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An examination of the investments in U.S. biotechnology firms by foreign and domestic corporate partners

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Abstract

This study examines the characteristics that make start-up biotechnology firms attractive alliance partners. We distinguish between firm specific and location-specific characteristics as well as between foreign and domestic corporate partners. We present and test a longitudinal model of alliance development based on data from 64 public biotechnology firms. The results provide evidence that foreign and domestic alliance capital inflows are driven by different factors. Firm-specific factors explain minimal variance in capital inflows from foreign alliance partners; rather, location-specific factors seem to matter more. The reverse is true for domestic alliance partners. Further, our results suggest that firm size moderates the relationship between location-specific factors and capital inflows from foreign alliance partners such that larger firms benefit more when located in technologically munificent environments.

Keywords: Agglomeration; Alliance; Biotechnology; Cluster; Investment; Patents

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1. Executive summary

Early stage technology companies may be characterized as research engines fueled with burning cash. New ventures in software, the internet, medical devices, biotechnology, and other emerging technology driven industries often have negative annual cash flows of tens of millions of dollars while developing their technology, building organizational infrastructure, and developing a presence in their market. These losses are well beyond most new technology start-up's ability to generate capital internally, therefore they must look to external sources for the necessary capital. This thirst for capital has led to the development of an extensive entrepreneurial finance systems in the U.S., which includes personal sources, friends and family, angel investors, venture capitalists, equity markets, and alliance partners. Researchers have developed models of decision processes for venture capitalists, angel investors, and equity markets; however, our understanding of firm- and location-level characteristics associated with alliances capital remains limited.

While much is known about established firms' motivations for developing alliances much less is known about entrepreneurial firms' alliance development motivations. Particularly lacking is investigation of resource flows between partners. Rather than focus on the relationship structure among alliance partners, this study seeks to inform researchers and practitioners as to the amount of financial resources flowing between partners. Specifically, this study seeks to determine the roles of firm-specific and location-specific resources in attracting alliance capital from domestic and foreign corporate partners.

Results show that technological munificence and recent patents play important roles in attracting alliance capital from corporate partners. These findings are consistent with earlier research that has reported a positive significant relationship between firm-specific resources and interorganizational relationships. These results also provide support for the contention that foreign partners use alliances to acquire or learn about location-specific technologies. Perhaps the most interesting results are achieved when alliance capital is disaggregated into its foreign and domestic components. The amount of domestic alliance capital received is significantly influenced by the number of recent patents held by the biotechnology firm. When observing foreign alliance capital, biotechnology firms' technological munificence becomes the significant determinant while the significance of recent patents is lost. Further, our results suggest that firm size moderates the relationship between location-specific factors and capital inflows from foreign alliance partners such that larger firms benefit more when located in technologically munificent environments. These results offer an important insight with regards to the different motives domestic and international firms have for developing interorganizational relationships. For domestic firms, the main purpose for developing interorganizational relationships is access to firm-specific technology. For foreign firms, our results partially support research that has provided a link between foreign investment and the location-specific advantages imbedded in U.S. firms.

Entrepreneurs should take note that potential alliance partners value both internal and external firm characteristics. A firm's ability to demonstrate its technological capabilities in the form of recent patent activity is particularly valued by domestic alliance partners while foreign partners value the technological environment in which firms are embedded. Firm location is an important strategic choice for entrepreneurs. While it may be easier to locate operations near one's home community, entrepreneurs should take note of the local technological munificence level and consider its impact on the firm.

2. Introduction

Early stage technology ventures may be characterized as research engines fueled with burning cash. New ventures in software, the internet, medical devices, biotechnology, and other emerging technology driven industries often have negative annual cash flows of tens of millions of dollars while developing their technology, building organizational infrastructure, and developing a market presence. These losses are well beyond most new technology start-up's ability to generate capital internally, therefore they must look to external capital sources. This thirst for capital has led to the development of an extensive entrepreneurial finance system in the U.S., which includes personal sources, friends and family, angel investors, venture capitalists, equity markets, and alliance partners. Researchers have developed models of decision processes for venture capitalists (Shepherd, 1999; Shepherd and Zacharakis, 2002; Tyebjee and Bruno, 1984; Zacharakis and Shepherd, 2001), angel investors (Haar et al., 1988; Wetzel, 1987), and equity markets (Deeds et al., 1997); however, our understanding of firm- and location-level characteristics associated with alliance capital remains limited as does our general understanding of partner selection (Hitt et al., 2000; Saxton, 1997; Chung et al., 2000).

While much is known about established firms' motivations for developing alliances (Gulati and Higgins, 2003) much less is known about entrepreneurial firms' alliance development motivations although researchers have begun to explore this issue (Baum et al., 2000; Deeds and Hill, 1996; Gulati and Higgins, 2003). Particularly lacking is investigation of resource flows between partners (Gulati and Higgins, 2003; Hansen, 1999; Podolny and Baron, 1997; Uzzi, 1996). Rather than focus on the relationship structure among alliance partners, this study seeks to inform researchers as to the level of financial resources flowing between partners and to examine the roles of firm-specific and location-specific resources in attracting alliance capital from domestic and foreign corporate partners.

This study advances alliance research in several ways. First, specific resource flows between alliance partners are examined rather than the results of assumed resource flows, alliance structure, or legitimacy issues. Second, we empirically test the extent to which firm resources and technological munificence explain variance in alliance capital using longitudinal data on a sample of newly public biotechnology firms. Third, we propose a relationship between firm location and alliance activity that is unique to the agglomeration literature. Lastly, alliance capital is disaggregated into its domestic and international components to identify similarities and differences in alliance partners' investment criteria. As a result, our research informs researchers and practitioners as to the firm- and location-specific characteristics associated with capital flows within alliances as well as indirectly identifying alliance investment criteria.

3. Theory and hypotheses

Researchers have studied alliance formation due to the important strategic roles alliances play (Eisenhardt and Schoonhoven, 1996; Hagedoorn and Schakenraad, 1994; Parkhe, 1993). Research informs us that firms enter into alliances for a number of reasons (see Gulati, 1998 for a current review). Alliances can be used to share risks (Hagedoorn, 1993), capital, technology, and firm-specific assets (Gulati, 1999) both domestically and internationally (Cantwell, 1991; Saxonhouse, 1986). Alliances may also imply a certain level of legitimacy or external endorsement (Stuart, 2000; Stuart et al., 1999) as evidenced by their positive influence on small firm valuation (Das et al., 1998). An alliance may also be entered into for the purpose of bringing together complementary assets possessed by different firms (Nohria and Garcia-Pont, 1991). Firms may also enter into alliances to learn from partners, or in other words, alliances can be used as access relationships (Stuart, 2000). Firms may use these access relationships as both means of exploration and exploitation (March, 1991). Research suggests that alliance partners are motivated to form exploration alliances to make new discoveries or to acquire basic knowledge that may be used to develop new products (Grant and Baden-Fuller, 2004; Koza and Lewin, 1998; Rothaermel and Deeds, 2004). Exploitation or knowledge application alliances are developed with the goal of joining existing competencies (Koza and Lewin, 1998) and complementary assets (Teece, 1986) across firm boundaries to commercialize knowledge developed through exploration (Grant and Baden-Fuller, 2004; Rothaermel and Deeds, 2004). Lastly, firms may develop alliances to draw upon spatially bounded (Rosenkopf and Almeida, 2003), country-specific knowledge (Almeida, 1996; Almeida et al., 2002; Shan and Song, 1997) that can be used either for exploration or exploitation. Accessing localized technological knowledge may be particularly important for international partners (Almeida and Kogut, 1999; Almeida et al., 2002). Each of these alliance motivations implies firms need additional resources beyond their current resource endowments to be competitive in certain markets (Hitt et al., 1999, 2000). If gaining access to resources or knowledge are the sources of advantage gained from alliance formation, potential alliances partners value may vary based upon their unique characteristics (Stuart, 2000) as well as their location (Almeida, 1996; Almeida and Kogut, 1999).

