ADVANCED TECHNOLOGY PROGRAM

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Determinants of Success in R&D Alliances

Jeffrey H. Dyer
Benjamin C. Powell
Mariko Sakakibara
Andrew J. Wang

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- On the Internet: www.atp.nist.gov/eao/eao_main.htm
- By e-mail: atp-eao@nist.gov
- By phone: 301-975-8978, Stephanie Shipp, Director, Economic Assessment Office, Advanced Technology Program
- By writing: Economic Assessment Office, Advanced Technology Program, National Institute of Standards and Technology, 100 Bureau Drive, Stop 4710, Gaithersburg, MD 20899-4710

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The Determinants of Success in R&D Alliances

Jeffrey H. Dyer
Marriott School of Management
Brigham Young University
University Provo, Utah 84602

Benjamin C. Powell
Culverhouse College of Commerce and Business Administration
University of Alabama
Tuscaloosa, AL 35487

Mariko Sakakibara
Anderson School of Management
University of California, Los Angeles
Los Angeles, CA 90095

Andrew J. Wang
Advanced Technology Program
National Institute of Standards and Technology
Gaithersburg, MD 20899

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U.S. DEPARTMENT OF COMMERCE
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TECHNOLOGY ADMINISTRATION
Robert Cresanti, Under Secretary for Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
William Jeffrey, Director

ADVANCED TECHNOLOGY PROGRAM
Marc G. Stanley, Director

Abstract

This study offers an examination of the determinants of innovative success in R&D alliances. The relative importance of a set of alliance design factors (e.g., alliance structure characteristics such as number and type of partners, and firm-level attributes such as prior alliance experience and existing R&D capabilities) and alliance management factors (e.g., frequency of communication among partners, effectiveness of governance arrangements). These factors are hypothesized to influence the alliance partners' ability to exchange knowledge and collaborate in R&D, and thereby influence their ability to produce innovations. The study uses a survey dataset of 397 firms involved in 142 R&D alliances that were supported by the Advanced Technology Program. Three measures of alliance success at the firm level are utilized: a perceptual measure of overall value, patent application, and financial value realized from technology commercialization. Alliance designers are largely successful in "optimally" choosing the structure of alliances. The empirical analysis shows that the number of alliance partners and the presence of competitor firms have little effect on alliance outcomes. Among the alliance management factors, effective governance arrangements and frequent communication are found to have an important and positive impact on alliance outcomes. Finally, the results show that more ambitious projects that "reach for the stars" have more successful outcomes.

(Alliances, Innovation, Knowledge Management).

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Acknowledgements

The background for this study was the earlier work by Jeffrey Dyer and Benjamin Powell under a contract with ATP's Economic Assessment Office (EAO). They interviewed company participants from ATP joint venture projects in the automotive industry to assess the factors that contribute to success in R&D collaborations. Their findings are published in the report *Determinants of Success in ATP-Funded R&D Joint Ventures: A Preliminary Analysis Based on 18 Automobile Manufacturing Projects,* GCR-00-803, National Institute of Standards and Technology, Gaithersburg, MD, December 2001.

ATP's Economic Assessment Office contracted with Westat, a survey research organization, to develop and implement survey instruments to collect original data from companies that have participated in ATP-supported projects. Andrew Wang, economist at ATP/EAO, initiated and directed the effort to carry out a special survey of company participants in ATP joint venture projects. Jennifer O'Brien, survey methodologist at Westat, oversaw design, development, and data collection for the Survey of ATP Joint Ventures.

Stephen Campbell, economist at ATP/EAO, provided invaluable support to this research in constructing data, conducting analysis, and commenting on interpretation of results. Andrew and Stephen presented analysis and findings related to this research at the American Statistical Association meeting in August 2004. Andrew presented an early version of this study at the International Society for New Institutional Economics meeting in October 2004. Jeffrey Dyer presented a version of this study at the Academy of Management meeting in August 2005.

For the present study, Stephanie Shipp, Director, EAO, provided comments and feedback on several drafts of the report. Brian Belanger, former ATP Deputy Director, and Lorel Wisniewski, present ATP Deputy Director, reviewed the final draft and provided comments. Dennis Leber, Statistician, NIST, also provided comments on the final draft. Robert Sienkiewicz, Supervisor, EAO, and Janet Brumby, Business Liaison Specialist, EAO, oversaw the publication of the report. Joann Brooks designed the cover.

