0354)	0.0023 (0.0345)
Technological diversity	0.1194*** (0.0347)	0.0438† (0.0347)	0.0998** (0.0357)	0.0711* (0.0355)	0.0821** (0.0357)	0.0495† (0.0372)
Equity ratio	0.0557* (0.0324)	0.0554* (0.0320)	0.0525* (0.0329)	0.0454† (0.0328)	0.0568* (0.0321)	0.0424† (0.0329)
Age total alliances		−0.0378 (0.0385)				
Total alliances		0.3522*** (0.0499)				
(Total alliances)^2		−0.0451*** (0.0128)				
Age upstream alliances			−0.0253 (0.0438)			−0.0480† (0.0432)
Upstream alliances			0.1511** (0.0684)			0.1643** (0.0673)
(Upstream alliances)^2			−0.0221† (0.0196)			−0.0348* (0.0199)
Age horizontal alliances				−0.0500† (0.0388)		−0.0656* (0.0408)
Horizontal alliances				0.3193*** (0.0552)		0.2299*** (0.0601)
(Horizontal alliances)^2				−0.0410*** (0.0111)		−0.0315** (0.0117)
Age downstream alliances					0.0418† (0.0365)	0.0559† (0.0369)
Downstream alliances					0.2416*** (0.0509)	0.1719*** (0.0540)
(Downstream alliances)^2					−0.0228** (0.0091)	−0.0143† (0.0096)
Log likelihood	−925.44	−872.54	−916.14	−889.09	−893.42	−866.81
Chi-square	313.40***	419.20***	332.00***	386.10***	377.44***	430.67***
Improvement over base $(\Delta\chi^2)$		105.80***	18.60***	72.70***	64.04***	117.27***

Standard errors in parentheses.

* $p<0.05$.

** $p<0.01$.

*** $p<0.001$.

† $p<0.1$.

that a high-technology firm in this sample can manage more downstream alliances than horizontal alliances ($p < 0.001$), and in turn more horizontal alliances than upstream alliances ($p < 0.001$). This implies that different alliance types demand different amounts of a firm's alliance management capability, and thus provides support for Hypothesis 2. Fig. 1, which is based on the coefficients in model 6, depicts the effect of alliance type on the relationship between allying and new product development. Corresponding to Hypothesis 2, the figure reveals that upstream alliances reach their inflection point first, followed by horizontal alliances, and finally by downstream alliances. This implies that upstream alliances require the largest amount of high-technology venture's alliance management capability, downstream alliances demand the least amount and horizontal alliances a moderate amount.

We also find the inflection point for the total number of alliances is 3.90 (model 2), which is, as excepted, above the inflection point for upstream alliances ($p < 0.001$), but below that of the downstream alliances ($p < 0.001$). This result can be interpreted as additional evidence that different alliance types demand different amounts of a firm's alliance management capability since the total number of alliances considers all alliances in a firm's portfolio together.

Hypothesis 3 postulates that a firm's alliance experience moderates the relationship between strategic alliances and new product development in such a fashion that a more experienced firm is able to manage a larger number of alliances. We split the sample in two sub-samples using the mean of alliance experience as decision criterion. Table 4 depicts the results for testing the alliance experience moderation Hypothesis 3. Model 7

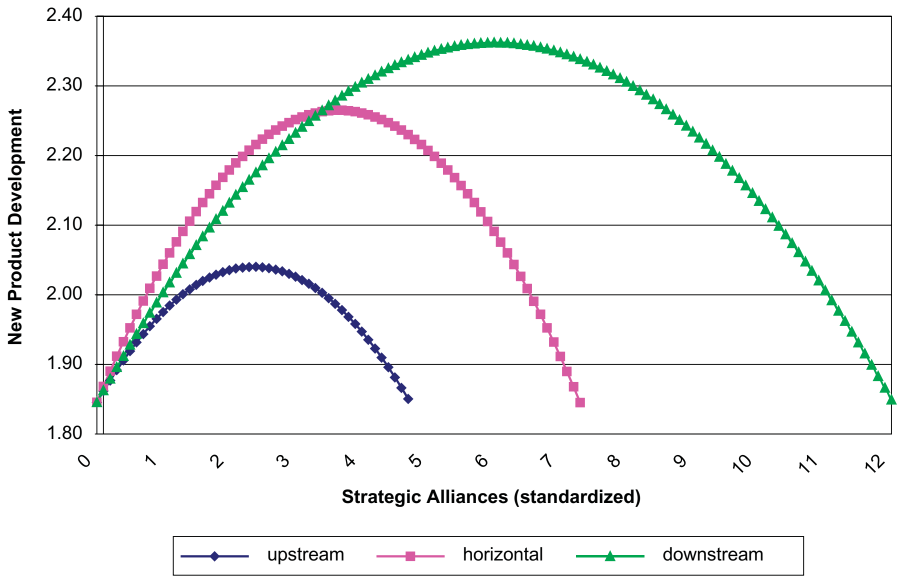

Fig. 1. Moderating effect of alliance type on the relationship between strategic alliances and new product development.