This begs several important questions. What is the corporate partner buying? Are all large firms in alliances buying essentially the same thing? If not, are there systematic differences between domestic and international partners? The answers to these questions depend on what small, entrepreneurial technology firms have to offer. We suggest that, in the broadest sense, potential corporate partners value these firms in two ways. First, they can be valued for their own sake—for their tacit or codifiable knowledge, or their intangible resources. Second, they can be valued for the access to localized knowledge and skills that they can provide through their network connections to their potential partners.

We argue that these two sources of value are based on different views of the firm. The first view is rooted in the resource-based theory of the firm (Wernerfelt, 1984). As bundles of resources, firms are endowed with both tangible and intangible assets that are not only valuable to the firm, but that may also have value for other firms. When the firm controlling these assets needs additional capital, and their assets are perceived as valuable to other firms with available capital, the stage is set for alliance development. The second view is based on a location approach (Marshall, 1920) where firms are considered actors embedded in geographic concentrations of knowledge (Feldman, 1993; Jaffe et al., 1993). As these are distinct perspectives, we examine each perspective separately.

Resource-based theory (Wernerfelt, 1984) is internally focused and analyzes a firm in terms of its resources and associated capabilities, rather than its outputs. A firm's tangible and intangible resources are the ultimate source of its ability to create value (Barney, 1991). In order for these resources to create sustainable competitive advantage, however, they must be valuable, difficult to imitate, rare, and not easily substitutable (Barney, 1991). Resources that have these properties include unique physical assets, assets protected by property rights like patents, copyrights and trademarks, intangible assets like brands and reputations, and intangible internal resources like tacit knowledge. In this framework investments by corporate partners will be motivated by the desire to access the new venture's distinctive resources.

It has been recognized at least since Marshall (1920) that a firm benefits not only from the resources that it controls but also from many aspects of its geographical location. Most traditional benefits of agglomeration are related to the generation of large and active markets for specialized inputs and outputs (Porter, 1998). There has been a renewed interest in the positive externalities of agglomeration (Krugman, 1991), spurred by the conspicuous recent successes of industrial clusters in many parts of the world (Saxenian, 1996). These recent successes have largely been in knowledge intensive industries. In such industries, many additional agglomeration benefits in the form of planned and serendipitous knowledge transfers are known to occur (Jaffe et al., 1993; Zucker et al., 1998b). In this framework investments by corporate partners will be motivated by the desire to access the local networks that new ventures are embedded in.

As stated previously, firms are viewed both as bundles of resources and as actors embedded in geographic concentrations of knowledge. Corporations with capital available for investment may be attracted to alliance partners based on their resource bundles, their access to local knowledge, or both. The following section presents hypotheses focused on location-specific (e.g. government grants, university science departments, medical schools, biotechnology firms) and firm-specific (e.g. R&D, recent patents, products in the pipeline, approved products) variables.

3.1. Geographic location

Firm location is an issue of interest in many high technology industries (Almeida, 1996; Almeida and Kogut, 1997; Jaffe et al., 1993; Zacharakis et al., 2003), but no more so than in the biotechnology industry (Bartholomew, 1997; DeCarolis and Deeds, 1999; Freeman and Barley, 1990; Zucker et al., 1998a,b). This interest is largely derived from the observation that firms in technology-based industries tend to cluster in areas such as Silicon Valley and route 128 in Massachusetts (Saxenian, 1996). While research has provided an explanation for how these clusters develop (Krugman, 1991; Marshall, 1920; Pouder and St. John, 1996) and the role they play in knowledge spillovers (Feldman, 1993; Jaffe et al., 1993; Mansfield, 1991), research into the influence of geographic location on other factors such as alliance formation and capital acquisition is lacking.

According to Lucas (1993), the pace of technical progress varies over time and space. One explanation for this geographic variance in technical progress is that an area with innovative activity will develop specialized resources that are critical to the next phase of innovation. Arthur (1990) refers to this process as self-reinforcing expertise. This is a powerful explanation for why economic activity has historically been clustered in areas rich in the "atmosphere of ideas" (Marshall, 1920). Krugman (1991) notes that knowledge spillovers are another important factor in certain industries' geographic concentration. Knowledge spillovers are defined as "positive externalities of scientific discoveries on the productivity of firms which neither made the discovery nor licensed its use from the holder of the intellectual property rights" (Zucker et al., 1998a: 65). Evidence for the existence of knowledge spillovers has been provided in studies of multiple industries (Feldman, 1993; Jaffe, 1989; Jaffe et al., 1993; Mansfield, 1991) and the biotechnology industry (DeCarolis and Deeds, 1999; Zucker et al., 1998a,b). Firms' ability to produce commercially viable products depends on scientific and technical knowledge internal to the firm as well as knowledge outside firms' boundaries (Nelson and Winter, 1982). As a result, the geographic concentration of knowledge and knowledge spillovers are likely to promote innovation rates higher than those in geographic areas lacking a concentration of firms (Feldman, 1993). The level of knowledge being generated in the firm's local geographic environment has been defined as the munificence of local area's technological knowledge base (DeCarolis and Deeds, 1999). This includes knowledge generated at research institutes and universities as well as for-profit firms. It is the munificence of the local area's knowledge base that allows for increased innovation and research productivity.

In industries that rely heavily on basic science, local firms, as well as the local area's knowledge infrastructure, help to determine a geographic area's munificence. This infrastructure rests heavily on the creators of new knowledge through the process of basic science, i.e., universities and non-profit research institutions that inhabit the firm's local area. To a corporate partner, access to these specialized suppliers of new and potential ground breaking knowledge are likely to be an important motivating factor in their partnering decisions. Past research has found knowledge and spillovers that are concentrated geographically diffuse slowly to other geographic regions (Almeida, 1996; Almeida and Kogut, 1997; Jaffe et al., 1993) thus allowing local firms to benefit from knowledge spillovers to a greater degree than non-local firms. To access this location-specific knowledge firms outside of a particular geographic region will seek relationships with firms located within the particular region either through direct investment in a wholly owned subsidiary or by forming an alliance with a local firm (Saxonhouse, 1986). Therefore the munificence of the technological knowledge base in a firm's local area is likely to have a significant impact on a corporate partner's investment decision. Thus,

Hypothesis 1. A firm's location, as measured by the munificence of the applicable technological knowledge base, will be positively related to the total, domestic, and foreign alliance capital the firm receives.

3.2. Recent patents

Another measure of technological capability in the biotechnology industry is patents (Deeds et al., 1997; Shan and Song, 1997; Spalding, 1991). Patents have been associated with innovation at both the company (Ashton and Sen, 1988; Shan et al., 1994) and country (Pavitt, 1982) levels. Patents are also considered a prime determinant of biotechnology firms' ability to attract foreign direct investment (Shan and Song, 1997), capital from equity markets (Deeds et al., 1997), and capital in general (Burrill and Lee, 1993). However, if corporate partners are interested in a new venture's research skills and knowledge base, it will be recent patenting activity and not the total patent library controlled by the firm that are of interest. This is especially true in industries such as biotechnology where the rate of technical advancement is rapid. Thus,

Hypothesis 2. The number of patents granted to the firm in recent years will be positively related to the total, domestic, and foreign alliance capital the firm receives.

3.3. R&D intensity

R&D spending is a necessary input into the innovation process (Capon et al., 1992; Yeoh and Roth, 1999). Internal investments in R&D are more efficient than acquiring technology (Yeoh and Roth, 1999) because continuous R&D efforts not only are important for developing economies of experience (Porter, 1980) but also for developing absorptive capacity and the ability to recognize and assimilate knowledge spillovers from other firms (Cohen and Levinthal, 1990). This ability to exploit external knowledge is particularly important. Hence, the greater a firm's ability to exploit external knowledge, the more a firm will be able to take advantage of the local pool of knowledge in which it is embedded.

