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THE EFFECT OF GENERAL AND PARTNER-SPECIFIC ALLIANCE EXPERIENCE ON JOINT R&D PROJECT PERFORMANCE

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Drawing on the organizational learning literature, we posited that both general, diverse-partner experience and partner-specific experience contribute to alliance performance, but at a declining rate. We tested hypotheses in unique data on the objective performance of projects between large pharmaceutical firms and biotechnology partners. The general alliance experience of the biotechnology partners, but not of the pharmaceutical firms, positively affected joint project performance. This relationship exhibited diminishing marginal returns. Contrary to predictions, partner-specific experience had a negative, marginally significant effect on joint project performance.

Strategic alliances are voluntary arrangements between firms to exchange and share knowledge as well as resources with the intent of developing processes, products, or services (Gulati, 1998: 293). As evidenced by their ubiquitous use in many different industries (Hagedoorn, 1993), alliances have become an important strategic tool. While alliances are used extensively, researchers have produced evidence suggesting that many, if not most, alliances do not live up to expectations or even fail altogether (Kogut, 1989). Understanding the performance of individual alliances is an important, yet underresearched, topic in strategic management.

Herein, we seek to make a theoretical as well as a methodological contribution to the understanding of alliance performance. Building on recent conceptual work that proposed the existence of an alliance management capability (Dyer & Singh, 1998; Ireland, Hitt, & Vaidyanath, 2002), we apply an organizational learning lens to outline a theory of alliance experience accumulation obtained from allying across a diverse set of partners, and from repeatedly allying with the same partner over time. Allying across a portfolio of partners leads to general alliance experience obtained from the breadth of a firm's alliance activity, while allying within the same dyad deepens partner-specific learning. We suggest that the relationship between alliance experience and alliance performance follows an experience curve, and is therefore positive, but characterized by diminishing marginal returns.

Empirical work investigating the performance of individual alliances is scarce, largely because of methodological barriers (Anderson, 1990; Gulati, 1998). The longevity of alliances has been used as a proxy for their performance (Barkema, Shenkar, Vermeulen, & Bell, 1997; Harrigan, 1986), as have perceptual measures obtained from one of the partners in a given alliance (Parkhe, 1993; Zollo, Reuer, & Singh, 2002). Others have equated alliance performance to the reaction of the stock market to alliance announcements (Anand & Khanna, 2000). And although alliance performance is a *joint outcome,* it has not been linked to characteristics of all the partners involved in an alliance.

In light of these barriers, in this study we sought to link the performance of collaborative R&D projects in the pharmaceutical industry to firms' general and partner-specific R&D alliance experience. By examining *project-level* new drug development outcomes between established pharmaceutical companies and their biotechnology partners, we introduced a performance outcome that was causally proximal to alliance experience. From an

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empirical standpoint, the performance of R&D alliances remains largely unexplored (Osborn & Hagedoorn, 1997). From a managerial perspective, determining whether alliance experience does lead to tangible and measurable benefits can provide insight into whether and how firms should go about building an alliance management capability.

THEORY AND HYPOTHESES

General Alliance Experience and Alliance Performance

We focus on how firms *learn to manage alliances* from alliance experience rather than on how firms *learn from alliances,* through transferring capabilities, for example (Simonin, 1997). Drawing on the organizational learning literature (Levitt & March, 1988), we argue that firms learn how to manage alliances through repeated engagements in these hybrid organizational forms with diverse partners. Lieberman (1984), for example, documented in a study of the chemical industry that prices fell with cumulative output; time effects were controlled for in the study. Thus, learning effects appear to be the key explanatory variable underlying the experience curve (Dutton & Thomas, 1984). More recently, researchers have emphasized that performance does not improve automatically as experience accumulates, but rather, improves as the outcome of organizational learning, which is posited to differ systematically across organizations (Pisano, Bohmer, & Edmondson, 2001).

Organizational learning occurs in an iterative fashion when firms engage repeatedly in an activity, draw inferences from their experiences, and store and retrieve the inferred learning for future engagements in the activity (Levitt & March, 1988). Inferences from past experiences might be encoded in routines, which are activated when certain stimuli are present (Nelson & Winter, 1982). Routines and superior management capabilities that result from experience are of particular interest, since they constitute the kinds of intangible resources more likely to be the source of performance improvements in future alliances (Barney, 1991).

The more complex an activity, the more significant the learning potential, but the more difficult to harness the learning (Levitt & March, 1988). This relationship maintains because acquired knowledge must first be transformed into applicable knowledge. Knowledge acquisition requires the specialization of individuals in clearly defined areas, whereas the application of new knowledge demands the integration of diverse sources of specialized knowledge (Demsetz, 1991). Knowledge integration is often made more difficult by the fact that the acquired knowledge tends to be tacit, but knowledge generally has to be explicit to be exploited effectively (Nonaka, 1994).

In the alliance context, tools, metrics, and dedicated personnel are common mechanisms to integrate knowledge acquisition and knowledge application (Kale, Dyer, & Singh, 2002). A firm's knowledge of managing alliances may be embodied in manuals, databases, diagnostic tools, and simulations that codify the key insights gained through reflection on past alliance experiences. Such tools may aid the firm in assessing current alliance performance and guide it in selecting appropriate future alliance partners.

Experience may also result in new intra- and interorganizational routines that facilitate internal coordination. New organizational structures that are charged with developing a firm's alliance capabilities can aid knowledge codification and facilitate cooperation over functional areas within the firm. The locus of this learning process can be the development of experience among dedicated alliance managers. Some firms have recently begun to institutionalize alliance experience to enhance alliance performance. For example, Eli Lilly established an Office of Alliance Management in late 1999 and views this dedicated alliance function as an "integrator, intermediary and catalyst for best practice performance" (Gueth, Sims, & Harrison, 2001: 4). In general, firms with prior alliance experience are more likely to establish a dedicated alliance function, which contributes to improved alliance performance as assessed by both managerial perception and stock market response (Kale et al., 2002).

Hypothesis 1a. The effect of a firm's general alliance experience on subsequent alliance performance is positive.