Table 4
Results of GLM Poisson regression predicting new product development for low alliance experience and high alliance experience sub-samples

	Model 7	Model 8	Model 9	Model 10
	Low alliance experience	Low alliance experience	High alliance experience	High alliance experience
Intercept	1.6306*** (0.0430)	1.6972*** (0.0465)	2.1181*** (0.0569)	2.1717*** (0.0591)
Firm size	0.1138*** (0.0327)	0.1082** (0.0365)	0.1082* (0.0511)	0.0331 (0.0498)
Firm age	0.0589† (0.0447)	0.0902* (0.0440)	0.1003* (0.0599)	0.0926† (0.0588)
Firm innovativeness	0.0518† (0.0383)	0.0233 (0.0377)	0.0301 (0.0578)	0.1010† (0.0960)
Public	0.1159** (0.0471)	0.1059** (0.0453)	−0.0048 (0.0621)	−0.0077 (0.0569)
Subsidiary	−0.0106 (0.0485)	0.0207 (0.0472)	−0.0998* (0.0623)	−0.0921† (0.0578)
U.S. firm	−0.0111 (0.0438)	−0.0129 (0.0421)	0.0401 (0.0591)	0.0167 (0.0546)
Technological diversity	0.0581† (0.0410)	0.0282 (0.0404)	0.1634** (0.0623)	0.0492 (0.0621)
Equity ratio	0.0196 (0.0432)	0.0351 (0.0442)	0.1320** (0.0444)	0.1274*** (0.0420)
Age total alliances		−0.0258 (0.0481)		−0.0398 (0.0653)
Total alliances		0.1962*** (0.0579)		0.4046*** (0.0920)
(Total alliances)^2		−0.0807*** (0.0268)		−0.0869** (0.0340)
Log likelihood	−602.91	−588.42	−282.91	−260.36
Chi-square	62.45***	91.42***	185.09***	230.20***
Improvement over base ($\Delta\chi^2$)		28.97***		45.11***

Standard errors in parentheses.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.
† $p<0.1$.

contains the baseline model for the low alliance experience sub-sample, while model 9 is the baseline for the high alliance experience sub-sample.

Models 8 and 10 are the respective full specifications for each sub-sample, and each provides a significant improvement over their respective baseline model ($p<0.001$ in each case). In both models, we find that the relationship between allying and new product development takes on an inverted U-shape since the linear alliance terms are each positive and significant, while the squared alliance terms are each negative and significant. Testing whether alliance experience moderates the relationship between allying and new product development requires a comparison of the respective inflection points. When taking the partial derivative with respect to alliances in models 8 and 10, we find that the inflection point for the low experience sub-sample is 1.21, while it is 2.33 for the high experience sub-sample (an increase of 93%, all else being equal). Applying a Wald-type test reveals that firms in the high alliance experience sub-sample can manage significantly more alliances than firms in the low experience sub-sample ($p<0.001$). This provides support for Hypothesis 3 suggesting that a firm's alliance experience positively moderates the relationship between firm allying and new product development. This relationship is reflected in Fig. 2, which is based on the coefficients in models 8 and 10. It depicts that firms with higher alliance experience are able to manage a significantly larger