R&D investments are also a component of competitive advantage (Pavitt and Patel, 1988). Investments in R&D enhance the firm's ability to develop and exploit technological know-how (Pisano, 1990) that in turn is critical to the development of future innovations (Dierickx and Cool, 1989). While R&D intensity has typically been measured as R&D expenditures as a percentage of sales (Hansen and Hill, 1991), previous research on biotechnology firms has used R&D expenditures as a percentage of total expenditures due to the fact that these firms generally in the development stage and have little, if any, sales (Deeds et al., 1997). Thus, by helping to create unique resources and by increasing future innovative capabilities, firm R&D intensity will be a factor in attracting alliance capital from corporate partners:

Hypothesis 3. R&D expenditures as a percentage of total expenditures will be positively related to the total, domestic, and foreign alliance capital the firm receives.

3.4. Products in the pipeline

A common indicator of technological competence or expertise in the pharmaceutical industry is the number of drugs in development or in the "pipeline". Financial analysts and potential investors monitor the products being pursued (Burrill and Lee, 1994) because in industries populated by high-technology firms success may be measured by the rate at which firms develop new products (Stalk and Hout, 1990). A firm's ability to rapidly develop and commercialize new products serves to establish external visibility and legitimacy, gain early entry into chosen markets, and increases the likelihood of survival (Schoonhoven et al., 1990). The strength of a firm's product pipeline is also an important indicator of future cash flows although the exact value of any product in the pipeline is uncertain (Schoonhoven et al., 1990). The amount and type of new drugs in a firm's research pipeline reveal to potential partners the future potential value of the company's current scientific capabilities. Research examining products under development in the biotechnology industry has used both the total number of products under development (Deeds et al., 1997) and the number of products approved for sale (Yeoh and Roth, 1999; Zahra, 1996). Drug approval success is important for two reasons. First, it is a clear sign that a biotechnology firm has the capability to move a drug from the initial discovery stage to a production and marketing stage (Cool and Schendel, 1987). Second, it is critical to the development of sustained competitive advantage (Yeoh and Roth, 1999). An investigation will be made here as to the importance of products in development (stages I, II, and III combined) and products approved for sale. Thus,

Hypothesis 4a. The number of products in a firm's pipeline will be positively related to the total, domestic, and foreign alliance capital the firm receives.

Hypothesis 4b. The number of products approved for sale will be positively related to the total, domestic, and foreign alliance capital the firm receives.

3.5. Interaction of technological munificence and firm size

Comparatively little is known about the quality and future performance of small firms (Stuart, 2000). There is evidence that larger firms are more likely to survive in some form than are smaller firms (Stuart, 2000) because they do not suffer from the liability of smallness (Aldrich and Auster, 1986). External actors such as customers, suppliers, employees, and investors tend to prefer interacting with larger established firms because the reliability and ability of larger firms is well known (Hannan and Freeman, 1984; Stinchcombe, 1965; Stuart, 2000). This preference may be applicable to alliance partners as well (Stuart, 2000). Larger firms are more likely to have larger, more stable, well-established network ties within their region than smaller firms in the same region. For alliance partners, this suggests that larger firms are better positioned than smaller firms to provide access to location-specific knowledge through an alliance for an extended period of time. Under these circumstances partners seeking access to a region will likely place a higher value on an alliance with a larger firm than a smaller firm within the same region. Therefore,

Hypothesis 5. The influence of technological munificence on the total, domestic, and foreign alliance capital the firm receives is contingent on firm size, such that its influence is greater for larger firms.

4. Methods

4.1. Sample selection

The time period examined in this study is 1982–1993. The Bioscan database was used to develop a list of all public biotechnology firms as of 1993. All U.S. biotechnology firms that went public between 1983 and 1993 (total of 225) were directly contacted by one researcher. Data requested from each firm included a prospectus from the firm's initial public offering of stock, 10ks, and annual reports from each year the firm was public. The researcher received 104 usable responses (material included at least the firm's prospectus from its initial public offering of stock) corresponding to a 46% response rate. Of these 104 firms, most did not include a complete set of information (prospectus, 10ks, annual reports). Annual reports and 10ks for the 5000 largest firms traded over the counter are available from the U.S. government. This data was used where possible. Some firms in the sample were not present in this database because they were not among the 5000 largest firms traded over the counter. The final data set includes 64 firms with complete sets of data representing 28.4% of the population. Each of these firms is independent, thus allowing for the assumption that they are free to make autonomous choices and bear the risks and responsibilities of these choices. By studying firms in a single industry, differences in environmental factors are minimized and will therefore not be examined in this research.

4.2. Dependent variable

4.2.1. Alliance capital

Three related dependent variables were examined in this study. Domestic alliance capital was measured as the sum of all alliance capital received each year by the focal firm from for-profit corporate partners headquartered in the United States as reported in the annual report or 10k. Foreign alliance capital was measured as the sum of all alliance capital received each year by the focal firm from for-profit corporate partners headquartered outside the United States as reported in the annual report or 10k. Total alliance capital was measured as the sum of domestic alliance capital and foreign alliance capital. Capital received from the federal government, universities, hospitals, and other non-profit organizations and institutions were not included in these measures. Each firm's data is included for each dependent variable whether they received alliance capital or not.

4.3. Independent variables

4.3.1. R&D intensity

R&D intensity was measured by dividing R&D expenditures into total firm expenditures. Traditionally, R&D intensity has been measured as the ratio of R&D expenditures to total sales (Graves, 1988). Given the early stage of development of the firms in the sample, most firms had little if any sales so total firm expenditures were used rather than sales (Deeds et al., 1997). R&D data were collected from annual reports and 10ks for each year.

4.3.2. Recent patents

Recent patents were measured as the number of patents granted directly to the firm during the prior 3 years. The 3-year period was used to measure the firm's recent development activity, rather than an aggregated measure of the firm's total patent library. Although problems using patent data have been identified, patents are a clearly understood signal to investors concerning firms' product development and commercialization processes, and are critical in attracting investment capital (Shan and Song, 1997). Patent data were collected from the U.S. Patent and Trademark Office.

4.3.3. Products in the pipeline and drugs approved

Products in the firm's development pipeline have previously been measured as a simple count of total products under development regardless of each product's stage of development (Deeds et al., 1997). Product stage data were collected from annual reports and 10ks. Although this data was self-reported, SEC requirements on information reporting are strictly enforced and apply to all firms in this sample thus minimizing the potential for bias. Drugs approved was a measure of the total number of products approved for sale by the FDA.

4.3.4. Technological munificence

In order to capture a firm's local technological munificence (measured at the Statistical Metropolitan Area (SMA) level) we developed a factor measure based on five variables: grant value, number of grants, competitors, medical schools, and graduate science departments. While several researchers have examined cluster activity at the state level (Krugman, 1991; Shaver and Flyer, 2000), the SMA level was chosen as the boundary for cluster activity in this study for two reasons. First, prior biotechnology agglomeration studies have used this level of analysis (Audretsch and Stephan, 1996; DeCarolis and Deeds, 1999; Zucker et al., 1998a,b), which allows results to be compared across studies. Second, research has demonstrated that different regions within the same state can specialize in different technologies even within the same industry (Zacharakis et al., 2003), suggesting that state or regional levels of analysis may be too broad to effectively account for specific types of localized knowledge. Rather, SMAs allow for a more explicit link between firms and the economic activity in their region (Folta et al., 2003). The variables included in the technological munificence measure were used because each is an important contributor to knowledge development in the biotechnology industry (Freeman and Barley, 1990). NIH funding, medical schools, and graduate science departments are critical players in the ongoing developments in biotechnology. These institutions and funded projects provide access to leading edge science as well as highly trained researchers. **Grant value** was measured as the total value of National Institutes of Health (NIH) grants awarded to universities that are in the top 100 recipients in terms of dollar value of NIH grants in a given year and are located in a given firm's SMA. Data for each year was measured as the sum of the value of grants in each SMA for each year plus the preceding 8 years to account for the cumulative affect of grant-funded research. The **number of grants** was measured as the total number of NIH grants awarded to universities that are in the top 100 recipients in terms of number of NIH grants in a given year and are located in a given firm's SMA.