Although some prior empirical work has found evidence for a positive linear relationship between alliance experience and more aggregated performance measures like firm-level patenting (Shan, Walker, & Kogut, 1994) or stock market responses (Anand & Khanna, 2000), we suggest that the relationship between alliance experience and alliance performance may not be linearly positive, but rather may exhibit diminishing marginal returns. This formulation implies that early alliance experiences allow for significant learning, which tapers off in subsequent alliance experiences, thereby contributing progressively less to an alliance capability. Empirical research on factors underlying the experience curve has documented that learning does indeed taper off and, in fact, does so fairly rapidly (Lieberman, 1984). Moreover, knowledge accumulated through experience has also been

shown to depreciate over time (Darr, Argote, & Epple, 1995).

The effect of alliance experience on alliance performance may follow the principle of diminishing marginal returns for a number of other reasons. Firms tend to enter the most promising alliances first, and doing this may limit their alliance opportunities with other potential partners (Deeds & Hill, 1996; Silverman & Baum, 2002), thereby leading to poorer outcomes in subsequent alliance activity. The difficulty of selecting the next best alliance is likely to be more pronounced when intangible resources like tacit knowledge form the foundation of a collaboration, as it is frequently the case in R&D alliances.

Moreover, once firms have developed and established routines, policies, and procedures based on a certain set of early alliance experiences, they may become trapped by this competency (Levitt & March, 1988) through a continued focus on similar alliance experiences that allow for little or no additional learning (Sampson, 2002). When the continued reliance on established routines and procedures curtails new learning, a firm's focus on exploitation crowds out necessary exploration (Levinthal & March, 1993), and an alliance management capability may turn into a core rigidity (Leonard-Barton, 1992). Choosing alliance partners, for example, that are similar to those of past alliances restricts variation in alliance experience and thus reduces organizational learning. Even entering alliances with new partners may not allow for significant new learning since there are also limits to what can be learned through experience (Simonin, 1997).

Given that alliance relationships often last several years, firms generally engage in multiple alliances concurrently. Thus, limits to a firm's alliance management capability may also contribute to diminishing returns to alliance experience. Generally, firms face limited financial and, more importantly, limited managerial resources. Simultaneously managing multiple alliances will eventually accentuate the cognitive limitations of managers (Simon, 1947), even those specifically trained to oversee a firm's network of relationships. Prior research has provided empirical support for cognitive limits to managerial capabilities when documenting diminishing effects of internationalization on the speed of technological learning and firm performance (Hitt, Hoskisson, & Kim, 1997; Zahra, Ireland, & Hitt, 2000). Similarly, the cognitive limits of alliance managers may result in inferior partner selection and alliance management, thus decreasing returns from alliance experience.

Hypothesis 1b. The effect of a firm's general alliance experience on subsequent alliance performance exhibits diminishing marginal returns: as general alliance experience increases, its contribution to alliance performance decreases.

Partner-Specific Alliance Experience and Alliance Performance

We argued that general alliance experience is derived from a portfolio of alliances with diverse partners. However, a portion of the knowledge and skills that accumulate from repeated allying over time may also be partner-specific. As such, alliance experience may be as much a dyadic construct as it is a firm-level one. Lane and Lubatkin (1998) provided support for a dyadic perspective in organizational learning by documenting that the ability of firms to learn from one another in an alliance depended on the similarity between the two firm's knowledge bases, organizational structures, and dominant logics. While we concentrate on how firms learn to manage alliances rather than on how firms learn from alliances, a focus on the dyad as the unit of analysis is important for disentangling the effect of alliance experience on alliance performance.

Through recurrent allying over time, dyadic alliance partners may be induced to invest in interfirm relation-specific assets that reduce transaction costs and thus increase value created (Dyer & Singh, 1998). The refinement of partner-specific interfaces and the development of partner-specific decision making as well as conflict resolution routines should enhance subsequent alliance performance. Moreover, learning accumulated through partner-specific alliance experience may lead to the emergence of dyadic interorganizational routines, characterized by stable interaction patterns among the two partners, that can facilitate the development of interfirm knowledge-sharing routines (Zollo et al., 2002). Interfirm knowledge-sharing routines lay the foundation for partner-specific absorptive capacity that enables alliance partners to recognize valuable knowledge and effectively transfer it across interfirm boundaries (Dyer & Singh, 1998).

Hypothesis 2a. The effect of partner-specific alliance experience on subsequent alliance performance is positive.

Just as we have argued that returns to an entire portfolio of alliances will diminish, we also posit that additional ties with the same partner will contribute progressively less to partner-specific alliance experience. Not only are the alliance opportunities between two firms limited, but also,

additional alliances with the same partner beyond the first few may also provide diminishing returns in terms of complementarities or learning. Indeed, additional alliances with the same partner may provide only redundant information (Gulati, 1995) and can also lead to inertia at the dyad level. Competency traps occur at the dyad level when the two partners continue to rely on established partnering routines, and thus restrict variation in their subsequent alliance experiences (Levinthal & March, 1993). Prior empricial work has demonstrated that group-level tacit knowledge accumulated over time exhibits diminishing returns owing to knowledge ossification (Berman, Down, & Hill, 2002). Moreover, two alliance partners may become complacent about how joint projects are managed once an initial routine has been developed and put in place. When studying shared experience in R&D teams, Katz (1982) found that team tenure yielded diminishing returns to team performance. This complacency effect may even be accentuated when the environmental demands on the alliance partners change owing to technological progress or regulatory changes (Miller & Shamsie, 1996).

Hypothesis 2b. The effect of partner-specific alliance experience on subsequent alliance performance exhibits diminishing marginal returns: as partner-specific alliance experience increases, its contribution to alliance performance decreases.

METHODS

Gulati concluded in his review of the alliance literature that, owing to a number of formidable empirical challenges, "the performance of alliances remains one of the most interesting and also one of the most vexing questions" (1998: 309). Surveys, where performance information is generally obtained from only one partner in an alliance (Parkhe, 1993; Zollo et al., 2002), and case studies (Doz, 1996) remain the principal methods for studying alliance performance. We stepped into this fray with a study that was designed with the methodological challenges in mind. Our data were dyadic and yielded proxies for different kinds of alliance experience. We related their effect to an objective outcome measure obtained from a large number of alliances over time. In particular, we first assessed the effect of each partner's *general alliance experience* on the performance of *project-level* new drug development collaborations, and second, we assessed the effect of each partner's *partner-specific alliance experience* on such project-level performance. We considered a collaborative drug development project successful if its product completed the regulatory drug approval processes imposed by the U.S. Food and Drug Administration (FDA) and/or by the European Medicines Evaluation Agency (EMEA) and subsequently received endorsement for sale.[1]

Research Setting

The dyads in our study consisted of alliances between pharmaceutical companies and their biotechnology partners. Traditional pharmaceutical companies like Novartis or Pfizer were established under the technological paradigm of chemical screening and are attempting to adapt to the emergence of biotechnology, which began with recombinant DNA technology, a scientific breakthrough that was accomplished in 1973.[2] The new biotechnology is a process innovation that is destructive to the competence of established pharmaceutical companies in discovering and developing new drugs (Stuart, Hoang, & Hybels, 1999). Alliances with new biotechnology firms are one way for pharmaceutical companies to adapt to the new biotechnology (Hill & Rothaermel, 2003).

