
Pergamon

Journal of High Technology
Management Research 12 (2001) 205–226

THE JOURNAL
OF HIGH
TECHNOLOGY
MANAGEMENT
RESEARCH

The effects of alliance portfolio characteristics and absorptive capacity on performance
A study of biotechnology firms

Gerard George[a,*], Shaker A. Zahra[b], Kathleen K. Wheatley[c], Raihan Khan[d]

[a]*School of Business, Weinert Center for Entrepreneurship, University of Wisconsin-Madison, 975 University Avenue, Madison, WI 53706-1323, USA*
[b]*J. Mack Robinson College of Business, Georgia State University, Atlanta, GA, 30303 USA*
[c]*College of Business Administration, University of Tennessee-Chattanooga, Chattanooga, TN, 37403 USA*
[d]*School of Management, Syracuse University, Syracuse, NY, 13244 USA*

Received 4 September 2000; received in revised form 31 October 2000; accepted 19 January 2001

Abstract

In many high technology industries, strategic alliances have become important for improving a firm's financial performance by providing knowledge that can be used to develop the capabilities needed to introduce new products. Therefore, researchers have examined those characteristics of alliances that can contribute to the performance of high technology companies. There is agreement that the structure and knowledge flows within alliances can affect a firm's innovativeness. However, to date, researchers have studied alliances as individual events or transactions, failing to recognize their synergistic effects as a coherent portfolio. Viewing alliances as a portfolio of strategic agreements, we suggest that portfolio characteristics will be associated with a high technology firm's innovative and financial performance. Also, we suggest that portfolio characteristics will influence absorptive capacity. We test these propositions using a sample of 2456 alliances formed by 143 biopharmaceutical firms. The results indicate that alliance portfolio characteristics and absorptive capacity jointly influence performance. The implications of these findings for high technology firms are discussed.

Keywords: Alliances; Portfolio; Biotechnology; Absorptive Cap

* Corresponding author. Department of Management and Human Resources, 975 University Avenue, Room 5252 Madison, WI 53706-1323, USA. Tel.: +1-608-262-8640; fax: +1-608-263-4392.
E-mail address: ggeorge@bus.wisc.edu

1047-8310/01/$ – see front matter
PII: S1047-8310(01)00037-2

1. Introduction

High technology industries are dynamic and fiercely competitive arenas that require constant innovation to meet changing customer needs. High technology products are complex and require the firm to possess knowledge and skills in multiple technological fields and have to be upgraded constantly in order to meet changes in market conditions and customer expectations. Therefore, high technology firms can no longer rely exclusively on their internal skills and knowledge in maintaining innovativeness. These companies access external sources of knowledge through alliances and harvest this knowledge by creating innovative products, goods, and services (Arora & Gambardella, 1994; Deeds & Hill, 1996; Zahra & Bogner, 2000).

Despite the large number of empirical studies on alliances, especially among high technology companies, few have considered these alliances as a portfolio (e.g., Hagedoorn & Schakenraad, 1994). Researchers have studied the effect of the number and types of particular alliances on value creation but, for the most part, have overlooked the potential synergies or tradeoffs companies experience when they pursue multiple alliances. High technology companies may enter multiple alliances at the same time, often seeking to achieve different goals. These goals include gaining access to resources, entering new markets, and acquiring complementary skills and capabilities. The goals that guide the formation of these alliances determine the way they are structured and managed which, in turn, influences the flow of knowledge among alliance participants. The characteristics of the portfolio of alliances a firm maintains, therefore, can determine the benefits it gains in terms of improved innovation and financial performance (Nooteboom, 1999). Therefore, it is important to identify the characteristics of an alliance portfolio that can significantly contribute to a company's financial performance.

Knowledge is a key foundation of competitive advantage in science-based industries (Grant, 1996). Young biotechnology firms may not possess this knowledge internally and, therefore, have to obtain it from external sources (Zahra, 1996). As firms develop relationships to gain access to external knowledge, their ability to process and transfer the knowledge gained in one context to another becomes critical (Powell, 1998). A firm's absorptive capacity, defined as the ability to value and apply knowledge, is a critical requirement for learning from external relationships (Cohen & Levinthal, 1990). Absorptive capacity has been linked to valuable organizational outcomes such as learning and innovation (Kim, 1998; Mowery, Oxley, & Silverman, 1996). Even in this stream of research, the role of absorptive capacity in determining a firm's potential gains from alliances has only been theorized (Koza & Lewin, 1998), but not adequately tested empirically (Zahra & George, 2000).

This study builds on past research by suggesting that alliance portfolio characteristics will determine the firm's absorptive capacity, which, in turn, can influence the performance of a high technology firm. Absorptive capacity, therefore, is expected to mediate the relationship between alliance portfolio characteristics and a high technology company's innovative and financial performance. To develop this proposition, the study integrates insights from two complementary theoretical perspectives. The first is the relational perspective of the firm (Dyer & Singh, 1998; Gulati, 1998, 1999; Koza & Lewin, 1998). This view posits that critical

resources and value creation activities span the boundary of the firm and may be embedded in its interfirm relationships (e.g., strategic alliances). The context of these relationships has important implications for the creation, sharing, and transfer of knowledge. Grounded in trust, these relationships can enable the high technology firm to acquire new knowledge that can improve its innovative activities (e.g., new product development). Using the relational perspective, therefore, we propose that if the high technology firm develops a portfolio of relationships that portends both stability and access to knowledge sources, then this portfolio would yield superior financial performance.

The second perspective is the learning theory, which views the value of knowledge as a key source of competitive advantage (Grant, 1996). It suggests that while the creation of knowledge is important, the conversion of this knowledge into new products is the foundation of superior performance (Leonard-Barton, 1995; Moon, 1999; Nonaka & Takeuchi, 1995). Developing a firm's absorptive capacity, therefore, is key to gaining a competitive advantage (Lane & Lubatkin, 1998). Alliances with other firms can provide the firm with adequate exposure and the experience necessary to develop its absorptive capacity (Cohen & Levinthal, 1990). The capability to value and exploit external knowledge can be used to develop products that strengthen the firm's competitive and financial performance.

Invoking the relational and learning perspectives, this article addresses two issues. First, it examines alliances as a portfolio of strategic agreements. As noted, the characteristics of the alliance portfolio would have important implications for innovativeness and financial performance. To accomplish this objective, the study addresses two characteristics of the alliance portfolio: structure and knowledge flow. Structure refers to whether an alliance is completed with a firm at the same level of the value chain (horizontal) or at a different level (vertical). Alliance structures, whether horizontal or vertical, are associated with varying degrees of innovativeness (Hagedoorn, 1993; Kotabe & Swan, 1995). Knowledge flows refer to the direction of knowledge transmission and the sharing that occurs among alliance partners (Hagedoorn & Schakenraad, 1994). When a portfolio of alliances is considered, this article suggests that portfolio characteristics, such as structure and knowledge flows, are likely to be related to performance.

Second, the study also explores the role of absorptive capacity in the context of alliance portfolio characteristics and firm performance. It suggests that alliance portfolio characteristics matter with regard to innovative and financial performance and that absorptive capacity mediates this relationship. By doing so, this study extends past empirical research on alliances and absorptive capacity, especially in the context of high technology industries. Section 2 of the paper presents the study's hypotheses using the relational and learning theoretical perspectives. This is followed by an empirical test of the hypotheses. Finally, the paper reviews the results and discusses their implications.