Data for each year was measured as the sum of the number of grants awarded in each SMA for each year plus the preceding 8 years. **Competitors** were measured as the percentage of the total population of biotechnology companies operating within each firm's SMA each year. **Medical schools** were measured as the number of the top 100 ranked medical schools in each firm's SMA each year. **Science departments** was measured as the number of universities with ranked graduate science departments (biochemistry, biology, botany, chemistry, microbiology) in each firm's SMA each year. These measures are similar to those used by DeCarolis and Deeds (1999). Results of the factor analysis are presented in Table 1. The table shows one factor with an eigenvalue of 4.0. Data for this variable were collected from the NIH, Ernst and Young's annual reports on the biotechnology industry, the National Research Council, and The Gourman Report.

4.4. Control variables

4.4.1. Firm size

When considering the impact of knowledge-based assets, it is important to control for the firm's overall asset base (DeCarolis and Deeds, 1999) as there is evidence that investors value firm size (Mudambi, 1998). Firm size was measured as the natural log of the firm's total assets and was collected from annual reports and 10ks.

4.4.2. Firm age

Past research has found no relationship between firm age and the number of alliances a firm is involved in (Shan et al., 1994). Despite this, new venture quality is difficult to establish because these ventures have a limited track record (Beatty and Ritter, 1986; Stuart et al., 1999). The age of each firm in the sample may therefore be used as a measure of operating uncertainty. Also, older firms have had a longer opportunity to develop firm-level resources similar to those of interest in this study. Firm age was measured as the age of the firm from incorporation and was collected from the firm prospectus, annual reports, and 10ks.

4.4.3. Exports

Exports were measured as the total dollar value of exports from each firm's SMA for each year. To control for other potential variables that may attract firms to a specific geographic region, the analyses included export activity because high export levels may

Table 1
Rotated factor patterns

Variables	Location
Number of NIH grants	0.91
Value of NIH grants	0.89
Number of ranked science departments	0.85
Number of ranked medical schools	0.76
Percentage of biotechnology industry	0.59
Percent of variance explained	80.15

attract firms to a geographic region in the hopes of enhancing their own export potential.

4.4.4. Foreign firms

Foreign firms were measured as the total number of foreign firms operating in each firm's SMA for each year. Past research has suggested that foreign firms may be attracted to geographic areas where other foreign firms already operate (Mitchell et al., 1994).

4.5. Model

An unbalanced panel data set relating to a significant portion of the biotech IPO firms for the period 1982–1993 was analyzed. As indicated, the study is interested in identifying the factors underlying the ability of these firms to attract capital from both alliance partners. As both firm-specific and time-specific effects are likely to be present, a panel estimation procedure was used (Chamberlain, 1982). The basic panel model may be specified as:

$$E_{it} = c_i + BX_{it} + u_{it}; \qquad t = 1,..,T. \quad i = 1,..,N. \tag{1}$$

E_{it} is the revenue raised by the firm that varies across the firms (i) and over time (t). X_{it} are the measured explanatory factors, which vary over time *and* over the firms. The symbol c_i represents the unmeasured effect associated with each firm, i.e., the firm-specific intangible factors that emerge after normalizing for firm-specific measurable characteristics like recent patenting activity, location, drug development efforts, age, etc. As can be seen, this intangible effect varies across firms, but is constant over time.

The panel model may be estimated in two different ways, depending upon the assumptions made about c_i. The first approach is to assume that each c_i is a set of parameters to be estimated. Since this approach assumes that the population value of each c_i is fixed, it is called the fixed effects approach or the fixed effects model (FEM). Formally, the FEM estimates the following specification:

$$E_{it} = c_i\mathbf{I} + BX_{it} + u_{it} \tag{2}$$

where $\mathbf{I}$ is an N-dimensional identity matrix.

The second approach is to treat the vector [$\mathbf{c}$] as a random variable with an underlying joint distribution with the other independent variables X_{it}. Since this approach assumes that each c_{ii} is a random variable, it is called the random effects approach or the random effects model (REM). Formally, the REM estimates the following specification:

$$E_{it} = c_0 + c_{1i}\mathbf{I} + BX_{it} + u_{it} = c_0 + BX_{it} + [c_{1i}\mathbf{I} + u_{it}] \tag{3}$$

where c_0 is the mean of each c_i (and functions like a single constant term), $\mathbf{I}$ is an N-dimensional identity matrix and c_{1i} is random component of each c_i. Since c_{1i} functions like another independent variable, the REM estimation takes account of the covariance between c_{1i} and the other independent variables X_{it}, to generate an agglomerated variance–covariance matrix. Effectively, the estimates generated by this procedure have variances that vary across the cross-section. Comparing (2) and (3), it may be seen that in the FEM, the firm-specific effects appear in mean capital received, whereas in the REM, these effects appear in the variance of capital raised.

4.6. Model estimation

The firm is the primary stratification variable, so that there is a 64-item unbalanced panel, with a time series of between four to eight observations in each stratum. There are a total of 368 observations in the panel. Ordinary least squares (OLS) regression provides the base-line model and null hypothesis estimates. These are generated under the OLS assumption that both firm-specific as well as time-specific effects have no statistically significant impact on capital raised, once the other variables in the estimating Eq. (1) are taken into account.

Both a fixed effects model (FEM) and a random effects model (REM) are estimated. As previously indicated, the FEM is based on the assumption that the differences between the strata are captured by different constant terms, while the REM is based on the assumption that the strata each have a different additive variance term. In other words, the FEM assumes that the strata differ in terms of their conditional means, while the REM assumes that the strata differ in terms of their conditional variances.

As the firms differ considerably in terms of alliance capital, the OLS model was tested for heteroskedasticity. The Breusch and Pagan (1979) test is passed in all cases, suggesting that the hypothesis of homoskedasticity cannot be rejected. However, using the White heteroskedasticity-consistent variance–covariance matrix improves the fit over the base-line OLS model, suggesting that the constant variance specification does not provide the best fit (White, 1980).

5. Results

Descriptive statistics and correlations are presented in Table 2. Table 2 shows that several independent variables, particular among them technological munificence, are significantly correlated with one another. Consequently, multicollinearity diagnostics were examined. The results of these analyses indicated that multicollinearity was not a significant issue as none of the variance inflation factors approached 10.0 (Hair et al., 1995). The average amount of alliance capital received by firms in our sample was \$8.25 million. Alliance capital from foreign partners averaged \$4.58 million while alliance capital from domestic partners averaged \$3.68 million. Our firms were located in SMAs with an average of 9.1 ranked university departments, 0.80 top 10 medical schools, 2212 NIH grants awarded to local universities valued at \$555 million, and 6.70% of the industry's biotechnology firms. The average location factor score for the sample firms was 8.45. The average firm in our sample had 6.14 recent patents, 5.71 products in development, and 3.42 drugs approved for sale. Our firms primarily focused on the therapeutic drug market and spent 58% of their expenditures on R&D activities.