We focused on bilateral dyadic R&D alliances based on formal interfirm agreements; data are more readily available for these formal alliances than they are for informal collaborations (like handshake deals).[3] Moreover, a focus on bilateral dyadic relationships rather than on strategic networks is appropriate since this industry generally does not exhibit alliance blocks, as do the automobile or airline industries.

Sample and Data

In a first step toward creating a dyadic database, we identified all pharmaceutical companies active globally in biotechnology as of 1980 through studying SIC listings and a variety of industry publica-

[1] In our sample, about 80 percent of the marketed drugs were approved for sale in the United States before or at the same time as they were approved in Europe. This pattern is consistent with that in the global pharmaceutical industry.

[2] A second path-breaking discovery, hybridoma technology, which allows the creation of monoclonal antibodies, was accomplished in 1975.

[3] Examples of prevalent informal cooperations include collaborations among scientists on exploratory research. Scientists are not only employees of their respective companies, but also part of the global scientific community (Zucker, Darby, & Armstrong, 2002).

tions.[4] While the emergence of biotechnology is traced back to scientific breakthroughs in the mid-1970s, the year 1980 marks the beginning of extensive interfirm cooperation in biotechnology owing to three important events (Stuart et al. 1999: 323): (1) the decision by the Supreme Court that new life forms could be patented, (2) the passage of the Patent and Trademark Act, which allowed universities to patent discoveries funded with federal dollars, and (3) the successful initial public offering of Genentech, the first public biotechnology firm. For the first year of our study period, 1980, our sample was composed of 43 pharmaceutical firms globally. This number is consistent with the oligopolistic industry structure of the global pharmaceutical industry, which is dominated by a few large companies that are active in proprietary drug discovery and development.

The industry became more concentrated over the 21-year period we studied. Consolidation reduced the number of distinctive pharmaceutical firms in our sample from 43 to 30 as of 2000. We accounted for an acquisition or merger by combining the alliance and patent data of the relevant firms, creating a comprehensive "family tree" linking all companies in existence as of 2000 back to their various "ancestors" alive in 1980.[5]

In a second step, we found all collaborative biotechnology projects that these pharmaceutical firms had initiated between 1980 and 1998. These data were obtained from Lifecycle, a proprietary database maintained by IMS Health, a pharmaceutical industry research firm. Lifecycle is commercially available and provides fine-grained data on R&D projects for a large number of pharmaceutical firms. IMS Health collects information globally from governmental agencies, industry conferences, patents and scientific publications, and contacts with scientists and managers within focal firms. Lifecycle allows researchers to identify biotechnology-based projects. But to ensure the accuracy of the data and to prepare them for statistical analysis, we had these data coded by a researcher on our team who held a medical degree. This process yielded 292 collaborative biotechnology projects in which 30 distinct pharmaceutical companies cooperated with 145 different, independent biotechnology partners during our study period, 1980–2000.

To gather information on alliance experience for both the pharmaceutical and the biotechnology partner over time, we linked the Lifecycle data to alliance information obtained from various volumes of *BioScan,* an industry publication, and from a database from Recombinant Capital, a consulting firm specializing in the life sciences. *BioScan* and the Recombinant Capital database appear to be the two most comprehensive publicly available data sources documenting alliance activity in the global biotechnology industry. Both sources are fairly consistent and accurate in reporting alliances (their intersource reliability was greater than 0.90). These sources catalogued alliance activity over the time period of our study and also included alliances initiated in the 1970s, thus allowing us to create lagged alliance experience measures.

Finally, we obtained data on patents assigned by the U.S. Patent and Trademark Office (USPTO) from 1975 onwards. We focused on patents obtained in the United States since it represents the largest market for biotechnology worldwide, and thus firms generally patent first in the U.S. In addition, firms active in biotechnology have a strong incentive to patent since intellectual property protection has been held up consistently in court and patenting is considered to be an essential activity.

Variables and Measures

Our dependent variable, *project success,* was binary, with 1 indicating successful completion of a new drug development project resulting in an FDA- and/or EMEA-approved, marketable new drug. This variable captured both the research *and* the development activities necessary to commercialize a new drug and thus appeared to be an appropriate proxy for joint R&D project success. Although we covered a lengthy time period in this study to ensure sufficient numbers of successes and failures, not all projects were completed by the end of our study period, because the new product development process in the pharmaceutical industry is protracted. Projects that were still in a preclinical stage

[4] We drew on BioScan, *Burrill & Company Life Sciences Annual Industry Reports, Ernst & Young's Annual Biotech Industry Reports, IMS Health Global Pharma Industry Reports,* and *Scrip's Yearbooks on the Global Pharmaceutical Industry,* among others.

[5] For example, two firms in the starting sample, Upjohn and Pharmacia, merged in 1995. In our analyses, the resulting organization was given the combined alliance and patent data of both companies, and we updated data using the organization's new identity. To assess whether this procedure affected our results, we created an indicator variable coded 1 for a firm that had merged with or acquired another firm. This variable was not significant in explaining collaborative R&D performance.

or in phase I, II, or III clinical trials[6] as of 2000 were not included in the final analysis. Out of the initial 292 joint projects considered, 63 projects had been successfully completed and 95 had been discontinued (failed) by 2000, leaving a final sample of 158 projects (54 percent) for which an unequivocal outcome measure was available.[7] As our dependent variable was binary, we applied a logistic regression model estimating how general and partner-specific alliance experience affected the probability of a joint R&D project's success.