2. Theoretical background and hypotheses

In recent years, there has been unprecedented growth in strategic alliances and various forms of collaboration in high technology, especially science-based, industries such as

biotechnology (Baum, Calabrese, & Silverman, 2000; Hagedoorn & Schakenraad, 1994; Powell, 1998). These alliances can give high technology firms access to different resources, especially new knowledge (DeCarolis & Deeds, 1999; Powell, Koput, & Smith-Doerr, 1996; Simonin, 1999; Steensma & Fairbank, 1999) that spurs innovation and new product development (Deeds & Hill, 1996) that enhance company growth and profitability (Dyer & Singh, 1998; Gulati, 1998). Given the importance of alliances, researchers have examined the effect of alliances on the performance of new ventures in the biotechnology industry (e.g., DeCarolis & Deeds, 1999; Deeds & Hill, 1996; Liebeskind, Oliver, Zucker, & Brewer, 1996; Zahra, 1996).

The growing popularity of cooperative research to develop innovative technologies (Nooteboom, 1999) is evidenced by a positive trend in strategic alliance formation in biotechnology (Biotechnology Industry Organization (BIO), 1999). These partnerships are formed based on the partners' complementarity of assets, either as a set of resources, capabilities, or knowledge competence (Helfat, 1997; Liebeskind et al., 1996). Alliances are also formed to develop synergistic relationships through technological complementarity among partners (Hagedoorn, 1993; Hagedoorn & Schakenraad, 1994). According to March and Simon (1958), most innovation occurs through borrowing rather than inventing. Since an organization receives knowledge and information from external sources, the characteristics of the relationships it maintains with alliance partners can also have a significant effect on its absorptive capacity as well as on its level of innovation (Dyer & Singh, 1998; Koza & Lewin, 1998). The relational perspective suggests that a firm's relationships can affect its performance. For instance, alliances that require frequent and long-term interactions can affect a company's gains quite differently from those characteristics that are short term or arms-length in nature (Dyer & Singh, 1998; Mowery et al., 1996; Nooteboom, 1999). Following the relational perspective, the benefits from alliances are likely to grow if the firm enters and maintains multiple alliances. Learning to organize and manage multiple alliances also gives the high technology firm the expertise to cultivate and exploit the knowledge gained from these alliances. Consistent with this proposition, in Fig. 1, we present a model that relates alliance characteristics, absorptive capacity, and firm performance.

Absorptive capacity refers to a firm's ability to value, assimilate, and apply knowledge received from external sources such as suppliers, customers, competitors, and alliance partners (Cohen & Levinthal, 1990). Accumulated knowledge that is obtained from external sources can enhance a firm's future ability to acquire new knowledge; prior exposure increases the company's ability to recognize the importance of new information (Lindsay & Norman, 1977). A company's ongoing research and development activities can play a major role in this regard. R&D investments can enhance the company's capabilities to evaluate external knowledge sources (Arora & Gambardella, 1994). Kim (1998) suggests that in order for absorptive capacity to develop, however, a firm must go beyond evaluating external knowledge and apply this knowledge to developing new products. Hence, this study captures two components of absorptive capacity: (a) the ability to evaluate and assimilate knowledge, and (b) the ability to apply that knowledge.

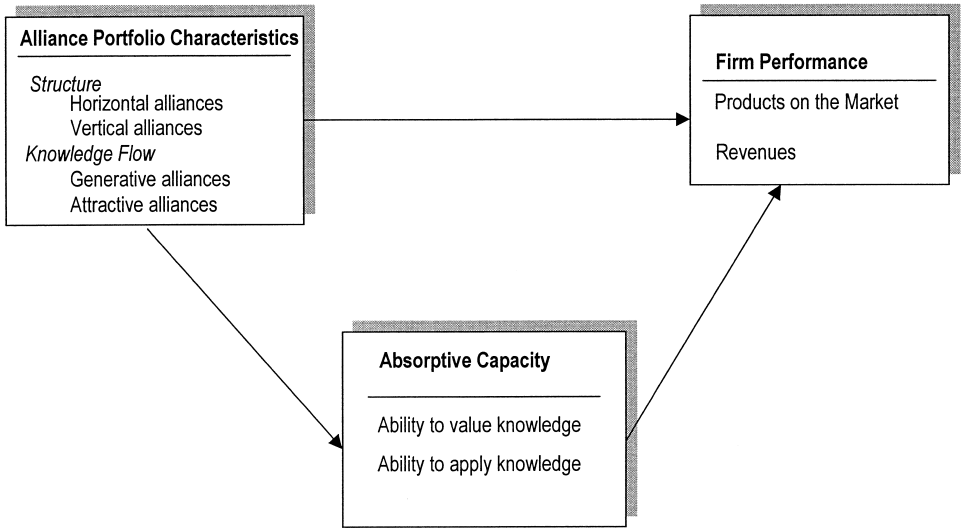

Fig. 1. Relationship between alliance portfolio characteristics and performance.

2.1. Portfolio analysis and absorptive capacity

Portfolio analysis has been extensively used in the finance literature, especially with regard to balancing risk and return within a portfolio of stocks (Sharpe, 1963). The basic tenet of the portfolio approach is "its concern with economic agents that act under uncertainty" (Markowitz, 1952, 1991). The biotechnology industry is an industry characterized by high uncertainty and hypercompetition (D'Aveni, 1994). Firms enter into alliances with different motivations that include learning new skills (Baum et al., 2000) or gaining access to complementary resources (Dyer & Singh, 1998). However, such alliances entail risks and may be unstable or transitional in nature (Das & Teng, 1996; Inkpen & Beamish, 1997). Thus, the use of portfolio theory becomes relevant in a context where firms enter into alliances with the intent of generating economic returns while bearing some risks associated with these alliances, conceptually similar to a portfolio of stocks. Firms enter multiple alliance agreements in order to overcome uncertainty and optimize risk, while increasing their economic returns through the acquisition of necessary resources. Also, information regarding a firm's portfolio of alliances is likely to provide greater insight into a firm's capabilities and performance than information from a single alliance. Portfolio analysis, as a tool, may provide better inferences on a firm's competence due to path dependency and accumulation of skills and resources (Christensen, 1997; Dosi, 1988). In this study, we begin to empirically test the characteristics of a firm's portfolio of alliances and its relationship to innovative and financial performance.

There are other practical and empirical reasons for our focus on alliance portfolios. As noted, high technology firms join multiple alliances to gain access to knowledge and skills across the various phases of their value chain. Examining a portfolio of alliances, rather than

individual transactions, takes us one step closer to the locus of value-creating activities. Studying alliance counts or single alliance announcements, as commonly done in past research, overlooks the synergistic effects of a firm's portfolio of alliances. A high technology firm is likely to capitalize on the multiple knowledge bases by developing alliances along different points of its value chain. These alliances can be used to expedite the design of new products. Other alliances can give high technology firms the marketing knowledge needed to expedite new product development and market introduction. The knowledge gained from entering multiple alliances can also intensify the frequency of new product development and increase the radicalness of these products.