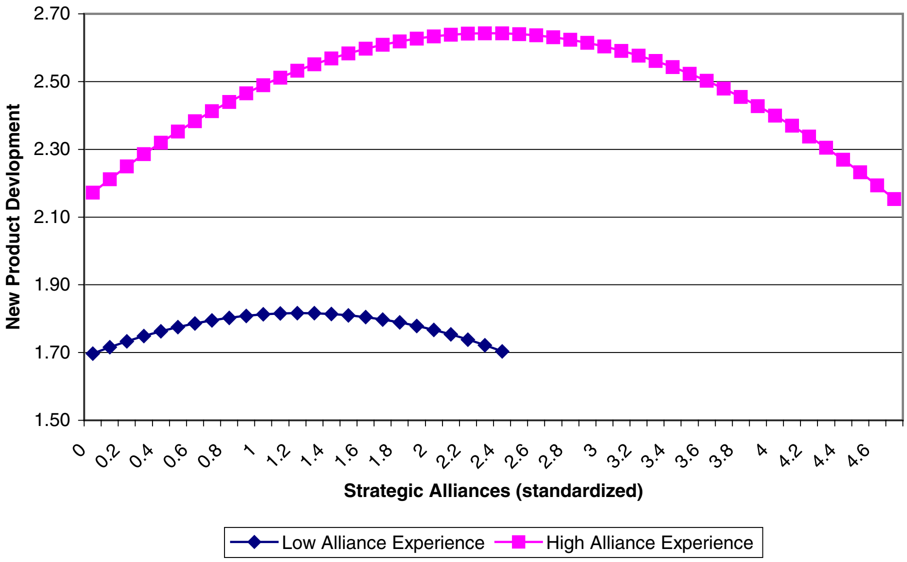

Fig. 2. Moderating effect of alliance experience on the relationship between strategic alliances and new product development.

number of alliances before reaching the inflection point than firms with less alliance experience. Thus, firms with greater alliance experience appear to possess a greater alliance management capability.

6. Discussion

While prior theoretical work has emphasized the notion of an alliance management capability in creating and sustaining competitive advantage (Dyer and Singh, 1998; Ireland et al., 2002), empirical work is this area has been slow in coming, mainly due to methodological impediments. We attempted to provide some preliminary empirical evidence for an alliance management capability, and here focused on the effects of alliance type and alliance experience in an entrepreneurial, high-technology setting. Since a common problem in strategic management research is the fact that capabilities tend to be unobservable (Godfrey and Hill, 1995), we focused on observable consequences of an unobservable capability. We used the relationship between a firm's alliances and new product development to gain some understanding of the effects of alliance type and alliance experience on a firm's alliance management capability. In particular, we focused on the point of diminishing total returns in the functional relationship between a firm's number of alliances and its new product development. While this represents necessarily an indirect approach to the phenomenon of interest, alliance capability, we submit that this research strategy is both novel and appropriate when relying on archival data. The sample consisted of 325 global biotechnology firms that entered into over 2200 R&D alliances in the 25-time period between 1973 and 1997. The empirical results were consistent with the theoretical model proposed. We attempt to make a contribution to the literature in four areas.

First, we found that an inverted U-shaped relationship between the number of alliances managed simultaneously and firm performance holds regardless of the type of the alliance considered. We differentiated between upstream, horizontal and downstream alliances. Prior research relating allying to firm performance in the entrepreneurial context has not differentiated between different types of alliances (Shan et al., 1994; Deeds and Hill, 1996). This finding adds robustness to the notion that there exist diminishing returns to high levels of alliance activity and that this relationship holds regardless of alliance type. While we were able to generalize the relationship between allying and firm performance to different alliance types, this exercise was merely a prerequisite to empirically investigate the effects of alliance type and alliance experience on alliance management capability.

Second, we found that different alliance types place differential demands on a high-technology venture's alliance management capability. Here, we focused on the position of the high-technology venture's partners in the industry value chain, and highlighted upstream, horizontal and downstream alliances. We argued that their differential demands on a high-technology venture's alliance management capability arise primarily from two factors: the difference between the *type of partners* and the focal firm, and the *type of knowledge* transferred through these alliances.

Third, we found support for a novel measure of alliance experience. The notion that a firm's alliance management capability is built through repeated alliance experiences over time is central to a theory of an alliance management capability. While prior research has proxied alliance experience mostly by a raw count of alliances, we employ a more subtle measure, alliance years, which is theoretically more proximate to the notion of experience accumulation (Dutton and Thomas, 1984). High-tech ventures with greater alliance experience were able to manage productively a larger number of alliances, while explicitly controlling for firm age, among other factors. Indeed, firm age was not significantly correlated with alliance experience, indicating that an alliance management capability does not simply occur with aging, but rather through the firm's direct participation in alliances over their life cycle. This finding further highlights the salience of alliance management capability for entrepreneurial firms.