Table 2
Correlation and descriptive statistics

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. Total alliance capital	79,972.42	597,201.05	1.00											
2. Foreign alliance capital	51,932.92	597,744.04	0.87***	1.00										
3. Domestic alliance capital	28,039.51	23,376.76	0.52***	0.07	1.00									
4. Firm age	7.53	2.89	0.07	0.02	0.11*	1.00								
5. Firm size	17.10	1.30	0.42***	0.31***	0.33***	0.16**	1.00							
6. Exports[a]	7.33	7.42	0.14**	0.21***	−0.09	0.04	0.11*	1.00						
7. Foreign firms	67.63	131.86	−0.03	0.01	−0.08	0.06	−0.02	0.63***	1.00					
8. Drugs approved	3.42	13.2	−0.07	−0.04	−0.09	0.15**	0.07	−0.12*	−0.02	1.00				
9. Technological munificence	8.45	3.07	0.25***	0.18***	0.21***	−0.07	0.28***	0.54***	0.38***	−0.36***	1.00			
10. Recent patents	3.73	6.36	0.19***	0.09	0.25***	0.49***	0.15**	0.07	0.01	−0.11*	0.16**	1.00		
11. R&D intensity	0.58	0.24	0.12*	0.04	0.17***	−0.15**	0.12*	0.04	−0.15**	−0.46***	0.33***	0.11*	1.00	
12. Total products in pipeline	5.71	13.12	−0.00	0.02	−0.04	0.20***	0.15**	−0.07	0.00	0.98***	−0.29***	−0.06	−0.42***	1.00

[a] Billions of dollars.

* $p<0.05$.

** $p<0.01$.

*** $p<0.001$.

Three sets of estimates are presented for each dependent variable—the base-line OLS estimates and two sets of panel estimates (FEM and REM). The overall estimation results that need to be discussed are the specification tests. In virtually all cases, the base-line OLS model was rejected in favor of the panel REM. The rejection of the OLS model in favor of a panel model means that firm-specific effects are important in determining the alliance capital that biotech IPOs can raise. Thus, it can be concluded that we have fairly strong evidence in favor of (intangible) firm-specific effects in alliance capital raised by biotech IPO firms.

In testing between the two panel specifications using the Hausman (1978) test, the REM was consistently preferred to the FEM. The superiority of the REM relative to the FEM means that firms differ in terms of the variance of their capital raised rather than in terms of the conditional mean amounts raised. In other words, two firms with identical measurable characteristics have the same mean level of capital raised. However, intangible firm-specific attributes cause one firm to have a greater variance associated with its level of capital raised and hence a greater uncertainty about the actual level it will achieve. If the FEM had been preferred to the REM, intangible firm-specific effects would cause two

Table 3
Regression results for total alliance capital

Regressor	OLS	Panel models	
		Fixed effects model	Random effects model
Constant	35,026.47 (1.56)	63,835.65 (0.01)	35,109.66 (1.54)
Firm age	79.67 (0.11)	5196.00 (.01)	115.31 (0.15)
Firm size	412.66 (0.20)	337.79 (0.15)	−42.94 (0.02)
Exports	-0.43×10^{-6} (1.17)	0.93×10^{-6} (1.28)	-0.21×10^{-6} (0.51)
Foreign firms	−31.24 (1.52)	−108.09 (2.72)***	−42.27 (1.88)*
Drugs approved	54.09 (0.28)	−705.60 (0.35)	68.19 (0.30)
Technological munificence	9837.08 (3.01)***	−4755.19 (0.25)	6886.94 (1.96)**
Recent patents	186.53 (0.65)	−98.13 (0.21)	175.14 (0.56)
R&D intensity	4160.07 (0.41)	28,906.39 (1.73)*	−4441.03 (0.41)
Technological munificence × firm size	695.22 (3.91)***	49.13 (0.17)	539.25 (2.83)***
Total products in pipeline	−652.09 (1.38)	−659.46 (0.99)	−423.91 (0.84)
Diagnostics			
R^2	0.1107	0.2968	0.1455
F (*df*)	4.17 (10, 245)	2.28 (84, 171)	–
Log-likelihood	−3003.0354	−2926.2142	–
Restricted log-likelihood	−3023.1722		
Sum squares	0.2316×10^{12}	0.1271×10^{12}	0.2332×10^{-12}
LM test: OLS vs. REM (p value)		$\chi^2(1)=7.29$ (0.0069)	
Hausman test: FEM vs. REM (p value)		$\chi^2(10)=15.01$ (0.1318)	

* Parameter significant at the 10% level.
** Parameter significant at the 5% level.
*** Parameter significant at the 1% level.

firms with identical measurable characteristics to have different mean levels of capital raised, though the variance of the two would be equal. Thus, in the following discussion, we focus on the REM estimates.

When total alliance capital (Table 3) is examined, technological munificence is noted as a powerful driver providing support for Hypothesis 1. The results are disaggregated by estimating separately the alliance capital received from domestic (Table 4) and foreign (Table 5) corporate partners. After disaggregating the data, the difference between domestic and foreign corporate partners becomes apparent. Technological munificence becomes a non-significant factor in the estimation of domestic alliance capital while recent patents become the principal driver in support of Hypothesis 2. Adding support to Hypothesis 1, in the estimation of foreign alliance capital, technological munificence is the primary significant variable. Thus, technological munificence seems to be of greater importance to foreign corporate partners (Table 5) while recent patents are of greater importance to domestic corporate partners (Table 4). Domestic and foreign investors appear to be looking for different characteristics when making their investment decisions. 3, 4a, and 4b were not supported. Hypothesis 5 predicted firm size and technological munificence would interact and have a positive effect on alliance capital acquisition.

Table 4
Regression results for domestic alliance capital

Regressor	OLS	Panel models	
		Fixed effects model	Random effects model
Constant	24,039.10 (1.51)	69,864.53 (0.01)	28,816.11 (1.75)*
Firm age	−12.23 (0.02)	2008.00 (0.01)	−411.49 (0.73)
Firm size	−538.06 (0.37)	−259.26 (0.16)	−838.50 (0.59)
Exports	-0.96×10^{-7} (0.36)	0.63×10^{-6} (1.22)	-0.66×10^{-8} (0.02)
Foreign firms	−7.26 (0.50)	−63.43 (2.25)**	−14.51 (0.86)
Drugs approved	141.77 (1.04)	−2107.23 (1.46)	136.30 (0.79)
Technological munificence	789.74 (0.34)	653.79 (0.05)	1278.29 (0.49)
Recent patents	508.81 (2.49)**	−99.62 (0.29)	460.63 (2.00)**
R&D intensity	1747.91 (0.25)	−14,756.24 (1.25)	834.85 (0.104)
Technological munificence × firm size	97.74 (0.77)	−212.81 (1.06)	−15.36 (0.11)
Total products in pipeline	−251.09 (0.75)	−594.44 (1.26)	−243.99 (0.66)
Diagnostics			
R^2	0.0222	0.2244	0.0605
F (*df*)	1.58 (10, 245)	1.88 (84, 171)	–
Log-likelihood	−2914.9668	−2838.5366	–
Restricted log-likelihood	−2922.9556		
Sum squares	0.1164×10^{12}	0.6408×10^{12}	0.1177×10^{12}
LM test: OLS vs. REM (p value)		$\chi^2(1)=8.49$ (0.0036)	
Hausman test: FEM vs. REM (p value)		$\chi^2(10)=9.86$ (0.4527)	

* Parameter significant at the 10% level.
** Parameter significant at the 5% level.