Drawing data from our alliance database, as a proxy for *general alliance experience* we used the number of R&D alliances each firm in a dyad had entered up to the year prior to the start of the focal biotechnology collaboration. We measured general alliance experience for both the pharmaceutical and the biotech partner, creating two variables *(alliance experience, pharmaceutical,* and *alliance experience, biotechnology)*. The two variables allowed us to test the effect of general alliance experience of each firm in each project while controlling for the firm's partner's alliance experience. Our measure of partner-specific alliance experience, called d*yad alliance experience,* was the number of prior R&D alliances between the pair of firms in a focal dyad. We excluded those alliances that would be counted as partner-specific alliance experience from the general alliance experience measure, to ensure the independence of the two experience measures. We centered the resulting variables to reduce the potential threat of collinearity (Aiken & West, 1991). We then squared the centered variables to test the argument that the effect of alliance experience on alliance performance exhibits diminishing marginal returns *(alliance experience, pharmaceutical, squared* and *alliance experience, biotechnology, squared)*.

To control for firm- and project-level confounding factors that might explain joint project-level performance, we included a number of variables based on past research (Henderson & Cockburn, 1994) and our discussions with IMS Health and other industry experts. We controlled for the year in which a project was initiated *(project year)*. Given a system of clinical trials divided into different phases, successful projects take longer to emerge. We also tested if the number of indications or disease states that a drug could target affected its likelihood of success *(indications)*. If a new drug has several indications, it is affecting the biological process or the molecule that is common among those indications.[8] Multiple indications that share underlying mechanisms or a target molecule can draw on a greater number of research models for testing and allow for greater knowledge transfer across the indications, thereby increasing the chances for a successful new product.

We also noted whether a project was protected under a U.S. and/or European patent (*patent protection,* coded 1 when a patent existed), since a patent-protected project is viewed as potentially more valuable and thus attracts more resources and managerial attention. We also discriminated between alliances that were initiated in the exploration stage prior to clinical trials and those alliances that were initiated during clinical trials (*exploration stage,* coded 1 when that was the time of initiation). Early-stage projects are less likely to reach commercialization. To assess differences in firm R&D quality, we included each partner's number of past successes in prior joint biotechnology drug development projects *(past successes, pharmaceutical,* and *past successes, biotechnology)*. These variables allowed us to estimate the probability of current joint project success while controlling for past successes.

We also controlled for the firms' technological competency in the new biotechnology area through

[6] The drug discovery process can be broken down into distinct sequential stages (Giovannetti & Morrison, 2000: 46-47). A leading drug candidate is developed in the preclinical stage. Subsequently, the FDA imposes increasingly stringent tests evaluating the efficacy and risk profile of the drug candidate. In phase I, the drug is administered to 20–30 healthy volunteers to evaluate its safety and dosage. In phase II, the drug is administered to 100–300 patient volunteers to assess efficacy and side effects. In phase III, the drug is administered to 1,000–5,000 patient volunteers to monitor reactions to long-term drug usage. The FDA will consider a drug for market approval after it completed all three phases of clinical trials successfully.

[7] A comparison of the means between the final sample and the projects that were still ongoing showed little evidence of systematic differences. When contrasted on the independent variables from our model in post hoc tests, the two groups had only these differences: continuing projects were less likely to be between firms that had prior alliances, and continuing projects were slightly more likely to be protected by patents.

[8] For example, rheumatoid arthritis, Crohn's disease, and HIV infection are listed as indications for a successful project in our sample resulting in the drug Infliximab, which was discovered by the biotechnology firm MedImmune and developed by the pharmaceutical company Johnson & Johnson, which now markets this new biotechnology drug under its commercial name Remicade. The therapeutic action of this drug is to affect TNFa, which plays a role in the origination and development of these diverse diseases.

TABLE 1
Descriptive Statistics and Bivariate Correlations

Variable	Mean	s.d.	Minimum	Maximum	1	2	3	4	5	6	7	8	9	10	11
1. Project success	0.39	0.49	0.00	1.00											
2. Project year	1991	3.53	1980	1998	−.45***										
3. Indications	1.56	0.95	1.00	5.00	.28***	−.10									
4. Patent protection	0.42	0.50	0.00	1.00	.73***	−.32***	.14								
5. Exploration stage	0.44	0.50	0.00	1.00	−.46***	.28***	−.12	−.35***							
6. Past successes, pharmaceutical	1.95	2.70	0.00	13.00	.12	.14	.14	.14	−.12						
7. Past successes, biotechnology	0.49	1.12	0.00	5.00	−.01	.13	.05	−.03	−.13	.25**					
8. Weighted patents, pharmaceutical	1,689.23	1,828.01	0.00	7,602.43	.14	−.09	.01	.14	−.17*	.41***	−.04				
9. Weighted patents biotechnology	335.59	1,081.95	0.00	6,241.63	.15	−.18*	.01	.13	−.03	.08	.01	.20**			
10. Alliance experience, pharmaceutical	21.61	18.93	0.00	100.00	.19*	.01	−.02	.18*	−.23**	.22**	.03	.53***	.29***		
11. Alliance experience, biotechnology	6.31	11.02	0.00	58.00	.16*	−.17*	−.06	.07	−.03	.04	.04	.19*	.56***	.26***	
12. Dyad alliance experience	0.59	1.34	0.00	10.00	−.12	.09	−.08	−.16*	.00	.15*	.47***	.07	.07	.05	.25**

$n = 158$.
* $p < .05$
** $p < .01$
*** $p < .001$

TABLE 2
Results of Logistic Regression Analysis Predicting Joint R&D Project Success[a]

Variable	Model 1		Model 2	
Intercept	588.97**	(206.78)	749.38***	(245.94)
Project year	−0.30**	(0.10)	−0.38***	(0.12)
Indications	0.74**	(0.30)	0.96***	(0.35)
Patent protection	3.89**	(0.65)	4.22***	(0.78)
Exploration stage	−1.77**	(0.63)	−1.51**	(0.66)
Past successes, pharmaceutical	0.06	(0.12)	0.08	(0.14)
Past successes, biotechnology	−0.10	(0.29)	−0.23	(0.36)
Weighted patents, pharmaceutical	−1.36E-4	(2.02E-4)	−1.78E-4	(2.37E-4)
Weighted patents, biotechnology	2.23E-4	(2.99E-4)	−3.33E-4	(3.92E-4)
Alliance experience, pharmaceutical			0.02	(0.03)
Alliance experience, pharmaceutical, squared			6.00E-4	(07.35E-4)
Alliance experience, biotechnology			0.15*	(0.09)
Alliance experience, biotechnology, squared			−3.70E-3†	(2.70E-3)
Dyad alliance experience			0.52	(0.68)
Dyad alliance experience			0.41†	(0.32)
χ^2	127.19***		135.93***	
Log-likelihood	−42.23		−37.86	
Pseudo R^2	.60		.64	

[a] Standard errors are in parentheses.
† $p < .10$
* $p < .05$
** $p < .01$
*** $p < .001$

examining patent data. We obtained patent counts for both firms in each partnership and updated them yearly.[9] We weighted each patent by the number of subsequent patent citations received to capture underlying patent portfolio quality (Trajtenberg, 1990). We then calculated a cumulative variable for each firm in a dyad by adding annual weighted patent counts up to the year before the initiation of a focal joint project *(weighted patents, pharmaceutical,* and *weighted patents, biotechnology)*.