Taken together, these empirical results provide some evidence that an alliance management capability exists and that it is heterogeneously distributed across firms. As conceptualized in prior work (Dyer and Singh, 1998; Ireland et al., 2002), it appears that an alliance management capability can be the source of a firm-level competitive advantage. Those firms that are able to manage a larger number of alliances effectively should be able to achieve higher new product development. Indeed, the results indicated that firms with greater alliance experience, all else being equal, achieved a greater level of new product development (Fig. 2). Since most technology ventures' competitive position is determined by their ability to develop commercially viable products (Deeds et al., 2000), firms that are more productive in new product development should have an advantage over their competitors.

Yet, these results also seem to indicate that firms should strike a balance in entering alliances. Too few or too many alliances appear not to be optimal, but an intermediate number of alliances appears to be most beneficial. Entering too many alliances opens up the venture to the risks of mismanagement, expropriation, and opportunism. On the other hand, too few alliances put the venture at a competitive disadvantage in the crucial race to develop new products. Moreover, it curtails their possibility of developing an alliance management capability.

Finally, this study also speaks to the broader issue of capabilities. The methodological approach supports the contention of Godfrey and Hill (1995) that tracking observable consequences of capabilities, rather than attempting to directly measure unobservable capabilities, is a fruitful approach to empirically testing capability theory in large scale, quantitative studies. However, the results demonstrate more than just the observable benefits from an unobservable capability. They also demonstrate that exceeding firm capabilities is detrimental to firm performance and that capabilities are constrained in the short term because they are built through experience over time (Teece et al., 1997).

6.1. Limitations and future research

This study contains several limitations, which in turn provide opportunities for future research. While an area of contribution, one critical issue concerns the definition and measurement of alliance management capability. We followed Godfrey and Hill's (1995) understanding of capabilities as unobservables, and thus relied on an indirect measure of alliance management capability. In particular, we attempted to track one observable consequence of a firm's alliance management capability, the number of alliances a high-technology venture can manage effectively. The absence of more direct measures of alliance capability in archival data indicates the need for future research to employ survey and qualitative methodologies to more directly proxy alliance management capability.

Further, our measure of alliance management is also incomplete to some extent since we focus only on one aspect of alliance management capability when alliance management capability is clearly a multi-dimensional construct. Other aspects include the ability to select appropriate partners, to build trusting relationships, to absorb and apply new knowledge gained, to develop tacit and codified routines and so forth (Dyer and Singh, 1998; Ireland et al., 2002). By drawing on the organizational learning and evolutionary economics literature, for example, researchers should attempt to develop and test alternative measures for an alliance management capability reflecting its multi-faceted nature. Moreover, while we find some tentative evidence that a firm's alliance management capability is positively related to its performance, more work is clearly needed to establish this relationship more firmly by linking it to other performance metrics such as venture growth or financial performance.

While we advanced a novel measure to proxy a firm's alliance management capability, we assessed only the different inflection points at one point in time, at the end of the study period. Yet, firms develop capabilities like an alliance management capability over time. Future research could attempt to sketch the evolution of a firm's alliance management capability over time, and thus enhance our understanding of the dynamics pertaining to development and maintenance of an alliance management capability. The capability lifecycle model recently suggested by Helfat and Peteraf (2003) might point the way to a more thorough empirical understanding of this type of dynamic capability.

We also need to learn more about the question of how the rents to allying are distributed, a particular salient issue for alliances between high-tech ventures and large established firms (Alvarez and Barney, 2001). An alliance management capability could allow a firm to not only create value through allying but also to appropriate the jointly created value. Here, entrepreneurial ventures may have to make important trade-offs concerning value creation and value appropriation when entering into alliances with large, established firms. Prior research has provided some tangential evidence that the large pharmaceuticals may have benefited from these alliances at the expense of the smaller biotech ventures (Rothaermel and Deeds, 2004; Lerner et al., 2003; Rothaermel, 2001b). In particular, it appears that large pharmaceutical firms may lead in the learning race (Hamel, 1991) because they appear to use alliances effectively to rebuild research capabilities that were made obsolete by the biotechnology revolution (Rothaermel, 2001a). What is lacking in this study of entrepreneurial firms and alliances is empirical evidence of how alliance value is created and appropriated. This is a critical area for future research.

While these results seem to indicate that firms might be able to create a competitive advantage based on a superior alliance management capability, they also underscore the risks inherent in high levels of alliance activity, in particular, if a firm's alliance intensity outstrips its alliance management capability. Essentially, the number of alliances that a firm can manage effectively need to be balanced, not too many alliances, but not too few either. While we provide some preliminary evidence for factors that determine where this balancing point may lay, we encourage future researchers to deepen our understanding of alliance management capability and how to keep a venture near or at the balance point of its alliance capability.