Table 5
Regression results for foreign alliance capital

Regressor	OLS	Panel models	
		Fixed effects model	Random effects model
Constant	10,987.36 (0.62)	13,781.54 (0.01)	7502.41 (0.41)
Firm age	91.90 (0.16)	4242.00 (0.01)	412.28 (0.68)
Firm size	950.72 (0.59)	597.05 (0.32)	762.16 (0.48)
Exports	-0.34×10^{-7} (1.16)	0.30×10^{-6} (0.51)	-0.19×10^{-6} (0.57)
Foreign firms	−23.98 (1.48)	−44.66 (1.38)	−29.68 (1.66)*
Drugs approved	−87.68 (0.57)	1401.63 (0.85)	−72.80 (0.41)
Technological munificence	9047.34 (3.51)***	4101.41 (0.27)	7665.45 (2.74)***
Recent patents	322.28 (1.41)	1.49 (0.01)	304.35 (1.23)
R&D Intensity	−5907.98 (0.74)	−14,150.14 (1.04)	−5661.27 (0.66)
Technological munificence × firm size	597.49 (4.24)***	261.94 (1.13)	526.41 (3.48)***
Total products in pipeline	−401.00 (1.07)	−65.02 (0.12)	−182.86 (0.46)
Diagnostics			
R^2	0.1044	0.2458	0.1395
F (*df*)	3.97 (10, 245)	1.99 (84, 171)	–
Log-likelihood	−2943.0647	−2874.2866	–
Restricted log-likelihood	−2962.2970		
Sum squares	0.1450×10^{12}	0.8472×10^{11}	0.1457×10^{12}
LM test: OLS vs. REM (p value)		$\chi^2(1)=3.15$ (0.0758)	
Hausman test: FEM vs. REM (p value)		$\chi^2(10)=5.57$ (0.8499)	

* Parameter significant at the 10% level.
*** Parameter significant at the 1% level.

Examining total alliance capital (Table 3), the interaction term is positive and significant in support of Hypothesis 5. Similar to the Hypothesis 1 results, the interaction term is positive and highly significant for foreign alliance capital (Table 5) but is negative and non-significant for domestic alliance capital (Table 4), thus providing more, though not complete, support for Hypothesis 5.

6. Discussion

The purpose of this study was to determine the extent to which firm- and location-specific characteristics were associated with the flow of capital from foreign and domestic corporate partners to entrepreneurial ventures. The study's findings provide significant new insights into alliance development and have important implications for the alliance, entrepreneurship, strategic management, international business, and agglomeration literatures. We found that technological munificence plays an important role in attracting alliance capital from corporate partners, especially when the venture receiving the alliance capital is more established. These results support recent work that suggested firms in industries characterized by dominant regional clusters may use alliances to access clusters to maintain strategic equality or gain knowledge necessary to develop a competitive advantage (Tallman et al., 2004).

The most interesting results are achieved when alliance capital is disaggregated into its foreign and domestic components. The amount of domestic alliance capital received is significantly influenced not by technological munificence but by the number of recent patents held by the biotechnology firm. Interestingly, other variables representing the firm's scientific capabilities (R&D intensity, products in the pipeline, approved drugs) are non-significant, suggesting that domestic firms may value access to patent portfolios more so than access to knowledge being developed through R&D, products being developed that may or may not ever be approved, or approved drugs whose revenues are likely already being dispersed to the parties holding rights to the drug. When observing foreign alliance capital, biotechnology firms' technological munificence remains a significant determinant while the significance of recent patents is lost. These results offer an important insight with regards to the different motives domestic and international firms have for developing interorganizational relationships. As previously noted, firms may enter into alliances to access their partner's knowledge for both exploration and exploitation purposes. Firms may also enter into alliances to draw upon spatially bounded, country-specific knowledge that can be used either for exploration or exploitation especially when geographic distance makes it difficult to monitor individual firm's capabilities. Our results provide evidence that domestic firms enter into alliances to access firm-specific knowledge. In each model the OLS analysis is rejected in favor of the panel REM providing evidence that firm-specific effects are important in accessing alliance capital from domestic corporate partners in support of the resource-based view of the firm (Penrose, 1959; Wernerfelt, 1984). Our findings are consistent with earlier research that has reported a positive and significant relationship between firm-specific resources and interorganizational relationships (Eisenhardt and Schoonhoven, 1996; Shan and Song, 1997). For foreign firms, our results support the conclusion that spatially bounded, location-specific activity is of particular importance (Bartholomew, 1997; Shan and Hamilton, 1991; Shan and Song, 1997), especially when the local alliance partner has some level of legitimacy. This prior research has implicitly assumed that access to country-specific advantages is constant in all areas of a country. Our results provide evidence that foreign firms actively develop relationships with biotechnology firms embedded in particular geographic locations having munificent technological environments. These results also give implicit support to research on knowledge spillovers (Feldman, 1993; Jaffe, 1989; Jaffe et al., 1993; Mansfield, 1991; Zucker et al., 1998a,b). Biotechnology firms embedded in technologically munificent areas are able to attract alliance capital from foreign firms to a greater extent than can geographically isolated firms. Our interaction results further suggest that more established firms in technologically munificent environments benefit to an even greater degree. Thus, established firms that are located in technologically munificent environments are the preferred alliance partner for foreign firms. This suggests that foreign firms are investing in access to region-specific, as opposed to country-specific advantages and provides support for Almeida's (1996) conclusion that local knowledge is more important to foreign firms than to similar domestic firms. These results also imply that at least in terms of partnering there are differential benefits to agglomeration economies based on firm size. Specifically, it appears that larger firms derive greater benefits, in terms of partnering, than smaller firms with the greatest differential benefit accruing to large firms in highly munificent locations. Therefore, in the largest agglomerations, assuming that partnering with foreign firms is important, smaller firms appear to operate at a competitive disadvantage to larger firms.

These results also provide evidence for the benefits of agglomeration economies (Pouder and St. John, 1996; Scott, 1992). In addition to qualified suppliers and skilled workers, biotechnology firms located in munificent technological environments gain access to informed investors (e.g. corporate partners) that non-local firms either do not have access to or have access to but at a higher cost. Further, access to these specialized assets supports a resource-based view of cluster development as firms within munificent technological clusters have access to specialized resources and information not available to non-local firms. While this access may not itself provide competitive advantage for firms within a particular cluster (Pouder and St. John, 1996), it would at minimum create competitive parity (Barney, 1991) and help ensure the continued development of the cluster (Porter, 1980). Non-local firms do not have access to the specialized assets within the cluster and do not benefit from the enhanced legitimacy provided to firms within the cluster. Further, non-local firms may find it difficult to maintain competitive parity with firms within the cluster (Pouder and St. John, 1996). However, as noted above our results also indicate that there exist differential benefits to agglomeration economies based on firm size, with larger firms seeing greater benefits than smaller firms. This finding is consistent with prior findings of declining benefits to new ventures from agglomeration economies (Deeds et al., 1999; Stuart and Sorenson, 2003). In fact, our results may provide some indication that these declining benefits to new ventures are due to their competitive disadvantage relative to the large firms in their local area.

Our results, while informative, leave unanswered two important questions: why do domestic firms not appear to value location-specific factors and why do foreign firms not value firm-specific factors when forming alliances? We can only speculate as to the answers to these questions but hope that future research might be informed by our suggestions. One particular factor that may explain the non-significant relationship between technological munificence and domestic alliance capital is the location domestic firms are embedded in. According to Lee and Burrill (1997) approximately 74% of biotechnology firms in the United States are located in the 10 largest biotechnology clusters. Simply put, for domestic firms, location may not play an important role in selecting alliance partners because most firms are already embedded in a technologically munificent environment thus minimizing the need to use alliances as a means to access location-specific advantages leaving only the potential partner's firm-specific knowledge as an attraction.

Conversely, foreign firms are not embedded in biotechnology environments as technologically munificent as those in the United States. According to Gittelman and Kogut (2003), colocation with research centers is a necessary requirement for success in the biotechnology industry. Thus a primary motivation for alliance formation from a foreign firm's point of view would be access to technologically munificent environments. Firm-specific factors would then likely be a secondary consideration when choosing alliance partners. In addition, lacking familiarity with the environment, foreign firms appear to place greater weight on size and stability, thus making large firms located in munificent regions the most valuable.

6.1. Limitations and managerial implications

While our research provides mixed results for the models, we acknowledge that these results may be questioned on the basis of generalizability. The biotechnology industry is obviously very unique. Despite the distinct characteristics of the biotechnology industry, the results may be generalizable for two reasons. First, basic science appears to be playing a greater role in the success or failure of individual firms (Dasgupta and David, 1994). Second, recent studies have shown that research results from the biotechnology industry are generalizable to other high technology industries such as semiconductors (Almeida, 1996). Finally, the phenomena of alliance formation and industrial clustering take place in varied industries, although the processes underlying these actions may be consistent across industries.