Executive Summary

Innovation is increasingly important to competition in technology intensive industries. In seeking innovation, individual firms often find that external knowledge and research partners are critical to success. Innovation is often the result of synthesizing or "bridging" ideas from different knowledge domains. Therefore, firms increasingly enter into research and development (R&D) alliances with other firms to combine complementary knowledge in the pursuit of new innovative technologies. Indeed, many governments around the world support cooperative research activities in the expectation that collaborating firms will successfully develop new technologies that will improve economic competitiveness.

Prior research suggests that alliance success is difficult to achieve, with failure rates around 50 percent. R&D alliances are even more challenging than other types of alliances, because knowledge sharing is characterized by inherently problematic issues that require careful governance, and because the innovation process itself is characterized by a high degree of uncertainty, which makes success extremely difficult to predict.

The perspective adopted in this study is that success in an R&D alliance is more likely to occur when the firms initiating the alliance: (a) partner with other firms that possess relevant complementary knowledge, and (b) effectively share and combine that complementary knowledge. Having the requisite knowledge within the alliance team and having the necessary processes in place to exchange that knowledge is critical to producing technical innovations. Effective "knowledge management" is therefore a fundamental driver of success in R&D alliances. Alliance success depends broadly on three categories of factors that influence the exchange of complementary knowledge: alliance "design" decisions made during the alliance formation stage; alliance "management" decisions made during the alliance execution stage; and "luck", that is, the playing out of random events under uncertainty. During the alliance formation stage, the designers of the alliance seek to identify the "win-win" opportunity for potential alliance members and recruit potential members based on a cost-benefit analysis of what each potential member might contribute to the alliance objective.

To examine how alliance-design and alliance-management factors influence R&D alliance success, this study uses a unique survey dataset that includes 397 firms in 142 R&D alliances. These R&D alliances received funding from the Advanced Technology Program, a U.S. federal government program that supports innovation and early-stage technology in U.S. industry. In the analysis, multiple firm-level measures of performance outcomes are utilized, including a perceptual measure (subjective assessment of overall value to the firm), a patent measure (patent applications filed by the firm), and a financial measure (revenues or cost savings realized by the firm from commercialization of technology). For 121 out of the 142 R&D

alliances represented in the dataset, survey response information is available from more than one partner in the alliance.

The empirical analysis produces the following conclusions. Alliance designers are largely successful in choosing an "optimal" structure for the alliance in terms of the number and type of alliance partners. The number of alliance partners has a weakly negative effect on patent application, but no effect on overall value or commercialization. The presence of competitors in an alliance has no effect on any of the three outcomes measures.

Effective contractual provisions and governance arrangements for alliance management have a positive effect on alliance success in terms of delivering overall value and generating patent applications. Goodwill trust among alliance partners has a weakly negative effect on overall value, and a negative effect on patent application. These results suggest that successful alliances do not simply depend on goodwill trust, but develop contractual-based trust based on effective contractual provisions and governance arrangements. In other words, in alliance management, one would do well to "Trust, but verify."

Frequency of communication has a strong positive effect on all three measures of R&D alliance performance, including the perceptual measure of overall value, the patent application measure, and the financial value from commercialization measure. R&D alliance managers can increase the likelihood of alliance success by establishing routines that encourage frequent communication. Frequent communication facilitates the knowledge sharing and coordination that is critical to alliance success.

Finally, "reaching for the stars" is a strong predictor of alliance success. More ambitious projects with farther reaching goals demonstrate greater success on all three measures of R&D alliance performance. More ambitious projects have intrinsically greater potential value and potential impact. In addition, more ambitious projects are likely to mobilize greater commitment and effort on the part of both the partner companies and the individual participants.

The research carried out in this study suggests that there are fundamental differences between R&D alliances and other types of alliances, and consequently, the factors that influence success may be quite different. Some factors may be determinants of success in some types of alliances, such as manufacturing or marketing alliances, but not in other types of alliances, such as R&D alliances where creativity and innovation are central. Though many research studies combine R&D alliances and other types of alliances as a single subject for analysis, this study concludes that R&D alliances should be treated as a separate and independent type of collaborative activity.

Part I

Introduction

Innovation is an increasingly important dimension of competition in technology intensive industries. In seeking innovation, individual firms often find that external knowledge and research partners are critical to success. Innovation is often the result of synthesizing or "bridging" ideas from different knowledge domains (Hargadon and Sutton, 2000; Burt, 2004). Therefore, firms increasingly enter into research and development (R&D) alliances with other firms to combine complementary knowledge in the pursuit of new innovative technologies. Indeed, many governments around the world support cooperative research activities in the expectation that collaborating firms will successfully develop new technologies that will improve economic competitiveness.