RESULTS

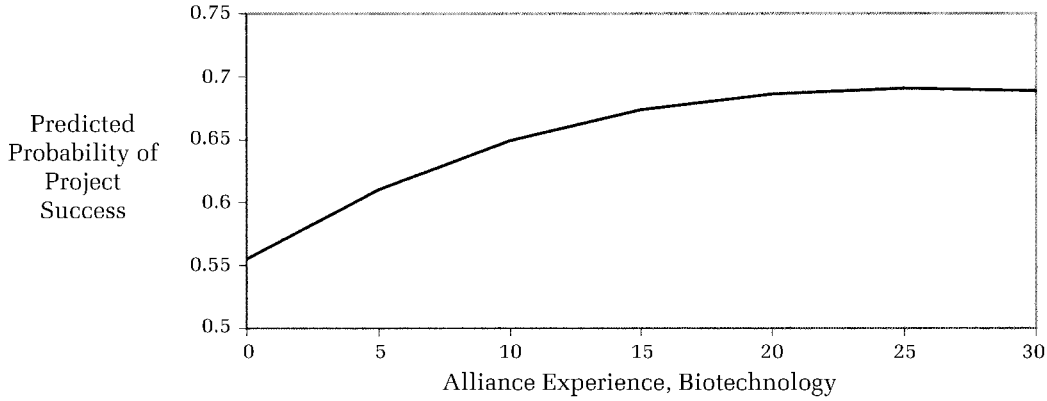
The average pharmaceutical company in our sample had entered 22 alliances, and the average biotechnology partner had formed 6 alliances. About 60 percent of all pharmaceutical-biotechnology pairs had engaged in at least one R&D collaboration prior to the current one under investigation. The average pharmaceutical company had engaged in about two successful past projects, whereas every second biotechnology partner had done one past successful project. The large pharmaceutical firms produced on the average five times more patents than their small biotechnology counterparts. The average project targeted more than one disease category. A little more than 40 percent of the projects were protected under patents. About 45 percent of the projects were initiated in the exploration stage. The average joint R&D project was ten years in the development process.

Table 1 depicts the descriptive statistics and bivariate correlation matrix, while Table 2 shows the regression analysis results. Model 1 contains the control variables only, serving as our baseline model. We show our evaluation of hypotheses in model 2, the full specification, which includes the linear and squared terms of each partner's general alliance experience as well as the linear and squared terms of partner-specific alliance experience. To assess the potential threat of collinearity, we estimated the variance inflation factors and found none greater than 7, so these values were below the recommended ceiling of 10 (Kleinbaum, Kupper, & Muller, 1988).

Hypothesis 1a predicts that a firm's general alliance experience has a positive impact on alliance performance, and Hypothesis 1b suggests that this relationship is characterized by diminishing marginal returns. The results displayed in model 2 indicate that the general alliance experience of an

[9] Because pharmaceutical firms patent in more diverse areas than biotechnology firms, we tried to eliminate unnecessary noise in our measure by focusing on technological areas in which biotechnology patents were emerging, such as U.S. patent class 435, Chemistry: Molecular Biology and Microbiology.

FIGURE 1
Effect of Biotechnology Alliance Experience on Project Success



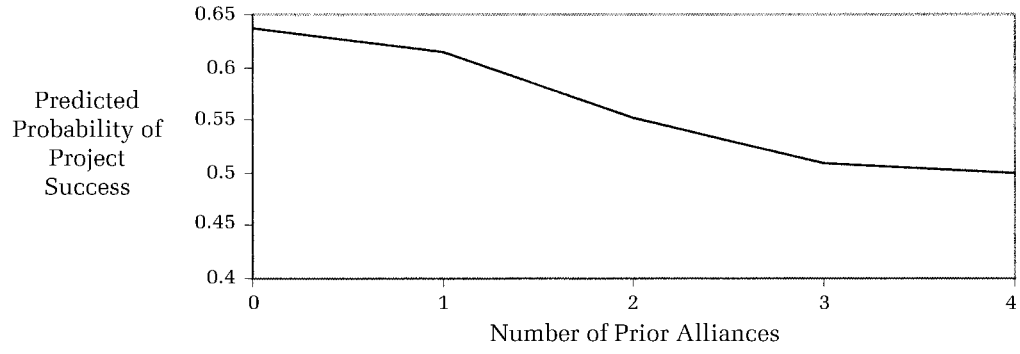
alliance's pharmaceutical partner does not appear to affect joint R&D project success, while the general alliance experience of the biotechnology partner does affect joint R&D project success. The linear coefficient of general alliance experience, biotechnology, is positive and significant ($p < .05$), providing partial support for Hypothesis 1a, as it holds for one of the partners in the focal dyad. The squared term of the biotech partner's general alliance experience is marginally significant and negative ($p < .10$).

Some scholars have highlighted the difficulty of detecting significant interaction effects at the traditional 95 percent significance level when an underlying relationship is hypothesized to be nonlinear (Jaccard, Wan, & Turrisi, 1990). Cohen, Cohen, West, and Aiken pointed to the problem of insufficient statistical power in attempts to detect interaction effects and recommended that "the research plan may be revised in ways that will increase [statistical power], primarily by increasing *n*, or increasing the number or level of variability in the independent variables, or possibly, by increasing alpha" (2003: 52 & 297). Although we were unable to increase the sample or to increase the number or variability in the independent variables, we submit that an increased alpha is appropriate when evaluating the significance of the squared terms in our moderated regressions. This increase would allow us to claim marginal support for Hypothesis 1b.