The relational and organizational learning perspectives highlight two important characteristics of the alliance portfolio. The relational perspective suggests that the structure of alliances has important implications for generating economic rents (Gulati, 1998; Koza & Lewin, 1998). For example, structural characteristics such as governance, power sharing arrangements, dependency, or asymmetry may have differing implications for maintenance and appropriation of economic rents (Kale, Singh, & Perlmutter, 2000; Tsai, 2000). These characteristics usually reflect the ownership, organization, and management of the alliance itself. The learning perspective also suggests that alliance characteristics affect the firm's ability to learn from its partner (Barkema, Bell, & Pennings, 1996). The way an alliance is structured and managed can induce trust and reduce opportunism, factors that can encourage the exchange of information and sharing of knowledge among partners (Kale et al., 2000). Learning from partners is a complex process that can be influenced by the structural characteristics of the alliance and the knowledge capability of the partners (Koza & Lewin, 1998; Mowery et al., 1996; Powell, 1998; Simonin, 1999). Some alliances enable partners to observe and learn from each other. Others, however, may limit the types and frequency of knowledge flows. Thus, the structure of the alliance is the form of the relationship wherein a partner may provide a resource upstream or downstream in the value creation process (Hagedoorn & Schakenraad, 1994). Thus, following the learning perspective, the structure of an alliance has important implications for the innovative and financial performance of partner firms.

2.1.1. Portfolio structure

Alliance structure embodies horizontal and vertical relationships. Horizontal relationships are primarily joint product development arrangements. They give the firm new knowledge in the design, prototyping, testing, development, and introduction of new products. The breadth of these relationships exposes the high technology firm to multiple and varied sources of ideas and knowledge, which can fuel innovation. Vertical relationships include outsourcing of important non-core functions or acquisition of complementary assets needed for innovation. These vertical relationships can deepen the firm's knowledge of specific fields, while giving it access to the resources and assets necessary to create and develop new products. As this discussion suggests, horizontal and vertical relationships give the firm access to different types of knowledge that go beyond what the firm already has, thereby broadening a firm's potential absorptive capacity.

Specifically, in the biotechnology context, we consider structure of the alliance portfolio for two main reasons. First, researchers have pointed to the importance of alliance structure to

stability of the relationship, and the ability to accomplish strategic objectives (Contractor & Lorange, 1988; Kogut, 1988). The structure of the alliances also indicates the firm's motivation to enter and maintain an alliance. Accordingly, horizontal relationships reflect power sharing and interdependence, whereas vertical relationships entail power asymmetry (Inkpen & Beamish, 1997). Second, the structure of the alliance affects the firm's ability to learn from its partners, and therefore, affects the firm's ability to evaluate and assimilate knowledge (Kale et al., 2000). The relational perspective suggests that the structure of an alliance determines the partners from whom the firm can acquire different skills. These relationships determine the types of knowledge to be gained and how the firm exploits them. Therefore, the structure of alliances is an important determinant of a firm's innovativeness and performance.

2.1.2. Portfolio knowledge flows

The knowledge flow characteristic of the partnership that influences learning is reflected by the direction of knowledge transfer and the sharing of that knowledge within an alliance. Alliances, therefore, can be generative or attractive in nature. Generative alliances usually involve joint R&D with other firms or research institutions. These alliances are important in supplying new technology to the firm and, therefore, are useful in shortening the learning cycle, expediting product development, and reducing R&D costs (Hagedoorn, 1993). Generative alliances, therefore, require frequent interactions and mutual sharing of knowledge among partners. Following the learning perspective, these interactions can induce learning by allowing members to observe each other and imitate others' best practices. Frequent interactions also induce trust, making partners more willing to exchange ideas and share sensitive information (Dyer & Singh, 1998). Attractive alliances, on the other hand, include purchasing and licensing agreements that give the firm access to new knowledge; with the sharing of knowledge frequently occurring in one direction. This sharing, however, can help expand the recipient firm's knowledge base. The learning perspective indicates that a firm's exposure to different bases of knowledge can intensify innovativeness (Huber, 1991; Zahra, Ireland, & Hitt, 2000). Thus, both generative and attractive alliances have the potential to expand the company's absorptive capacity. Knowledge flow is especially important in the biotechnology industry because each type of alliance agreement may provide access to different types and amounts of knowledge transfer. These variations provide different levels of learning that ultimately influence the level of absorptive capacity.

By managing its portfolio of attractive and generative partnerships, biotechnology firms can better acquire and utilize new knowledge and build a competitive advantage. The above discussion suggests that alliance characteristics designated by structure (horizontal or vertical alliances) and knowledge flow (generative or attractive) will be related to the firm's absorptive capacity (ability to value and apply knowledge). Therefore, we expect a significant relationship between the firm's alliance characteristics and its absorptive capacity. Hence, we posit that:

Hypothesis 1: A firm's alliance portfolio characteristics will be positively and significantly related to absorptive capacity. That is:

Hypothesis 1a: The structure of the alliance portfolio will be positively related to absorptive capacity.

Hypothesis 1b: The knowledge flow characteristics of the alliance portfolio will be positively related to absorptive capacity.

2.2. Absorptive capacity and performance

The organizational learning perspective highlights the importance of knowledge accumulation and exploitation within organizations (Blackler, 1995; Daft & Weick, 1984; March & Simon, 1958). Past research on absorptive capacity also highlights the importance of knowledge in providing the firm with a competitive advantage (Leonard-Barton, 1995; Van den Bosch, Volberda & de Boer, 1999). Firms that possess superior capabilities to value and apply this knowledge would, in essence, have superior innovation and performance. In fact, Cohen and Levinthal (1989) have examined the relationship between absorptive capacity and learning and developed two dimensions of absorptive capacity that affect innovative performance within an evolving and uncertain environment. The first dimension centers on the increased efficiency of a firm in assimilating new knowledge. As a firm assimilates new knowledge, learning occurs and future knowledge assimilation intensifies and becomes more efficient. The second dimension is the use of knowledge to exploit technological advancements, which is closely related to the outcomes of innovative behavior. Therefore, the firm must be able to gain knowledge by scanning the external environment and then transferring the knowledge throughout the firm to create value (Granstrand & Sjolander, 1990).

Success in science-based industries requires the firm to develop and hone its capabilities (Bogner, Thomas, & McGee, 1996). Absorptive capacity is considered as a set of capabilities, such as the ability to value, assimilate, and apply knowledge (Cohen & Levinthal, 1990; Kim, 1998). The underlying assumption is that these capabilities are socially complex routines that could be a valued organizational resource (Collis, 1994; Hall, 1992). Absorptive capacity can improve a firm's performance by "exploiting existing internal and external firm-specific competencies to address changing environments" (Teece, Pisano, & Shuen, 1997, p. 510).

Past research on absorptive capacity has been grounded in the uncertain and evolving environment of high technology industries. In these industries, firms need dynamic capabilities to respond to change (Kraatz, 1998; Nicholls-Nixon, 1995). By learning from experience, a firm is better able to acquire and assimilate knowledge in the future (Cohen & Levinthal, 1989; Herriot, Levinthal, & March, 1985). Absorptive capacity also encourages change in a company by promoting innovative behavior as a way to identify and exploit technological advances (Van den Bosch et al., 1999). Combining knowledge is an important way to create new products (Zander & Kogut, 1995) and improve financial performance (Zahra et al., 2000). Consequently, firms that have superior capabilities to acquire and exploit new knowledge would be expected to have superior innovation and performance. These observations suggest the following hypothesis:

Hypothesis 2: Absorptive capacity will be positively related to firm performance.