Unfortunately, while R&D alliances have become a popular mechanism to pursue innovation, prior research suggests that alliances have failure rates of around 50 percent (Kogut, 1989; Alliance Analyst, 1998; Kale et al, 2002). R&D alliances are presumably even more challenging than other types of alliances because collaborators must simultaneously share knowledge while trying to prevent undesired knowledge spillovers (Hamel, 1991; Oxley and Sampson, 2004). The free exchange of knowledge by partners is critical for ideas and knowledge to be recombined in such a way as to produce innovations (Hargadon and Sutton, 2000). However, various factors—attributes of partners, governance arrangements, communication processes—may inhibit the exchange of complementary knowledge in an alliance, thereby decreasing the probability of innovation. Moreover, even when R&D alliance partners are able to simulate the free flow of knowledge that can occur within a firm, the innovation process itself is characterized by a high degree of uncertainty, which makes success extremely difficult to predict.

Understanding how firms can enhance the probability of success in R&D alliances is an important question for both firms and governments. Researching the determinants of knowledge sharing and innovative success in R&D alliances is especially challenging since innovation processes are inherently uncertain. Despite these challenges, numerous scholars have examined a variety of factors that may influence the performance outcomes of R&D alliances.

This study seeks to provide a more complete understanding of the factors that influence success in R&D alliances. The perspective adopted in this study is that success in an R&D alliance is more likely to occur when the firms initiating the alliance: (a) partner with other

firms that possess relevant complementary knowledge, and (b) effectively share and combine that complementary knowledge. Having the requisite knowledge within the alliance team and having the necessary processes in place to exchange that knowledge is critical to producing technical innovations. Effective "knowledge management" is therefore a fundamental driver of success in R&D alliances. Alliance success depends broadly on three categories of factors that influence the exchange of complementary knowledge: alliance "design" decisions made during the alliance formation stage; alliance "management" decisions made during the alliance execution stage; and "luck", that is, the playing out of random events under uncertainty. During the alliance formation stage, the designers of the alliance seek to identify the "win-win" opportunity for potential alliance members and recruit potential members based on a cost-benefit analysis of what each potential member might contribute to the alliance objective. In this cost-benefit analysis, if alliance designers properly optimize their decision, then each member's contribution to the alliance is balanced against the burden that it imposes on the alliance. As such, in an *ex post* analysis, the analyst would not expect to see differential results in actual performance outcomes related to alliance design characteristics.

In real life, however, not all *ex ante* factors may have been fully optimized. Not all alliance design decisions and alliance management decisions results are necessarily fully "optimal" in an equilibrium sense. For example, if *ex ante* design decisions on the number of firms to include in an alliance, or whether to include competitor firms, were optimal, then we would not expect to see these alliance characteristics to be correlated with alliance outcomes in an *ex post* analysis. But such alliance design and management decisions are in fact made by actors in a context of imperfect information, uncertainty, and learning, so we can expect that these decisions are less than perfect, and therefore, we assess whether some decisions turn out to be "less optimal" than others in an *ex post* analysis.

To examine how alliance-design and alliance-management factors influence R&D alliance success, we use a unique survey dataset that includes 397 firms in 142 R&D alliances. These R&D alliances received funding from the Advanced Technology Program, a U.S. federal government program that supports innovation and early-stage technology in U.S. industry. The data were collected by the Advanced Technology Program.

In our analysis of the determinants of R&D alliance success, we go beyond prior studies in several ways. First, we focus exclusively on R&D alliances. Many prior studies include all types of alliances (e.g., marketing, manufacturing, R&D, etc.) rather than focusing specifically on R&D alliances. R&D alliances are different from other types of alliances, especially in their focus on knowledge sharing and innovation, so analyses that pool different types of alliances are difficult to interpret for R&D alliances. Second, we develop our analysis by drawing upon multiple theoretical perspectives from economics, organization theory, and strategic management. Prior studies of R&D alliances focus on a narrow set of factors that may influence R&D alliance success, typically relying on a particular theoretical lens rather than drawing on a broad set of theoretical perspectives. While using a single theoretical perspective has the advantage of allowing for deeper theoretical insight, it has the disadvantage of excluding many