To determine the net effect of alliance experience, we took the coefficients obtained from model 2 and plotted the predicted probabilities of project success against biotech alliance experience, with all other variables evaluated at their mean value. Figure 1 indicates that a biotechnology firm's prior general alliance experience has a positive, but diminishing, impact on the probability that a joint pharmaceutical-biotechnology R&D project will succeed. Meaningful increases appear to be had only within two standard deviations above the mean value for general alliance experience.

At the dyad level of analysis, we postulate in Hypotheses 2a and 2b that the effect of partner-specific alliance experience on alliance performance is positive, but its contribution decreases as partner-specific alliance experience increases. Our results contradict our predictions: the linear coef-

FIGURE 2
Effect of Dyad-Specific Alliance Experience on Project Success



ficient of partner-specific alliance experience is not significant, and the squared term is negative and marginally significant ($p < .10$). Figure 2 plots the relationship between partner-specific alliance experience and joint R&D project success and shows that as partner-specific alliance experience increases, the probability of joint R&D project success decreases, asymtoptically approaching its minimum within two standard deviations of the mean.

Our findings also show that a number of project-level control variables were significant predictors of joint project success. The later a project was initiated in our study period, the lower its probability of successful completion, because new drug development is such a protracted process. Also as expected, the greater the number of indications (medical problems) a project targeted, the higher its probability of success. Moreover, projects that resulted from patent-protected intellectual property were also more likely to succeed. Finally, as anticipated, projects that were initiated prior to clinical trials were less likely to result in marketable drugs.

DISCUSSION

Drawing on the organizational learning literature, we contribute to a theoretical understanding of alliance experience effects on alliance performance with the following insight: when the multiple sources of alliance experience are disentangled, the relationship between alliance experience and performance is complex and appears to be nonlinear. We differentiated between learning to manage alliances by accumulating experience *across* multiple partners (general alliance experience) and learning to manage alliances by accumulating experience *within* a dyadic relationship, through recurring alliances with a single partner (partner-specific alliance experience). More broadly, general alliance experience reflected the breadth of a firm's knowledge search when it attempted to improve alliance peformance, while partner-specific alliance experience reflected the depths of knowledge search within a given dyad (Katila & Ahuja, 2002). We then tested whether firms obtained tangible performance benefits from their general and partner-specific alliance experience. Specifically, we examined whether biotechnology drug development projects between pharmaceutical companies and their biotechnology counterparts were affected by each of the partners' alliance experience as well as by their joint dyadic alliance experience.

Our results underscore the complexity of the relationship between experience and performance. We found that only the general alliance experience of the biotechnology partner in an alliance mattered in explaining joint project success, when controlling for the general alliance experience of the pharmaceutical firm. Moreover, we found some evidence that there are diminishing returns to general alliance experience: prior general alliance experience has a positive effect on the likelihood of alliance success that decreases as alliance experience increases. Our results also suggest that partner-specific alliance experience may decrease alliance performance.

One way to interpret the pattern of our results is to argue that the large pharmaceutical firms we studied are already "further down the learning curve" owing to their extensive prior experience in alliances.[10] This idea would imply that our alliance experience measure might not be fine-grained enough to pick up a movement downwards along the flatter part of the learning-to-do-alliances curve. Indeed, our data lend credence to this interpretation since the large pharmaceutical firms entered on average three and a half times as many alliances as their biotech counterparts over our lengthy study period. Moreover, the pharmaceutical companies as a group are more homogeneous in their alliance experience.[11]

Yet results obtained from post hoc analysis in combination with input received from industry experts appeared to point to the difficulties for the large pharmaceuticals in leveraging their alliance experience.[12] This interpretation resonates with the fact that large pharmaceuticals have just recently begun to create distinct organizational configurations based on structures, processes, and routines that leverage and support their alliance activities. For example, Eli Lilly's Office of Alliance Management was not fully functioning until 2000, when its staffing was completed. Many other pharmaceutical companies have lagged behind Lilly's organizational innovation since Lilly is consid-

[10] We thank an anonymous reviewer for bringing this interpretation to our attention.

[11] The pharmaceutical companies' coefficient of variance is only one half of that for the biotechnology firms (88% vs. 175%).

[12] To assess the possibility of capabilities transfer from the biotechnology firms to the pharmaceutical companies, we examined the effect of the pharmaceutical companies' prior R&D alliance experience in biotechnology on R&D projects that the pharmaceutical firms undertook alone. There were 94 solo pharmaceutical firm projects with clear (14) successes and (80) failures. We found that the pharmaceutical firms' alliance experience was not significant in predicting project success, and thus a capability transfer from the biotechs to the pharmaceuticals did not seem to take place.

ered a leader in alliance management in the pharmaceutical industry (PriceWaterhouseCoopers, 2000).

This latter interpretation of our results suggests that the benefits of alliance experience are not automatic but instead depend on the extent to which organizations can actively mobilize and leverage their experience. It appears that to reap benefits from prior alliance experience, a firm needs to possess absorptive capacity, the potential capacity to acquire and assimilate new knowledge and the realized capacity to transform and exploit the new knowledge (Zahra & George, 2002). This might be a more difficult task for large pharmaceutical companies than for the smaller biotechnology partners. The difference between the two populations of organizations is striking both in terms of their relative size and their degree of vertical integration. For example, the European pharmaceutical company Novartis, the number eight worldwide, had revenues of $20 billion in 1999, nearly matching the combined revenues of all biotechnology firms. Moreover, although the large pharmaceutical firms are fully vertically integrated, most biotechnology firms focus on drug discovery and early-stage development. Thus, different levels of organizational complexity, reflecting differences between pharmaceutical and biotechnology companies in size as well as in vertical integration and diversification, might explain why large firms appear to be unable to leverage their alliance experience.

In contrast, there are fewer structural barriers to leveraging alliance experience in smaller firms. In most small biotechnology firms, generally only one key individual, often the founder or a top-level manager, manages all the firms' alliances. Individual learning about entering, managing, and exiting alliances takes place more readily, as the significant finding for the biotechnology firms' general alliance experience reflects. The cognitive limits of the individuals managing the biotech alliances, however, might explain the tentative finding of diminishing returns to alliance experience.