6.2. Future research directions

Although this research examines factors affecting firms' ability to attract foreign and domestic alliance capital, there remains a great deal of variance in the dependent variables that needs to be explained. One avenue of explanation may be investigation of top management teams' social capital. Researchers have investigated the TMT in terms of the rate of alliance formation (Eisenhardt and Schoonhoven, 1996) but little attention has been paid to the amount of capital transferred in these alliances. In high-technology industries especially, firms' boards of directors may very well play a resource dependence role in attracting capital through alliances. A second area of interest is the role of venture capitalists. Venture capital firms may sit on the boards of many biotechnology firms and may be in position to help firms they have invested in cooperate with one another. A third area of inquiry is the firm's reputation. Research has recently investigated the effects of interorganizational endorsements on the acquisition of capital from equity markets (Stuart et al., 1999). This should be extended to the acquisition of capital from alliance partners.

A final area of research concerns technological munificence. This research examined five variables related to location yet left many potential factors out of the analyses. Other organizations such as venture capital firms, equipment and biological reagent suppliers, and research institutes should also be examined for their contribution to geographic clustering in biotechnology.

7. Conclusion

Quality science and technological munificence are important factors in biotechnology firm success. Quality science is a direct input into the product development process and technological munificence provides the opportunity to benefit from knowledge spillovers. Our results provide evidence that alliance partners recognize the value of these characteristics differently. Domestic alliance partners place particular value on quality science while foreign alliance partners focus instead on technological munificence. For entrepreneurs and executives at technology-based firms our results provide some guidance. Entrepreneurs and executives need to view the choice of firm location as an important strategic decision that will have a clear impact on the firm's ability to attract much needed capital and resources. Foreign firms recognize the differences in firm location and take actions designed to maximize their access to knowledge spillovers. One of these actions is the investment in technology ventures located in technologically munificent environments. Lastly, entrepreneurs and executives need to recognize that domestic firms are interested in alliance partners that are able to demonstrate quality research efforts. Taken together, our results provide evidence that foreign and domestic firms may have significantly different motivations when selecting alliance partners.

References

Aldrich, H., Auster, E.R., 1986. Even dwarfs started small: liabilities of age and size and their strategic implications. Research in Organizational Behavior 8, 165–198.

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

Almeida, P., Kogut, B., 1997. The exploration of technological diversity and the geographic localization of innovation. Small Business Economics 9, 21–31.

Almeida, P., Kogut, B., 1999. The localization of knowledge and the mobility of engineers in regional networks. Management Science 45, 905–917.

Almeida, P., Song, J., Grant, R.M., 2002. Are firms superior to alliances and markets? An empirical test of cross-border knowledge building. Organization Science 13, 147–161.

Arthur, B.W., 1990. Positive feedbacks in the economy. Scientific American, 92–99 (February).

Ashton, W., Sen, R., 1988. Using patent information in technology business planning. Research and Technology Management, 42–59 (November).

Audretsch, D.B., Stephan, P.E., 1996. Company-scientist locational links: the case of biotechnology. American Economic Review 86, 641–652.

Barney, J., 1991. Firm resources and sustained competitive advantage. Journal of Management 17, 99–120.

Bartholomew, S., 1997. National systems of biotechnology innovation: complex interdependence in the global system. Journal of International Business Studies 28, 241–266.

Baum, L.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, 267–294.

Beatty, R., Ritter, J., 1986. Investment banking, reputation and the underpricing of initial public offerings. Journal of Financial Economics 15, 213–232.

Breusch, T., Pagan, A., 1979. A simple test for heteroskedasticity and random coefficient variation. Econometrica 47, 1287–1294.

Burrill, G.S., Lee, K.B., 1993. Biotech 93: Accelerating Commercialization. Ernst & Young, San Francisco.

Burrill, G.S., Lee, K.B., 1994. Biotech 94: Accelerating Commercialization. Ernst & Young, San Francisco.

Cantwell, J., 1991. The international agglomeration of R&D. In: Casson, M. (Ed.), Global Research Strategy and International Competitiveness. Blackwell, Oxford, U.K., pp. 104–133.

Capon, N., Farley, J.U., Lehmann, D.R., 1992. Profiles of product innovators among large U.S. manufacturers. Management Science 38, 157–169.

Chamberlain, G., 1982. Multivariate regression models for panel data. Journal of Econometrics 18, 5–46.

Chung, S., Singh, H., Lee, K., 2000. Complementarity, status similarity and social capital as drivers of alliance formation. Strategic Management Journal 21, 1–22.

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

Cool, K., Schendel, D.E., 1987. Strategic group formulation and performance: the case of the U.S. pharmaceutical industry, 1963–1982. Management Science 33, 1102–1124.

Das, S., Sen, P.K., Sengupta, S., 1998. Impact of strategic alliances on firm valuation. Academy of Management Journal 41, 27–41.

Dasgupta, P., David, P., 1994. Toward a new economics of science. Research Policy 23, 487–521.

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, 953–968.

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

Deeds, D.L., DeCarolis, D., Coombs, J.E., 1997. The impact of firm-specific capabilities on the amount of capital raised in an initial public offering: evidence from the biotechnology industry. Journal of Business Venturing 12, 31–46.

Deeds, D.L., DeCarolis, D., Coombs, J.E., 1999. Dynamic capabilities and new product developmet in high technology ventures: An empirical analysis of new biotechnology firms. Journal of Business Venturing 15, 211–229.

Dierickx, I., Cool, K., 1989. Asset stock accumulation and sustainability of competitive advantage. Management Science 35, 1504–1511.

Eisenhardt, K.M., Schoonhoven, C.B., 1996. Resources-based view of strategic alliance formation: strategic and social effects in entrepreneurial firms. Organization Science 7, 136–150.

Feldman, M.P., 1993. An examination of the geography of innovation. Industrial and Corporate Change 2, 451–470.

Folta, T.B., Cooper, A.C., Baik, Y., 2003. Returns to cluster size for biotechnology firms. Working paper, Purdue University.

Freeman, J., Barley, S.R., 1990. The strategic analysis of inter-organizational relations in biotechnology. In: Loveridge, R., Pitt, M. (Eds.), The Strategic Management of Technological Innovation. John Wiley & Sons, New York, pp. 127–156.

Gittelman, M., Kogut, B., 2003. Does good science lead to valuable knowledge? Biotechnology firms and the evolutionary logic of citation patterns. Management Science 49, 366–382.

Grant, R.M., Baden-Fuller, C., 2004. A knowledge accessing theory of strategic alliances. Journal of Management Studies 41, 61–84.

Graves, S.B., 1988. Institutional ownership and corporate R&D in the computer industry. Academy of Management Journal 31, 417–428.

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.

Gulati, R., Higgins, M.C., 2003. Which ties matter when? The contingent effects of interorganizational partnerships on IPO success. Strategic Management Journal 24, 127–144.

Haar, N.E., Starr, J., MacMillan, I.C., 1988. Informal risk capital investors: investment patterns on the East Coast of the U.S.A. Journal of Business Venturing 3, 11–29.

Hagedoorn, J., 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. Strategic Management Journal 15, 371–385.

Hagedoorn, J., Schakenraad, J., 1994. The effect of strategic technology alliances on company performance. Strategic Management Journal 15, 291–309.

Hair, J., Anderson, R., Tatham, R., Black, W., 1995. Multivariate Data Analysis. Prentice-Hall, Upper Saddle River, NJ.

Hannan, M.T., Freeman, J., 1984. Structural inertia and organizational change. American Journal of Sociology 49, 149–164.

Hansen, M.T., 1999. The search-transfer problem: the role of weak ties in sharing knowledge across organization subunits. Administrative Science Quarterly 44, 82–111.