2.3. Portfolio characteristics and performance

Thus far, we have discussed absorptive capacity as important for a firm's innovation and performance. Literature on alliances also suggests that knowledge transcends the boundaries of the firm and that absorptive capacity could be a function of the relatedness of the partner's knowledge base and technological capabilities (Lane & Lubatkin, 1998; Mowery et al., 1996). A firm's absorptive capacity is a product of the relationships and access to knowledge from external sources (Cockburn & Henderson, 1998). Though our preceding discussion would suggest that alliance characteristics and absorptive capacity may influence firm performance (Hypotheses 1 and 2, respectively), the benefits of alliances are not likely to be limited to the development of knowledge capabilities. The relational perspective indicates that firms gain "a supernormal profit (that is) jointly generated in an exchange relationship that cannot be generated by either firm in isolation and can only be contributed by joint idiosyncratic contributions of the specific alliance partners" (Dyer & Singh, 1998, p. 662). These rents are possible when alliance partners combine, exchange, or invest in assets and knowledge capabilities (Nooteboom, 1999). Consequently, the benefits of alliance characteristics are also expected to go beyond improving absorptive capacity.

One potential source of relational rents (i.e., financial performance) is through investments in specialized assets in conjunction with the assets of the partners (Amit & Schoemaker, 1993; Carney, 1998). Alliance partners can improve their productivity by making relationship-specific investments in site, physical assets, and human assets (Williamson, 1985). Site specificity refers to the successive production stages that are immobile in nature, being located close to one another, thereby reducing inventory, transportation, and manufacturing coordination (Dyer, 1996), or improved coordination in R&D and knowledge sharing routines in high technology industries (Nobel & Birkinshaw, 1998). Physical asset specificity refers to the investment in specialized physical assets such as capital investments in production and technology development that are tailored to increase productivity of the exchange among partners. Investments in specialized physical assets have been found to have positive effects on a firm's performance (Holm, Eriksson, & Johanson, 1999). Human asset specificity refers to developing know-how through repeated interactions between alliance partners. As partners work together, they increase efficiency by improving communication, knowledge sharing, and their relative capacity to absorb and utilize knowledge for innovation and product development (Lane & Lubatkin, 1998; Mowery et al., 1996). As the relationship develops, both alliance partners begin to invest in relationship-specific assets that yield relational rents. Researchers have found that investments in such nonrecoverable relational assets can lead to improved performance of both alliance partners (Carney, 1998; Holm et al., 1999).

Clearly, the characteristics of the alliance portfolio, such as structure and flow, would influence the development of performance-enhancing capabilities that exceed the development of a firm's absorptive capacity. Though alliances are a major source of external knowledge (Liebeskind et al., 1996; Powell, 1998), they also generate relational rents through, among others, investments in specialized assets. Therefore, we expect the structure of alliances to have a greater effect on firm performance than would be explained by absorptive capacity (Lane & Lubatkin, 1998). Theory development suggests that horizontal alliances are likely to

give the firm access to multiple types of knowledge. However, vertical alliances may provide access for biotech firms to commercialize their products or innovations. Vertical alliances may also increase speed to market as biotech firms frequently ally with larger pharmaceutical firms to enhance their market presence and capitalize upon the large sales force of these pharmaceutical firms. With regard to knowledge flow, attractive alliances may enable the firm to import knowledge from multiple sources, fueling innovation and improving performance. These observations suggest the study's third and final hypothesis:

Hypothesis 3: Alliance characteristics will explain a significant variance in firm performance over and above the variance explained by its absorptive capacity.

Hypothesis 3a: Compared to horizontal alliances, vertical alliances will explain a greater amount of variance in firm performance over and above the variance explained by its absorptive capacity.

Hypothesis 3b: Compared to generative alliances, attractive alliances will explain a significant variance in firm performance over and above the variance explained by its absorptive capacity.

3. Method

3.1. Sample

To test the study's hypotheses, data were drawn from the biopharmaceutical industry. In this study, we consider only the human diagnostics and therapeutics segment, defined as those firms involved in the R&D of drugs or diagnostics for humans (DeCarolis & Deeds, 1999; Shan, Walker, & Kogut, 1994; Zahra, 1996). We chose the human diagnostics and therapeutics sector because firms in this sector have extensively used alliances to gain access to necessary technology and knowledge. Also, there are significant differences in the degree of innovativeness, R&D spending levels, and the drug approval process between the human therapeutics sector and other sectors such as agricultural or veterinary biotechnology. We believed this sector to be most appropriate because it had similar motivations for firms to enter alliances and reduced within-industry differences that may confound results and inferences.

Two steps were used to identify firms in the sample. In the first step, a straightforward classification through SIC codes, yielded 504 firms — 104 firms in Human Diagnostics (SIC #2835), 96 firms in biological products excluding diagnostics (SIC #2836), and 304 in pharmaceutical preparations (SIC #2384). This classification included human therapeutics from biotechnology as well as bulk and specialty drugs. The second step involved eliminating firms from the pool of 504 based on a firm's business focus, as provided in *The 1997 Guides to Biotechnology Companies*. Only firms involved in gene therapy, human diagnostics, and therapeutics were included in the analysis. This process yielded 147 publicly traded firms with a primary business focus in human gene therapy, diagnostics, and therapeutics. We excluded four firms that had incomplete alliance information. The final sample consisted of 143 firms.

3.2. Measures

Data were collected from secondary sources to construct three primary measures: alliance portfolio characteristics, absorptive capacity, and performance, as explained below.

3.2.1. Alliance portfolio characteristics

Consistent with prior research, an alliance was defined as any cooperative relationship between firms to develop or commercialize a new product (Deeds & Hill, 1996; Shan et al., 1994). Data on alliances were obtained from *Recombinant Capital*, a comprehensive database on biotechnology firm alliances recommended by the BIO. The database listed all the alliances that each biotechnology firm had joined since its formation. The database also had notations on the type (licensing, joint venture, etc.), purpose (business focus), period (number of years), and size (value in million dollars) of each alliance. The data used in this study included all alliances (formal agreements) that the firm had entered into until the end of 1995.

Next, the 2456 alliances completed by the 143 firms in the sample were coded as four submeasures: (a) horizontal alliances, (b) vertical alliances, (c) knowledge generative alliances, and (d) knowledge attractive alliances, as done previously by Hagedoorn and Schakenraad (1994) and Kotabe and Swan (1995). Two coders with graduate academic training in the life sciences were used. Coders agreed on their classification of 96.3% of the alliances. For the remaining 3.7%, a third coder (with a PhD degree in pharmacy) cast the deciding vote. Horizontal linkages included joint R&D, patent swaps, technology transfers, and joint ventures that supplemented a firm's technology base. Vertical links included outsourcing and distribution links. Generative linkages involved joint R&D with other firms or research institutions. Attractive alliances involved purchasing and licensing agreements. Generative linkages, which supplied new technology to the firm, were useful in shortening the learning cycle, expediting product development, and reducing R&D costs.

3.2.2. Absorptive capacity

A firm's absorptive capacity represents its ability to value and assimilate information (Cohen & Levinthal, 1990). Consistent with this definition, we used two submeasures for absorptive capacity: R&D spending and the number of patents, as follows.