In addition to having the ability to learn, firms must also seek to learn from their experience. The smaller biotechnology firms have a greater incentive to learn from their alliance experience because these relationships are more critical to their survival. For the majority of biotechnology firms, alliances are their most significant sources of revenues and capital as well as frequently their only access to the market for pharmaceuticals (Rothaermel, 2001). Our tentative finding that partner-specific experience can have a negative effect on project success suggests that, from this perspective, a biotech firm's incentives to leverage experience gained with a specific partner may in fact decline over repeated interactions. Or, as in the area of mergers and acquisitions, where Haleblian and Finkelstein (1999) found a U-shaped relationship between acquisition experience and acquisition performance, firms are inappropriately generalizing from their prior experience with the same partners.

Our assertion that the relationship between alliance experience and performance is not automatic but may depend on instituting organizational learning processes builds on recent work that has shown systematic interorganizational differences in experience benefits. In their research on the introduction of a new medical procedure among hospital surgical teams, Pisano and his colleagues (2001) found that wide performance differences were related to insituting processes that enabled good performers to actively reflect on their experience, thereby improving their subsequent implementations of the new procedure. Because we examined different sources of experience, our study suggests that experience effects can be meaningfully unpacked to reveal different dynamics and can lead to varying strategies for capturing and leveraging these fundamental kinds of organizational knowledge for performance benefits. Although our results highlight the significant barriers to leveraging partnership experience firms face, the negative consequences of underinvesting in an alliance capability may be too great to ignore.

Our second avenue of intended contribution is methodological. We concur with prior researchers emphasizing that alliance outcomes are most appropriately studied at the level of *individual* alliances (Parkhe, 1993; Zollo et al., 2002). In contrast to prior work, however, this research focused on an objective, jointly determined outcome measure of collaborative R&D rather than relying on perceptual performance measures of one partner involved in an alliance. As such, we examined *joint, project-level* drug development alliances between pharmaceutical and biotechnology companies over a long time period (1980–2000), employing detailed controls for project-level characteristics. We also verified the accuracy of our key independent variables, which were proxies for different types of alliance experience, by drawing on two comprehensive but independent data sources to ensure accuracy and completeness.

Limitations and Future Research

Our study is prone to several limitations, which in turn offer opportunities for future research. Relying on a binary, tangible outcome measure like successful project completion narrowed our defini-

tion of performance to some degree. Alliance experience may have intangible spillover benefits, like knowledge acquisition, that our dependent variable did not capture. Zollo and coauthors (2002), for example, measured alliance performance as a composite of three different self-reported perceptual assessments of satisfaction with knowledge accumulation, satisfaction with options value, and overall satisfaction. Using this subjective measure, they found partner-specific alliance experience did affect alliance performance. An alliance project that would be classified as a failure in our sample might still be a success in terms of their measure, if the firm derived learning and/or option value from this project. Indeed, the perceptions of managers regarding alliance performance may also affect objective performance by influencing investment decisions and interactions with partners. A future study linking alliance experience to successful knowledge acquisition more explicitly might capture the spillover benefits from allying more accurately.

Although alliances may differ in their contribution to experience, we measured alliance experience by counting R&D alliances, which is a fairly course-grained measure. Ideally, alliance experience variables should also reflect the *quality* of collaborations and the managerial processes that underpin them, not only their *quantity*. In future efforts, researchers could attempt to go beyond simple count measures to develop alliance experience measures that reflect learning benefits over time more accurately. Given the difficulty of measuring learning directly for all the alliances in a firm's portfolio, the presence of formal alliance processes and alliance management specialists may serve as good proxies for alliance experience quality. More broadly, an understanding of how alliance experience is leveraged in the course of collaboration is critical for representing alliance quality in other contexts. This concern raises a final limitation of our study. Since we focused on one type of alliance in one type of industry, the intersection between pharmaceuticals and biotechnology, further work is needed to establish the validity and generalizability of our results.

Managerial Implications

The results raise a number of questions related to the leveraging of alliance experience, yet they do suggest some points of intervention for alliance managers concerned with raising alliance performance. Firms should assess whether they are providing sufficient resources and organizational support to leverage alliance experience. Increasing efforts to codify knowledge and creating systems to coordinate and disseminate information between alliance managers across projects and across time may be possible mechanisms for the development of an organizational memory that can be leveraged in subsequent alliances. Finally, firms seeking to optimize alliance performance should carefully assess alternative partners rather than merely turning to partners with whom they have had prior alliance experience. Our results sound a cautionary note for the potential to overstate the performance benefits of working with the same partner. It may be advisable to sample from a broad set of experiences with diverse partners (Anand & Khanna, 2000), while taking alliance-based competitive dynamics into account (Silverman & Baum, 2002).

In conclusion, our results seem to provide some evidence for the existence of a firm-level alliance management capability. Apparently, many firms, in particular large, established firms, seem to fall short when harnessing their alliance experience. Effective alliance management, however, should be seen as a distinctive competence, which can find its expression in superior alliance performance and can thus contribute to a firm's competitive advantage.

REFERENCES

Aiken, L. S., & West, S. G. 1991. ***Multiple regression: Testing and interpreting interactions***. Newbury Park, CA: Sage.

Anand, B., & Khanna, T. 2000. Do firms learn to create value? The case of alliances. ***Strategic Management Journal,*** 21: 295-315.

Anderson, E. 1990. Two firms, one frontier: On assessing joint venture performance. ***Sloan Management Review,*** 33 (2): 19-30.

Barkema, H. G., Shenkar, O., Vermeulen, F., & Bell, J. H. J. 1997. Working abroad, working with others: How firms learn to operate international joint ventures. ***Academy of Management Journal,*** 40: 426-442.

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

Berman, S. L., Down, J., & Hill, C. W. L. 2002. Tacit knowledge as a source of competitive advantage in the National Basketball Association. ***Academy of Management Journal,*** 45: 13-31.

Cohen, P., Cohen, J., West, S. G., & Aiken, L. S. 2003. ***Applied multiple regression/correlation analysis for the behavioral sciences*** (3rd ed.). Hillsdale, NJ: Erlbaum.

Darr, E. D., Argote, L., & Epple, D. 1995. The acquisition, transfer and depreciation of knowledge in service organizations: Productivity in franchises. ***Management Science,*** 41: 1750-1762.

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.

Demsetz, H. 1991. The theory of the firm revisited. In O. E. Williamson & S. Winter (Eds.), ***The nature of the firm:*** 159-178. New York: Oxford University Press.