The results for alliance experience address only one source of potential alliance experience, alliance management capability accumulated through repeated engagements in the focal activity. A second source that demands additional study is role of the prior alliance experience of the management teams. It is unlikely that a firm can simply buy alliance experience in the labor market through hiring alliance-experienced managers because the market price should anticipate any rent-generating potential (Barney, 1986). Therefore, it appears that complex, embedded and partly tacit routines are at the root of a competitive advantage derived from an alliance management capability. Important questions such as the role of management recruiting and training as well as knowledge management are fruitful topics for future research.

We highlighted alliance type and alliance experience in impacting alliance management capability in the entrepreneurial context. Future research could investigate what other factors, besides alliance type, alliance experience and the establishment of a dedicated alliance function (Kale et al., 2002), are critical in developing and enhancing a firm's alliance management capability because most large firms have now established some type of dedicated alliance function (Booz et al., 1997). Clearly, future research should attempt to deepen our understanding of the *processes* of alliance management. A longitudinal field study might address this topic most fruitfully.

While we focused on different alliance types in isolation (Hypothesis 2) and on the combined effect of a given mixture of alliances (Hypothesis 3) when exploring a high-technology venture's alliance management capability, we did not investigate how different alliance types interact with one another, and thus we were not able to discuss the differential impact of portfolios made up of different mixtures of upstream, horizontal and downstream alliances on a firm's alliance management capability. It is also important to note that there may be important benefits to allying that are not captured by the dependent variable, new product development, employed in this study.

As emphasized in the methods section above, the link between early stage upstream alliances and new product development appears to be more tenuous than the link between downstream alliances and new product development. This notion seems to be validated by data presented by Lerner et al. (2003), who drew a random sample of 200 biotechnology alliances begun since January 1980 and found that only 14% led to an approved drug by December 1998. When focusing only on cooperative drug development projects that already progressed to phase I or phase II of clinical trials, they found that likelihood of success increased to 26%. This opens up a promising avenue of future research, in particular, in light of the fact that that one upstream alliance might provide the basis for several horizontal and downstream alliances.[7]

We focus on entrepreneurial biotechnology firms, and thus on a single, high-technology industry. While such an approach controls for industry idiosyncrasies, it raises the question of generalizability. The biotechnology industry is characterized by a highly uncertain and risky new product development process that can extend over multiple years. Moreover, regulatory agencies like the Food and Drug Administration in the U.S. or the European Medicines Evaluation Agency impose strict approval processes consisting of distinct and sequential stages. Despite these unique characteristics, the transfer of basic science from universities to start-ups and subsequently to established firms appears to be important in a diverse set of industries. Recent empirical work has shown that this entrepreneurial phenomenon seems to be generalizable beyond biotechnology, as it appears to hold across a large number of different industries since university inventions are generally commercialized by new ventures, which later either enter alliances with established firms or are acquired altogether (Lowe and Ziedonis, 2003).

6.2. Managerial implications

The finding that the relationship between alliance intensity and firm performance appears to be characterized by diminishing returns, and the notion that alliance experience is built through cumulative alliance activity, often in a more or less simultaneous fashion, also point to an interesting normative tension. High-technology ventures need to enter alliances to gain access to critical resources and to build an alliance management capability, yet, too many alliances, too early, may have detrimental effects. This yin and yang of allying for entrepreneurial firms requires significant managerial skill. A manager must understand the firm's limits to its alliance management capability at a given point in time, while realizing that alliance management capability is not finite but can be built through repeated allying over time.

Taken together, the results should guide practitioners towards a cautious, balanced approach to allying (Niederkofler, 1991). Managers should recognize that different

[7] We thank an anonymous reviewer for this insight.

alliances place different demands on the venture's alliance management capability. They need to consider entering their next alliance not in isolation, but as part of the firm's overall portfolio of alliances and in the context of the firm's alliance management capability. While the opportunity presented by an alliance may appear to be significant, the risks, given the firm's existing alliances and current stage of development, may outweigh the potential benefits. The right balance of alliances, under the right conditions, appears to provide tangible benefits to a high-tech venture's new product development. On the other hand, too many alliances entered into early in the firm's development, expose entrepreneurial ventures to significant risks. Maximizing a firm's benefits from allying requires a manager to keep the venture near or at the balance point of its alliance management capability. This balance point changes over time, making alliance management a demanding, but potentially rewarding managerial task.

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