To gauge the firm's ability to acquire and value external knowledge, we used R&D commitment as a key measure. Defined as the absolute value of R&D spending in millions, R&D commitment has been used in prior studies to gauge absorptive capacity (Cohen & Levinthal, 1990). Past studies have used R&D spending as a measure of a firm's input into innovative activities. In this study, we extend this tradition by using it as a proxy for a firm's absorptive capacity. The investments high technology firms make in maintaining a strong R&D program allow them to attract and keep talented scientists who follow scholarly developments in the field (Kim, 1997; Zahra, 1996). This allows these researchers to understand and capture the knowledge created by alliances. Some of this knowledge is tacit and therefore requires a great deal of expertise. Kim (1997) and Kodama (1995) note the crucial importance of a firm's internal R&D in determining its ability to import, comprehend, and assimilate external knowledge. R&D funds is used also to employ outside experts who

are knowledgeable in emerging fields. Use of outside experts can compress the absorption cycle of externally acquired information (Kim, 1997). R&D funds are crucial to supporting different research projects, a process that enhances learning by doing. This learning enables the firm to import and use externally created knowledge.

In addition, we used the number of patents in specific fields as a measure of absorptive capacity (Austin, 1993). Though patents have been used as a measure of a firm's innovation (e.g., Deeds & Hill, 1996; Mowery et al., 1996), this study employs patents as a measure of the firm's ability to apply or exploit knowledge as suggested by Zahra and George (2000). For the firm to gain a patent, it has to demonstrate some degree of newness that reflects a change in the firm's basic knowledge structure. Patents also record the firm's evolving or emerging knowledge and therefore represent a milestone in its progress in discovery and innovation. Firms usually combine multiple knowledge bases as they pursue product innovation (Zander & Kogut, 1995). This combinative knowledge is often revealed in the firm's own patenting behavior and others' citations of the firm's patents (Almeida, 1996). Patents, therefore, codify some of the learning that has occurred in the high technology firm, which reveals the firm's ability to understand, assimilate, and use external knowledge (i.e., greater absorptive capacity). Therefore, we used U.S. Patent Class 930 and 935 as indicative of innovative capability within a specialized field.

3.2.3. Performance

Consistent with Fig. 1, we employed two measures of firm performance. Given that most biotechnology firms do not make a net profit (BIO, 1999), we used: (a) *the number of products on the market* to gauge firm success in developing and introducing new products (DeCarolis & Deeds, 1999; Shan et al., 1994) and (b) *net sales-to-assets* to measure a company's financial performance that accounted for revenues relative to size (Wu & Ho, 1997). This ratio was especially important given a firm's need to generate cash flow to support future R&D.

The data for net sales and R&D spending were collected from *Compact Disclosure*, all for 1996. The number of products on the market was gathered from *The 1997 Guides to Biotechnology Companies*, all for 1996.

3.3. Control variables

The analyses used three control measures: age, industry sector, and venture origin. *Organizational age* has been related to firm survival and mortality rates (Hannan & Freeman, 1984; Levinthal, 1991). Organizational age, taken from *The 1997 Guides to Biotechnology Companies* was measured in years from the date of incorporation, as done in prior research (Cooper, Woo, & Dunkelberg, 1989; Deeds & Hill, 1996; Zahra, 1996; Zahra et al., 2000). Next, *industry sector* was used to control for within-industry differences. Therefore, we dummy-coded the firm's industry sector by their SIC classification. Finally, we used *venture origin* to control for corporate or independent ventures. Researchers suggest that significant differences exist between independent and corporate biotech ventures due to differences in their resource base and capabilities (Zahra & George, 1999).

Table 1
Descriptive statistics and correlations ($N = 143$)

Variables	Mean (S.D.)	1	2	3	4	5	6	7	8	9	10	11	12
(1) Age	9.65 (3.23)	1											
(2) Venture origin	0.20 (0.404)	.03	1										
(3) Pharma sector (2834)	0.31 (0.466)	−.12	.28**	1									
(4) Diagnostics sector (2835)	0.15 (0.362)	.06	−.02	−.29**	1								
(5) Ability to value knowledge (R&D spending)	106.21 (306.18)	.05	.57**	.42**	−.14	1							
(6) Ability to apply knowledge (patents)	3.36 (10.76)	.35**	.15†	.15†	−.09	.41**	1						
(7) Horizontal alliances	6.15 (7.55)	.12	.47**	.37**	−.13	.74**	.58**	1					
(8) Vertical alliances	10.98 (13.96)	.24**	.52**	.33**	−.13	.75**	.43**	.75**	1				
(9) Generative alliances	6.02 (5.76)	.22**	.41**	.28**	−.10	.62**	.57**	.90**	.76**	1			
(10) Attractive alliances	6.40 (7.36)	.15†	.48**	.34**	−.13	.74**	.53**	.77**	.86**	.73**	1		
(11) Products on market	1.15 (2.22)	.35**	.27**	−.05	.04	.56**	.31**	.08	.44**	.13	.26**	1	
(12) Net sales/assets	0.33 (0.39)	.23**	.22*	.18*	.11	.41**	.19*	.27**	.37**	.26**	.26**	.41**	1

* $P < .05$.
** $P < .01$.
† $P < .10$.

4. Results

Table 1 presents the summary statistics and correlations among the variables. As Table 1 indicates, most of the study's predictions are supported by the significant correlations observed among the variables with many of the correlations being quite large ($P < .001$). Next, to examine the relative effects of portfolio characteristics on performance, we used hierarchical multiple regression analysis. Therefore, we entered the control variable (company age, venture origin, and industry sector) in Step 1. Age, venture origin, and industry sector controls were statistically significant in some of the regression equations, thus supporting their use as control measures.

To test Hypothesis 1 (Hypotheses 1a and 1b), we introduced portfolio characteristics as predictors of the absorptive capacity measures in Step 2 (Table 2). To test Hypothesis 2, we introduced absorptive capacity as a predictor of performance in Step 2 (Table 3). Subsequently, to test Hypothesis 3 (Hypotheses 3a and 3b), we introduced the portfolio characteristics in Step 3 of the hierarchical regression (Table 3). Finally, to determine the unique amount of variance explained by each block of variables, we examined the increase in adjusted R^2.

Hypothesis 1 (Hypotheses 1a and 1b), which suggested a significant association between alliance portfolio characteristics and absorptive capacity, was supported because three of the four portfolio characteristics were related to the two measures of absorptive capacity. Specifically, as reported in Table 2, horizontal (Hypothesis 1a) and knowledge attractive alliances (Hypothesis 1b) had positive beta coefficients ($\beta = 0.30$ and .55, $P < .10$ and $P < .01$,

Table 2
Portfolio characteristics as predictor of absorptive capacity

Step	Independent variables	Ability to value knowledge (R&D spending) β	Adj. R^2	Δ Adj. R^2	Ability to apply knowledge (Patents) β	Adj. R^2	Δ Adj. R^2
1	Constant	− 56.81	.38***		− 11.39	.14***	
	Venture origin	0.16**			− 0.12		
	Pharma sector (2834)	0.08			− 0.02		
	Diagnostics sector (2835)	0.00			− 0.03		
	Age	− 0.04			0.29** *		
2	Horizontal alliances	0.60***	.72***	.34	0.30†	.47***	.33
	Vertical alliances	0.34***			− 0.43* *		
	Generative alliances	− 0.42***			0.21		
	Attractive alliances	0.23 *			0.55** *		

Standardized beta values are reported for the final step.
Adjusted R^2 are reported for each step. $N = 143$.
* $P < .05$.
** $P < .01$.
*** $P < .001$.
† $P < .10$.