Hansen, G.S., Hill, C.W.L., 1991. Are institutional investors myopic? A time-series study of four technology driven industries. Strategic Management Journal 12, 1–16.

Hausman, J., 1978. Specification tests in econometrics. Econometrica 46, 1251–1271.

Hitt, M.A., Nixon, R.D., Clifford, P.G., Coyne, K.P., 1999. The development and use of strategic resources. In: Hitt, M.A., Clifford, P.G., Nixon, R.D., Coyne, K.P. (Eds.), Dynamic Strategic Resources: Development, Diffusion and Integration. Wiley, Chichestershire, England, pp. 1–14.

Hitt, M.A., Dacin, M.T., Levitas, E., Arregle, J.-L., Borza, A., 2000. Partner selection in emerging and developed market contexts: resource-based and organizational learning perspectives. Academy of Management Journal 43, 449–467.

Jaffe, A.B., 1989. Real effects of academic research. American Economic Review 79, 957–970.
Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. Quarterly Journal of Economics 108, 577–598.
Koza, M.P., Lewin, A.Y., 1998. The co-evolution of strategic alliances. Organization Science 9, 255–264.
Krugman, P., 1991. Geography and Trade. MIT Press, Cambridge, MA.
Lee, K.B., Burrill, G.S., 1997. Biotech 97: Alignment. Ernst & Young, San Francisco.
Lucas Jr., R.E., 1993. Making a miracle. Econometrica 61, 251–272.
Mansfield, E., 1991. Academic research and industrial innovation. Research Policy 20, 1–12.
March, J.G., 1991. Exploration and exploitation in organizational learning. Organization Science 2, 71–87.
Marshall, A., 1920. Industry and Trade. MacMillan, London.
Mitchell, W., Shaver, J.M., Yeung, B., 1994. Foreign entrant survival and foreign market share: Canadian companies' experience in United States medical sector markets. Strategic Management Journal 15, 555–567.
Mudambi, R., 1998. The role of duration in multinational investment strategies. Journal of International Business Strategies 29, 239–262.
Nelson, R., Winter, S., 1982. An Evolutionary Theory of Economic Change. Harvard University Press, Cambridge, MA.
Nohria, N., Garcia-Pont, C., 1991. Global strategic linkages and industry structure. Strategic Management Journal 12, 105–124 (Summer Special Issue).
Parkhe, A., 1993. Strategic alliance structuring: a game theoretic and transaction cost examination of interfirm cooperation. Academy of Management Journal 36, 794–829.
Pavitt, K., 1982. R&D, patenting and innovative activities. Research Policy 11, 33–51.
Pavitt, K., Patel, P., 1988. The international distribution and determinants of technological activities. Oxford Review of Economic Policy 4 (4), 35–55.
Penrose, E., 1959. The Theory of the Growth of the Firm, 3d ed. Oxford University Press, New York.
Pisano, G.P., 1990. The R&D boundaries of the firm: an empirical analysis. Administrative Science Quarterly 35, 153–176.
Podolny, J.M., Baron, J.N., 1997. Resources and relationships: social networks and mobility in the workplace. American Sociological Review 62, 673–693.
Porter, M., 1980. Competitive Strategy. Free Press, New York.
Porter, M.E., 1998. Clusters and the new economics of competition. Harvard Business Review 76 (6), 77–90.
Pouder, R., St. John, C.H., 1996. Hot spots and blind spots: geographical clusters of firms and innovation. Academy of Management Review 21, 1192–1225.
Rosenkopf, L., Almeida, P., 2003. Overcoming local search through alliances and mobility. Management Science 49, 751–766.
Rothaermel, F.T., Deeds, D.L., 2004. Explorations and exploitation alliances in biotechnology: a system of new product development. Strategic Management Journal 25, 201–221.
Saxenian, A., 1996. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Harvard University Press, Cambridge, MA.
Saxonhouse, G., 1986. Industrial policy and factor markets: biotechnology in Japan and the United States. In: Patrick, H. (Ed.), Japan's High Technology Industries. University of Washington Press, Seattle.
Saxton, T., 1997. The effects of partner and relationship characteristics on alliance outcomes. Academy of Management Journal 40, 443–461.
Schoonhoven, C.B., Eisenhardt, K.M., Lyman, K., 1990. Speeding products to market: waiting time to first product introduction in new firms. Administrative Science Quarterly 35, 177–207.
Scott, A.J., 1992. The Roepke lecture in economic geography: the collective order of flexible product agglomerations: lessons for local economic development policy and strategic choice. Economic Geography 68, 219–233.
Shan, W., Hamilton, W., 1991. Country-specific advantage and international cooperation. Strategic Management Journal 12, 419–432.
Shan, W., Song, J., 1997. Foreign direct investment and the sourcing of technological advantage: evidence from the biotechnology industry. Journal of International Business Studies 28, 267–284.

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

Shaver, J.M., Flyer, F., 2000. Agglomeration economies, firm heterogeneity, and foreign direct investment in the United States. Strategic Management Journal 21, 1175–1193.

Shepherd, D.A., 1999. Venture capitalists' assessment of new venture survival. Management Science 45, 621–632.

Shepherd, D., Zacharakis, A., 2002. Venture capitalists' expertise: a call for research into decision aids and cognitive feedback. Journal of Business Venturing 17, 1–20.

Spalding, B., 1991. Patent patterns in biotech. Bio/technology 9, 817.

Stalk, G., Hout, T.M., 1990. Competing Against Time. Free Press, New York.

Stinchcombe, A.L., 1965. Social structure and organization. In: March, J.G. (Ed.), Handbook of Organizations. Rand-McNally, Chicago, pp. 142–193.

Stuart, T.E., 2000. Interorganizational alliances and the performance of firms: a study of growth and innovation rates in a high-technology industry. Strategic Management Journal 21, 791–811.

Stuart, T.E., Sorenson, O., 2003. The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms. Research Policy 32, 229–254.

Stuart, T.E., Hoang, H., Hybels, R.C., 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. Administrative Science Quarterly 44, 315–349.

Tallman, S., Jenkins, M., Henry, N., Pinch, S., 2004. Knowledge, clusters, and competitive advantage. Academy of Management Review 29, 258–271.

Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15, 285–305.

Tyebjee, T.T., Bruno, A.V., 1984. A model of venture capitalist investment activity. Management Science 30, 1051–1066.

Uzzi, B., 1996. The sources and consequences of embeddedness for the economic performance of organizations: the network effect. American Sociological Review 61, 674–698.

Wernerfelt, B., 1984. A resource-based view of the firm. Strategic Management Journal 5, 171–180.

Wetzel Jr., W.E., 1987. The informal venture capital market: aspects of scale and market efficiency. Journal of Business Venturing 2, 299–313.

White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica 48, 817–838.

Yeoh, P.-L., Roth, K., 1999. An empirical analysis of sustained advantage in the U.S. pharmaceutical industry: impact of firm resources and capabilities. Strategic Management Journal 20, 637–653.

Zacharakis, A.L., Shepherd, D.L., 2001. The nature of information and overconfidence on venture capitalists' decision making. Journal of Business Venturing 16, 311–332.

Zacharakis, A.L., Shepherd, D.L., Coombs, J.E., 2003. The development of venture-capital-backed internet companies: an ecosystem perspective. Journal of Business Venturing 18, 217–231.

Zahra, S.A., 1996. Technology strategy and new venture performance: a study of corporate-sponsored and independent biotechnology ventures. Journal of Business Venturing 11, 289–321.

Zucker, L.G., Darby, M.R., Armstrong, J., 1998a. Geographically localized knowledge: spillovers or markets? Economic Inquiry 36, 65–86.

Zucker, L.G., Darby, M.R., Brewer, M.B., 1998b. Intellectual human capital and the birth of U.S. biotechnology enterprises. American Economic Review 88, 290–306.