factors that may be important for empirical understanding. Third, we employ multiple measures of alliance success. Most prior studies have inadequate measures of R&D alliance success. Firm-level measures such as firm profitability or stock price are only remotely related to R&D alliance performance outcomes. Alliance survival is a poor measure of R&D alliance success since most R&D alliances are designed to last for a limited time period. Survey-based perceptual measures capture the degree to which an alliance has achieved broad and diverse goals, but may also be subject to a variety of response biases. Weaknesses associated with each type of performance measure suggest that a study of performance outcomes of R&D alliances would ideally include a combination of objective and subjective measures. We utilize multiple measures of performance outcomes at the firm-level, including a perceptual measure (subjective assessment of overall value to the firm), a patent measure (patent applications filed by the firm), and a financial measure (revenues or cost savings realized by the firm from commercialization of technology). Finally, we employ firm-specific measures of alliance outcomes from multiple members of an alliance. Most prior studies do not have alliance-wide measures of performance outcomes, that is, they do not have data from different members in the alliance. Different firms in an alliance have different objectives, and benefits to each firm may vary depending on a variety of factors. In order to better understand alliance "success" and factors that influence success, we use data from more than one alliance partner for 121 out of the 142 R&D alliances represented in the sample. We find substantial variance within an alliance in terms of individual partner firms' assessment of the success of the alliance. For example, in 16 percent of the alliances, one alliance partner rated the alliance as "successful" or "very successful" in delivering value to the firm, while another alliance partner rated the alliance as "unsuccessful" or "very unsuccessful" in generating value. Although there is positive correlation in performance outcomes among alliance partners, our analysis indicates that alliance success is an individual firm-level phenomenon, so data gathered from only one partner cannot generalize to the "alliance" level.

We examine alliance design factors that are expected to influence alliance success. We consider alliance structure characteristics such as the number of partners, type of partners (e.g., presence of competitors), and geographic proximity of partners. We also consider firm-level attributes such as the firm's prior experience with alliances in general or with specific alliance partners, and the firm's existing stock of R&D knowledge and capabilities. These alliance design factors (alliance structure characteristics and firm-level attributes) are largely established at the time of alliance formation, and reflect the decisions made by the alliance designers.

We also examine alliance management factors that are expected to influence alliance success. Alliances that are able to establish effective governance arrangements and institute processes that build trust are expected to be more likely to share knowledge and achieve innovation success. Alliances that facilitate communication among partners effectively are also expected to be more likely to achieve innovation success. Alliance partner commitment and effort devoted to the alliance project, as measured by technical personnel resources allocated, is also expected to relate to alliance success. These alliance management factors develop during the course of the project, that is, in the process of alliance execution.

In summary, we examine the relative importance of alliance design factors and alliance management factors in determining R&D alliance success. We also examine whether partners in an R&D alliance realize similar, or dissimilar, benefits from participation in the alliance. Finally, applying insights from our analyses, we explore what both firms and governments might do to increase the likelihood of success in R&D alliances.

Part II

Theoretical Perspectives on R&D Alliance Success

The theoretical perspectives underpinning hypotheses tested in this study are derived from both our review of prior literature on R&D alliance success, and from our exploratory interviews with participants in R&D alliances that received funding support from the Advanced Technology Program (ATP) at the National Institute of Standards and Technology (NIST). We conducted semi-structured interviews that focused on the question: What are the factors that contribute to, or inhibit, alliance success? The participants in these interviews consistently identified factors that related to knowledge sharing in the alliance, which in turn affected success in achieving technical objectives, generating research outcomes, and commercialization of technology (Dyer and Powell, 2001). Drawing on prior research and on these interviews, we developed the theoretical logic and hypotheses presented in the following sections.

Alliance Design Factors: Alliance Structure

Number of Alliance Partners

In alliance design, firms that initiate an alliance aim to optimize the number of partners to involve in the alliance. Additional partners may bring additional knowledge and resources to the alliance, but each additional partner also brings additional transaction and coordination costs (Gulati and Singh, 1998). Each additional partner firm must be included in negotiations regarding the goals of the collaboration, protection of intellectual property, control and ownership of research output, how to share knowledge and collaborate in R&D, etc. Adding more partners to an alliance may also hinder knowledge sharing by increasing the risk of unintended knowledge leakage (Oxley and Sampson, 2004). The greater the number of partners in an alliance, the more reluctant individual firms may be to share knowledge, fearing greater potential for unintended knowledge spillovers when more firms have access to the knowledge.