Table 3
Portfolio characteristics and absorptive capacity as predictors of performance

Step	Independent variables	Products on market			Net sales/assets		
		β	Adj. R^2	Δ Adj. R^2	β	Adj. R^2	Δ Adj. R^2
1	Constant	0.08	.16***		0.05	.15***	
	Venture origin	0.16			−0.01		
	Pharma sector (2834)	−0.09			0.14		
	Diagnostics sector (2835)	0.08			0.22**		
	Age	0.19*			0.16†		
2	Ability to value knowledge (R&D spending)	0.45***	.40***	.24	0.36*	.22***	.07
	Ability to apply knowledge (patents)	0.04			0.06		
3	Horizontal alliances	0.25	.45***	.05	−0.07	.23***	.01
	Vertical alliances	0.65**			0.39*		
	Generative alliances	−0.57**			−0.06		
	Attractive alliances	−0.37*			−0.28		

Standardized beta values are reported for the final step.
Adjusted R^2 are reported for each step. $N = 143$.
* $P < .05$.
** $P < .01$.
*** $P < .001$.
† $P < .10$.

respectively), whereas vertical alliances (Hypothesis 1a) had a negative coefficient ($\beta = -0.43$, $P < .01$) when the ability to apply knowledge (patents) was the dependent variable. Generative alliances were not related to patent output. Together, the portfolio characteristics accounted for a change in adjusted R^2 of .33 for the ability to apply knowledge. When the dependent variable was the firm's ability to value externally generated knowledge (R&D commitment), horizontal and vertical alliances (Hypothesis 1a) had positive coefficients ($\beta = 0.60$ and .34, respectively, $P < .001$) whereas generative alliances (Hypothesis 1b) had a negative coefficient ($\beta = -0.42$, $P < .001$) and attractive alliance was a significant predictor of R&D spending ($\beta = 0.23$, $P < .05$). Together, the portfolio characteristics accounted for a change in adjusted R^2 of .34 of a firm's R&D commitment.

Hypothesis 2, on the association of absorptive capacity and firm performance, received partial support (Table 3). Of the two absorptive capacity measures, only the ability to value knowledge (R&D investment) was a significant predictor of products on the market ($\beta = 0.45$, $P < .001$) and net sales/assets ($\beta = 0.36$, $P < .05$).

As predicted, Hypothesis 3 was supported. Alliance portfolio characteristics explained additional statistically significant variance in the products on the market ($\Delta R^2 = .05$) and a marginal but significant difference in net sales/assets ($\Delta R^2 = .01$) over and above the predictive power of absorptive capacity and the control variables (age, venture origin, and industry sector).

Of the controls used, venture origin was a significant predictor of R&D spending, which was consistent with other studies that suggest that corporate ventures have additional

resources at their disposal and hence have higher R&D spending (e.g., Zahra, 1996; Zahra & George, 1999). Also, age was a significant predictor of performance as well as absorptive capacity. This result underscored the importance of time to develop a firm's absorptive capacity and leveraging it towards value creation.

5. Discussion and implications

High technology industries are important for the growth of the national economy. Given the fierce competition that prevails in these industries, researchers have attempted to identify the factors that determine success and failure of high technology firms (Carroll, 1993; Rumelt, Schendel, & Teece, 1991). There is agreement that constant innovation is the key to gaining and maintaining competitive advantage in these industries. However, innovation hinges on the ability of the high technology firm to assimilate and exploit different types of knowledge. In younger high technology industries such as biotechnology, very few firms have the resources (especially knowledge) needed to sustain innovation. Strategic alliances are an important means by which high technology firms can achieve this objective. Today, many high technology firms are members of multiple alliances, aiming to achieve multiple goals.

This article contributes to the literature by examining and providing support for the importance of alliance portfolio characteristics for firm performance. Both the relational and learning perspectives highlight the importance of alliance structure for value creation and this paper provides support for the key propositions of these two perspectives. The article also extends the literature by exploring and addressing the differential relationships between portfolio characteristics and performance. These issues have been discussed in the literature but have not been documented empirically. Another contribution of this study is highlighting the intermediary role of absorptive capacity as a source of influence on firm performance. Even though the role of absorptive capacity in creating value has been the subject of interest in the literature, it has not been carefully documented in empirical research (Zahra & George, 2000). These two contributions should be viewed in the context of inadequate empirical testing in prior studies of the role of absorptive capacity within research on strategic alliances. Simonin (1999, p. 596) notes that "unlike the profusion of conceptual work, there has only been limited empirical work on the role of knowledge in strategic alliances that goes beyond small-sample, in-depth studies of a few organizations." This study begins to address this gap in the literature by examining 2456 alliances of 143 biotechnology firms.

The results have three important implications. First, consistent with the relational and learning perspectives, the results support the importance of studying alliance characteristics (i.e., how information is transferred between firms) and their potential affect on value creation in high technology firms. This finding has theoretical and practical implications. It reinforces the importance of considering alliances as a bundle of capabilities, which is an issue that needs greater attention in future empirical research. The findings indicate that future researchers should explore the way alliances are structured in order to determine if structure impacts potential gains that the firm can achieve. Counting alliances, as widely done in prior

research, may not fully capture the gains realized from these alliances. Researchers need to probe their structure and knowledge flow patterns as well, as suggested by proponents of the relational and organizational learning perspectives. Indeed, as evident from the theory section, the proponents for the relational and learning perspectives converge in their views about the role of alliances in creating value in high technology firms.

The practical implication of our results is unique in that alliances can be viewed as a portfolio. Similar to a portfolio of stocks, where investors hedge risk through diversification or maximize risk to maximize return, managers may view alliances as capability-enhancing or as a means for acquiring access to resources. For example, managers can opt for vertical rather than horizontal alliances to maximize the probability of bringing a product to market. Managers might develop this portfolio in a way that reduces the overall risk of organizational failure. Alternatively, executives may attempt to balance the business vs. the technological risks associated with the use of a diverse set of alliances.

Second, the results highlight the differential effect of the portfolio characteristics on performance. As the results indicate, the beta coefficients for different portfolio characteristics are not in the same direction. For example, horizontal alliances are positively related to patents (innovative capability), whereas vertical alliances are negatively related to patents. Also, vertical alliances are positively related to performance, whereas horizontal alliances are not significant predictors of company performance. With these results in mind, future researchers should study portfolio characteristics in different industries and organizational cohorts. In the current biotechnology sample, it is plausible that in order to commercialize their products, biotechnology firms establish ties with larger pharmaceutical firms who have a dedicated marketing and sales network. Smaller firms that do not have the financial resources to establish their own sales team may opt to enter such vertical alliances with pharmaceutical firms. Though our sample includes independent and well-known biotechnology firms (e.g., Amgen and Biogen), these firms may opt to outsource their marketing efforts in order to remain with their core competence of drug research. We do not know if the mix of alliance portfolio characteristics or the effect of these characteristics on company performance will persist in other high technology industries or in more established firms. Here too, we believe it is beneficial for future scholars to use the relational and learning perspectives in examining the effect of different dimensions of alliance characteristics.

The third implication of our results centers on the role of absorptive capacity. Following Cohen and Levinthal's (1989, 1990) work on this construct, absorptive capacity has been extensively invoked conceptually (Kim, 1998; Koza & Lewin, 1998; Nicholls-Nixon, 1995) but with little empirical verification (e.g., Lane & Lubatkin, 1998). Thus, the role of the absorptive capacity construct has not been verified across different organizational contexts. Our results highlight the importance of this construct for firm performance and its role within the alliance portfolio characteristic framework. They also suggest that alliance portfolio characteristics are related to absorptive capacity and, in turn, organizational performance. We can explain about 45% of the variance in products on the market and 23% of the variance in net sales/assets when we combine the predictive power of the two constructs. Absorptive capacity enables the firm to transform knowledge gained from outside to products, goods, and services. Future researchers may want to further explore the intricacies of differential

relationships between alliance portfolio characteristics and the firm's absorptive capacity, using the relational and learning perspectives discussed in this paper.