Doz, Y. 1996. The evolution of cooperation in strategic alliances: Initial conditions or learning processes? ***Strategic Management Journal,*** 17: 55-83.

Dutton, J. M., & Thomas, A. 1984. Treating progress functions as a managerial opportunity. ***Academy of Management Review,*** 9: 235-247.

Dyer, J. H., & Singh, H. 1998. The relational view: Cooperative strategy and sources of interorganizational competitive advantage. ***Academy of Management Review,*** 23: 660-679.

Giovannetti, G. T., & Morrisson, S. W. 2000. ***Convergence: The biotechnology industry report.*** Palo Alto, CA: Ernst & Young.

Gueth, A., Sims, N., & Harrison R. 2001. Managing alliances at Lilly. ***In vivo: The business & medicine report,*** June: 1-9.

Gulati, R. 1995. Social structure and alliance formation patterns: A longitudinal analysis. ***Administrative Science Quarterly,*** 40: 619-652.

Gulati, R. 1998. Alliances and networks. ***Strategic Management Journal,*** 19: 293-317.

Hagedoorn, J. 1993. Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences. ***Strategic Management Journal,*** 14: 371-385.

Haleblian, J., & Finkelstein S. 1999. The influence of organizational acquisition experience on acquisition performance: A behavioral learning perspective. ***Administrative Science Quarterly,*** 44: 29-56.

Harrigan, K. R. 1986. ***Managing for joint venture success.*** Lexington, MA: Lexington Books.

Henderson, R., & Cockburn. I. 1994. Measuring competence? Exploring firm effects in pharmaceutical research. ***Strategic Management Journal***, 15: 63-84.

Hill, C. W. L., & Rothaermel, F. T. 2003. The performance of incumbent firms in the face of radical technological innovation. ***Academy of Management Review,*** 28: 257-274.

Hitt, M. A., Hoskisson, R. E., & Kim, H. 1997. International diversification: Effects on innovation and firm performance in product-diversified firms. ***Academy of Management Journal,*** 40: 767-798.

Ireland, R. D., Hitt, M. A., & Vaidyanath, D. 2002. Alliance management as a source of competitive advantage. ***Journal of Management,*** 28: 413-446.

Jaccard, J., Wan, C. K., & Turrisi, R. 1990. The detection and interpretation of interaction effects between continuous variables in multiple regression. ***Multivariate Behavioral Research,*** 25: 467-478.

Kale, P., Dyer, J. H., & Singh, H. 2002. Alliance capability, stock market response, and long-term alliance success: The role of alliance function. ***Strategic Management Journal,*** 23: 747-767.

Katila, R., & Ahuja, G. 2002. Something old, something new: A longitudinal study of search behavior and new product introduction. ***Academy of Management Journal,*** 45: 1183-1194.

Katz, R. 1982. The effects of group longevity on project communication and performance. ***Administrative Science Quarterly,*** 27: 81-104.

Kleinbaum, D. G., Kupper, L. L., & Muller, K. E. 1988. ***Applied regression analysis and other multivariate methods*** (2nd ed.). Boston: PWS-Kent.

Kogut, B. 1989. The stability of joint ventures: Reciprocity and competitive rivalry. ***Journal of Industrial Economics,*** 38: 183-198.

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

Leonard-Barton, D. 1992. Core capabilities and core rigidities: A paradox in managing new product development. ***Strategic Management Journal,*** 13: 111-125.

Levinthal, D. A., & March, J. G. 1993. The myopia of learning. ***Strategic Management Journal,*** 14: 95-112.

Levitt, B., & March, J. G. 1988. Organizational learning. In W. R. Scott (Ed.), ***Annual review of sociology,*** vol. 14: 319-340. Greenwich, CT: JAI Press.

Lieberman, M. B. 1984. The learning curve and pricing in the chemical processing industries. ***RAND Journal of Economics,*** 15: 216-228.

Miller, D., & Shamsie, J. 1996. The resource-based view of the firm in two environments: The Hollywood film studios from 1936 to 1965. ***Academy of Management Journal,*** 39: 519-543.

Nelson, R. S., & Winter, S. 1982. ***An evolutionary theory of economic change.*** Cambridge, MA: Harvard University Press.

Nonaka, I. 1994. A dynamic theory of organizational knowledge creation. ***Organization Science,*** 5: 14-37.

Osborn, R. N., & Hagedoorn, J. 1997. The institutionalization and evolutionary dynamics of interorganizational alliances and networks. ***Academy of Management Journal,*** 40: 261-278.

Parkhe, A. 1993. Strategic alliance structuring: A game-theoretic and transaction cost examination of interfirm cooperation. ***Academy of Management Journal,*** 36: 794-829.

Pisano, G. P., Bohmer, R. M. J., & Edmondson, A. C. 2001. Organizational differences in rates of learning: Evi-

dence from the adoption of minimally invasive cardiac surgery. ***Management Science,*** 47: 752-768.

PriceWaterhouseCoopers. 2000. ***Global pharmaceutical company partnering capabilities survey.*** Toronto: PriceWaterhouseCoopers.

Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. ***Strategic Management Journal,*** 22: 687-699.

Sampson, R. 2002. ***Experience, learning and collaborative returns in R&D alliances.*** Working paper. Stern School of Business, New York University.

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

Silverman, B. S., & Baum, J. A. C. 2002. Alliance-based competitive dynamics. ***Academy of Management Journal,*** 45: 791-806.

Simon, H. 1947. ***Administrative behavior.*** New York: Macmillan.

Simonin, B. L. 1997. The importance of collaborative know-how: An empirical test of the learning organization. ***Academy of Management Journal,*** 40: 1150-1174.

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

Trajtenberg, M. 1990. ***Economic analysis of product innovation: The case of CT scanners.*** Cambridge, MA: Harvard Press.

Zahra, S. A., & George, G. A. 2002. Absorptive capacity: A review, reconceptualization, and extension. ***Academy of Management Review,*** 27: 185-203.

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: 925-950.

Zollo, M., Reuer, J. J., & Singh, H. 2002. Interorganizational routines and performance in strategic alliances. ***Organization Science,*** 13: 701-713.

Zucker, L. G., Darby, M. R., & Armstrong, J. S. 2002. Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. ***Management Science,*** 48: 138-153.

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