With each additional partner, the number of alliance partners increases linearly as N, but the number of dyadic relationships increases quadratically as N(N-1)/2. With two firms there is one relationship to manage; with three firms there are three relationships; with four firms, six relationships, and so on. In our interviews with R&D alliance participants, many observed

that knowledge sharing and coordination was more difficult with more members. As one participant stated, "The more people you have, the more people you have to coordinate. It gets unwieldy at some point." (Dyer and Powell, 2001, p.14). Above some threshold number of partners, transaction and coordination costs become significant, and concerns about knowledge leakage inhibit the ability of alliance partners to share knowledge, which is critical to R&D alliance success. In the cost-benefit calculation for deciding how many partners to include in an alliance, if alliance designers err in optimizing the number of partners to involve, we expect that the tendency is to underestimate transaction and coordination costs. Hence, we expect that alliances with a greater number of partners will have lower performance outcomes.

Hypothesis 1: The greater the number of R&D alliance partners, the lower the performance outcomes of the R&D alliance.

Presence of Competitors

Prior research suggests that R&D alliances are fraught with risks because firms must simultaneously share knowledge and technology, as well as protect knowledge (Hamel, 1991; Oxley and Sampson, 2004). Firms must find the right balance between maintaining open knowledge exchange to further the technological goals of the alliance while also preventing unintended leakage of knowledge. Preventing opportunism within R&D alliances is a prime concern, and especially challenging for a number of reasons.

First, joint R&D often requires high levels of investment in complementary assets or knowledge by the participants. When a firm performs part of a research project, the knowledge it gains may be useless unless combined with the work of partner firms with complementary knowledge. This creates potential for opportunistic behavior on the part of partner firms that possess the complementary assets or knowledge. In effect, these knowledge assets are "transaction-specific" assets, and in this transaction relationship there is significant potential for opportunism (Klein et al, 1978; Williamson, 1985).

Second, R&D alliances are characterized by a high degree of uncertainty regarding both inputs and outputs. Monitoring inputs and "effort" on the part of one's partner is extremely difficult. R&D alliance tasks are largely intellectual in nature and, therefore, third party monitoring is inefficient. Under these conditions, effective self monitoring (Demsetz, 1988) is required because it is impossible to really know whether an alliance partner is truly sharing its most relevant knowledge. In short, the high degree of uncertainty regarding inputs and outputs provides numerous opportunities for opportunistic behavior on the part of alliance partners.

Finally, there are significant information asymmetries among partners in R&D collaborations. Each firm brings different knowledge to the table and may be reluctant to share information due to the desire to prevent unintended knowledge spillovers. Once technological information is revealed, the receiver of knowledge has no incentive to pay for the information. Thus, a primary challenge in R&D alliances is to figure out how to openly share knowledge

that is relevant to the alliance objectives while preventing undesirable knowledge spillovers.

These challenges to knowledge-sharing in R&D alliances are exacerbated in the case of competitor collaborations where partners are ultimately engaged in a zero-sum game in the marketplace (one partner's commercial success ultimately has a negative impact on the commercial success of another partner). For example, the decision regarding the extent to which a partner should fully collaborate (sending the most high caliber researchers, sharing proprietary knowledge, etc.) may be characterized by a Prisoner's Dilemma game, where despite the fact that the two firms would be better off by jointly cooperating, both firms individually have the incentive not to share skills and information. Hamel's (1991) detailed examination of nine alliances revealed that firms typically try to internalize their partner's skills while protecting their own. As one manager in his study observed, "[Our partner] tries to suck us dry of technology ideas they can use in their own products. Whatever they learn from us, they'll use against us worldwide." (Hamel, 1991, p.87). In our interviews, an R&D alliance manager stated, "Having direct competitors in the [alliance] definitely inhibited information sharing. I don't take guys to the [alliance] meetings if they talk too much; sometimes I have to say to them 'That's enough. You are talking too much.'" (Dyer and Powell 2001, p.13).

Even if the outcome of research effort is not characterized as a zero-sum game, R&D alliances with direct competitors could lead to a collective reduction of research efforts. Katz (1986) demonstrates the possibility that when firms cooperate in cost-reducing R&D, but compete in product markets, the firms might collaborate to conduct less R&D to lessen the severity of competition in product markets. Branstetter and Sakakibara (2002) empirically examine Japanese government-sponsored R&D consortia and find that the research productivity of participating firms is lower when the degree of product market competition among participants is higher.

Hypothesis 2: If an R&D alliance involves firms that are direct competitors in product markets, then the performance outcomes of the R&D alliance are lower.