5.1. Limitations

Despite the fact that our results are encouraging, they should be interpreted with caution because of the study's limitations. To consider the alliances that a firm has forged since its inception also raises some difficult conceptual and measurement issues. Similar to a stock portfolio where risk and return measures are likely to exhibit high correlation, some of the measures of structure and knowledge flow exhibit high correlations. Such correlations may also be indicative of multicollinearity issues that need to be addressed in future research designs. Also, the study's cross-sectional design makes it difficult to establish causal relationships among the variables. Due to path dependence in a firm's evolution of capabilities, future research should consider alliance characteristics using time-series models that can better clarify the relationships between alliance characteristics and performance as well as control for past innovative and financial performance. Such time-series analysis may also allow the use of multiple control measures for each time frame. For instance, firm size, executive compensation, and products commercialized in any given year could be used as control measures. Also, given the dynamic evolution of the biotechnology industry, the results might capture relationships among variables of interest at only one point in time. Moreover, while there are several important benefits for single industry studies, the fact that this research was conducted in the biotechnology industry might limit the generalizability of the findings. Finally, the current results might reflect the nature of the measures used, especially those related to absorptive capacity. Future studies might benefit from exploring other indicators of absorptive capacity; indeed, the use of alternative measures would only help to establish the robustness of the current findings.

5.2. Future research directions

The results have important implications for future research into high technology firms. The notion of considering alliances as a portfolio that can be managed deserves further study. How do firms use their portfolio to gain access to different types of knowledge? How do firms balance risks in their alliance portfolio? This study combines two theoretical perspectives and empirically tests their position that to this point has received conceptual attention but inadequate empirical scrutiny. The relational perspective of the firm posits that managing relationships effectively would yield economic rents (Dyer & Singh, 1998). Our findings support this proposition and improve our understanding of a firm's absorptive capacity. The organizational learning literature emphasizes the importance of a firm's ability to assimilate, value, and leverage information from external sources to derive a competitive advantage. Future researchers should seek to further validate the propositions of these two perspectives in different segments of the biotechnology industry or other high technology industries.

In high technology industries, such as biotechnology, managing a portfolio of relationships may be crucial to firm survival and growth. The empirical support for the importance of portfolio characteristics as a means of value creation is encouraging and worthy of attention in future research on managing high technology firms. Understanding the effect of alliances on a firm's performance is a central issue in the literature. Alliances contribute to a firm's performance directly by creating relational rents. Alliance characteristics also contribute significantly to the firm's absorptive capacity that, in turn, influences its financial and innovative performance. We hope that future researchers will draw upon the learning and relational perspectives as they examine the processes by which high technology companies build their absorptive capacity and effectively harness it in pursuit of value-creating innovations.

Acknowledgments

The support of the Brethen Operations Management Institute at Syracuse University and the Weinert Center for Entrepreneurship at University of Wisconsin-Madison is gratefully acknowledged. We thank the anonymous reviewers for their constructive comments.

References

Almeida, P. (1996). Knowledge sourcing by foreign multinationals: patent citation analysis in the U.S. semiconductor industry. *Strategic Management Journal*, *17*, 155–165.

Amit, R., & Schoemaker, P. (1993). Strategic assets and organizational rent. *Strategic Management Journal*, *14*, 33–46.

Arora, A., & Gambardella, A. (1994). Evaluating technological information and using it. *Journal of Economic Behavior and Organization*, *24*, 91–114.

Austin, D. H. (1993). An event-study approach to measuring innovative output: the case of biotechnology. *American Economic Review*, *83* (2), 253–258.

Barkema, J. G., Bell, J. H. J., & Pennings, J. M. (1996). Foreign entry, cultural barriers, and learning. *Strategic Management Journal*, *17* (2), 151–167.

Baum, J. A. C., Calabrese, T., & Silverman, B. S. (2000). Don't go it alone: alliance network composition and startups' performance in Canadian biotechnology. *Strategic Management Journal*, *21* (3), 267–294.

Biotechnology Industry Organization (BIO). (1999). The editors and reporters guide to biotechnology. Available at: http://www.bio.org.

Blackler, F. (1995). Knowledge, knowledge work and organizations: an overview and interpretation. *Organization Studies*, *16*, 1021–1047.

Bogner, W. C., Thomas, H., & McGee, J. (1996). A longitudinal study of the competitive positions and entry paths of European firms in the US pharmaceutical market. *Strategic Management Journal*, *17* (6), 85–107.

Carney, M. (1998). The competitiveness of networked production: the role of trust and asset specificity. *Journal of Management Studies*, *35* (4), 457–479.

Carroll, G. R. (1993). A sociological view on why firms differ. *Strategic Management Journal*, *14* (4), 237–249.

Christensen, C. M. (1997). *The innovator's dilemma: when new technologies cause great firms to fail*. Boston, MA: Harvard Business School Press.

Cockburn, I., & Henderson, R. (1998). Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery. *Journal of Industrial Economics*, *46*, 157–183.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: the two faces of R&D. *Economic Journal*, 569–596 (September).

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, *35* (1), 128–152.

Collis, D. J. (1994). Research note: how valuable are organizational capabilities. *Strategic Management Journal*, *15*, 143–152.

Contractor, F. J., & Lorange, P. (1988). Why should firms co-operate? The strategic and economic basis for co-operative ventures. In: F. J. Contractor, & P. Lorange (Eds.), *Cooperative strategies in international business* (pp. 3–28). Lexington, MA: Lexington Books.

Cooper, A., Woo, C., & Dunkelberg, W. (1989). Entrepreneurship and the initial size of firms. *Journal of Business Venturing*, *4*, 317–322.

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review*, *9*, 284–295.

Das, T. K., & Teng, B. S. (1996). Risk types and inter-firm alliance structures. *Journal of Management Studies*, *33* (6), 827–843.

D'Aveni, R. (1994). *Hypercompetition: the dynamics of strategic maneuvering*. New York, NY: Basic Books.

DeCarolis, D. M., & Deeds, D. L. (1999). The impact of stocks and flows of organizational knowledge on firm performance: an empirical investigation of the biotechnology industry. *Strategic Management Journal*, *20* (10), 953–968.

Deeds, D. L., & Hill, C. W. (1996). Strategic alliances and the rate of new product development: an empirical study of entrepreneurial biotechnology firms. *Journal of Business Venturing*, *11*, 41–55.

Dosi, G. (1988). Sources procedures, and microeconomic effects of innovation. *Journal of Economic Literature*, *26* (3), 1120–1172.

Dyer, J. (1996). Specialized supplier networks as a source of competitive advantage: evidence from the auto industry. *Strategic Management Journal*, *17*, 271–292.

Dyer, J., & Singh, H. (1998). The relational view: cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review*, *23* (4), 660–679.

Granstrand, O., & Sjolander, S. (1990). The acquisition of technology and small firms by large firms. *Journal of Economic Behavior and Organization*, *3*, 367–386.

Grant, R. M. (1996). Prospering in dynamically-competitive environments: organizational capability as knowledge integration. *Organization Science*, *7* (4), 375–387.

Gulati, R. (1998). Alliances and networks. *Strategic Management Journal*, *19*, 293–317.

Gulati, R. (1999). Network location and learning: the influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal*, *20*, 397–420.

Hagedoorn, J. (1993). Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. *Strategic Management Journal*, *14* (5), 371–385.

Hagedoorn, J., & Schakenraad, J. (1994). The effects of strategic technology alliances on company performance. *Strategic Management Journal*, *15*, 291–309.

Hall, R. (1992). The strategic analysis of intangible resources. *Strategic Management Journal*, *13*, 135–144.

Hannan, M. T., & Freeman, J. H. (1984). Structural inertia and organizational change. *American Sociological Review*, *49*, 149–164.

Helfat, C. E. (1997). Know-how and asset complementarity and dynamic capability accumulation: the case of R&D. *Strategic Management Journal*, *18*, 339–360.

Herriot, S. R., Levinthal, D., & March, J. G. (1985). Learning from experience in organizations. *AEA Papers and Proceedings*, *75* (2), 298–302.

Holm, D. B., Eriksson, K., & Johanson, J. (1999). Creating value through mutual commitment to business network. *Strategic Management Journal*, *20*, 467–486.

Huber, G. P. (1991). Organizational learning: the contributing processes and the literatures. *Organization Science*, *2*, 88–115.

Inkpen, A. C., & Beamish, P. W. (1997). Knowledge, bargaining power, and the instability of international joint ventures. *Academy of Management Review*, *22* (1), 177–202.

Kale, P., Singh, H., & Perlmutter, H. (2000). Learning and protection of proprietary assets in strategic alliances: building relational capital. *Strategic Management Journal*, *21* (3), 217–237.

Kim, L. (1997). *Imitation to innovation: the dynamics of Korea's technological learning*. Boston, MA: Harvard Business School Press.

Kim, L. (1998). Crisis construction and organizational learning: capability building in catching-up at Hyundai Motor. *Organization Science*, *9*, 506–521.

Kodama, F. (1995). *Emerging patterns of innovation: sources of Japan's technological edge*. Boston, MA: Harvard Business School Press.

Kogut, B. (1988). Joint ventures: theoretical and empirical perspectives. *Strategic Management Journal*, *9* (4), 319–333.

Kotabe, M., & Swan, K. S. (1995). The role of strategic alliances in high-technology new product development. *Strategic Management Journal*, *16*, 621–636.

Koza, M. P., & Lewin, A. Y. (1998). The co-evolution of strategic alliances. *Organization Science*, *9*, 255– 264. 264.

Kraatz, M. S. (1998). Learning by association? Interorganizational networks and adaptation to environmental change. *Academy of Management Journal*, *41* (6), 621–644.

Lane, P. J., & Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. *Strategic Management Journal*, *19*, 461–477.

Leonard-Barton, D. (1995). *Wellsprings of knowledge*. Boston, MA: Harvard Business School Press.

Levinthal, D. A. (1991). Random walks and organizational mortality. *Administrative Science Quarterly*, *36* (3), 397–421.

Liebeskind, J. P., Oliver, A. L., Zucker, L., & Brewer, M. (1996). Social networks, learning and flexibility: sourcing scientific knowledge in new biotechnology firms. *Organization Science*, *7* (4), 428–443.

Lindsay, P., & Norman, D. (1977). *Human information processing*. Orlando, FL: Academic Press.

March, J. G., & Simon, H. (1958). *Organizations*. New York: Wiley.

Markowitz, H. M. (1952). Portfolio selection. *Journal of Finance, 7*, 77–91 (March).

Markowitz, H. M. (1991). Foundations of portfolio theory. *Journal of Finance, 46*, 469–477.

Moon, C. W. (1999). Impact of organizational learning contexts on choice of governance mode for international strategic combinations. *Journal of High Technology Management Research*, *10* (1), 167–202.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. (1996). Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal*, *17*, 77–91.

Nicholls-Nixon, C. (1995). Responding to technological change: why some firms do and others die. *Journal of High Technology Management Research*, *6* (1), 1–16.

Nobel, R., & Birkinshaw, J. (1998). Innovation in multinational corporations: control and communication patterns in international R&D operations. *Strategic Management Journal*, *19*, 479–496.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: how Japanese companies create the dynamics of innovation*. New York, NY: Oxford Univ. Press.

Nooteboom, B. (1999). *Inter-firm alliances: analysis and design*. London: Routledge.

Powell, W. W. (1998). Learning from collaboration: knowledge and networks in the biotechnology and pharmaceutical industries. *California Management Review*, *40*, 228–240.

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly*, *41*, 116–145.

Recombinant Capital. http://www.recap.com.

Rumelt, R. P., Schendel, D., & Teece, D. J. (1991). Strategic management and economics. *Strategic Management Journal*, *12*, 5–30.

Shan, W., Walker, G., & Kogut, B. (1994). Interfirm cooperation and startup innovation in the biotechnology industry. *Strategic Management Journal*, *15*, 387–394.

Sharpe, W. (1963). A simplified model of portfolio analysis. *Management Science*, *9*, 277–293.

Simonin, B. (1999). Ambiguity and the process of knowledge transfer in strategic alliances. *Strategic Management Journal*, *20* (7), 595–624.

Steensma, H. K., & Fairbank, J. F. (1999). Internalizing external technology: a model of governance mode choice and an empirical assessment. *Journal of High Technology Management Research*, *10* (1), 1–35.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*, 509–533.

The 1997 GEN Guides to Biotechnology Companies. http://www.genengnews.com/. Larchmont, NY: Mary Ann Liebert.

Tsai, W. (2000). Social capital, strategic relatedness and the formation of intraorganizational linkages. *Strategic Management Journal*, *21* (9), 925–939.

Van den Bosch, F., Volberda, H., & de Boer, M. (1999). Coevolution of firm absorptive capacity and knowledge environment: organizational forms and combinative capabilities. *Organization Science*, *10* (5), 551–568.

Williamson, O. (1985). *The economic institutions of capitalism*. New York: Free Press.

Wu, C., & Ho, S. K. (1997). Financial ratio adjustment: industry-wide effects or strategic management? *Review of Quantitative Finance and Accounting*, *9*, 71–88.

Zahra, S. A. (1996). Technology strategy and new venture performance: a study of corporate-sponsored and independent biotechnology ventures. *Journal of Business Venturing*, *11* (4), 289–322.

Zahra, S. A., & Bogner, W. C. (2000). Technology strategy and software new ventures' performance: exploring the moderating effect of the competitive environment. *Journal of Business Venturing*, *15* (23), 135–173.

Zahra, S. A., & George, G. (1999). Manufacturing strategy and new venture performance: a comparison of independent and corporate ventures in the biotechnology industry. *Journal of High Technology Management Research*, *10* (2), 313–345.

Zahra, S. A., & George, G. (2000). *Absorptive capacity: a review and reconceptualization*. Best Paper Proceedings of the Academy of Management National Meeting, Toronto.

Zahra, S. A., Ireland, R. D., & Hitt, M. A. (2000). International expansion by new venture firms: international diversity, mode of market entry, technological learning and performance. *Academy of Management Journal, 43* (5), 925–950.

Zander, U., & Kogut, B. (1995). Knowledge and the speed of the transfer and imitation of organizational capabilities: an empirical test. *Organization Science*, *6* (1), 76–92.