Geographic Distance between Alliance Partners

Prior research shows that geographic proximity plays an important role in facilitating interaction and knowledge-sharing between collaborating firms (Saxenian, 1994; Dyer, 1996; Almeida and Kogut, 1999). For example, Dyer (1996) finds a strong relationship between geographic proximity of automaker and supplier facilities, and the extent to which the firms engage in face-to-face interaction. He also finds that greater face-to-face interaction between supplier-customer engineers leads to fewer defects and higher overall product quality. Geographic distance presumably increases the cost of frequent face-to-face communication, thereby decreasing knowledge sharing and reducing coordination effectiveness (especially when tasks are highly interdependent).

Hypothesis 3: The greater the geographic distance between R&D alliance partners, the lower the performance outcomes of the R&D alliance.

Alliance Design Factors: Firm Attributes

General and Partner-Specific Alliance Experience

Prior research generally suggests that firms with greater partnering experience develop "relational capabilities" that enhance their ability to extract value from subsequent alliances (Anand and Khanna, 2000; Kale et al, 2002). Partner experience can be either "general alliance experience" or "partner-specific alliance experience." Whereas the former refers to experience gained from all prior alliances, the latter refers to prior alliance experience with a specific partner. Firms that engage repeatedly in an activity are able to draw inferences from their experiences, and store and retrieve such inferred learning for use in subsequent engagements in the activity (Levitt and March, 1988). In the alliance context, firms with substantial experience in alliances often have dedicated personnel charged with capturing, codifying, and communicating best practices in managing alliances. Similarly, when firms have repeated alliances with specific partners, the partnering firms may be induced to invest in relation-specific assets that reduce transaction and coordination costs. Moreover, learning accumulated through partner-specific experience may lead to the emergence of stable and efficient inter-organizational knowledge-sharing routines (Dyer and Singh, 1998; Zollo et al, 2002).

Most studies have found results consistent with the expectation that general and partner-specific experience lead to superior alliance performance. However, a recent study by Hoang and Rothaermel (2005) calls into question the relationship between partner-specific experience and R&D alliance performance. In their study of R&D alliances for new drug development, they find that general partnering experience has a positive effect on performance for small biotechnology firms, but not for their larger pharmaceutical firm partners. They suggest that larger firms have already acquired significant experience and capabilities at alliances, so there is little difference in capabilities of these firms. Interestingly, contrary to their expectations, they find that partner-specific experience has a weakly negative effect on successful drug development. Hoang and Rothaermel suggest that the reason for this counterintuitive finding may be that partners inappropriately generalize from their prior experience with that partner—but the next drug development project is not like the last one. The logic for this conclusion is similar to that in Haleblian and Finkelstein's (1999) study of acquisition and performance, which concludes that firms with a moderate amount of experience in acquisitions may be less successful in subsequent acquisitions if the new acquisition is significantly different in nature from prior acquisitions. Another plausible reason for this result may be that for firms pursuing innovation objectives in alliances, repeated transactions with the same partner—while promoting efficiency—may not result in novelty. Thus, previous findings of a positive relationship between partner-specific experience and alliance performance in general may not hold for R&D alliances in particular. Our study offers the opportunity to examine the effects of both general and partner-specific experience on R&D performance, using multiple performance measures.

Hypothesis 4a: The greater the general alliance experience of the firm, the better the performance outcomes of the R&D alliance for the firm.

Hypothesis 4b: The greater the partner-specific experience of the firm with its alliance partners, the better the performance outcomes of the R&D alliance for the firm.

R&D Capability

Generally, we expect that the overall R&D capability and total stock of knowledge of an R&D organization would have a positive impact on performance outcomes of an R&D alliance that the organization participates in. A proxy measure for an organization's overall R&D capability and stock of knowledge is the total number of R&D personnel at the organization. To realize benefits from participating in alliances, firms must identify, assimilate, and commercialize useful knowledge developed through collaboration. A firm's ability to take advantage of externally generated knowledge—its absorptive capacity—depends upon the stock of related knowledge accumulated by the firm (Cohen and Levinthal, 1989; 1990). Relatively few empirical studies have examined the impact of absorptive capacity on the benefits that firms obtain from participation in alliances. Mowery et al. (1996) find that pre-alliance technological overlap with alliance partners enhances a firm's absorption of technological capabilities, but a firm's R&D intensity has no effect. We also expect that economies of scale and scope in R&D characterize the R&D capability of a firm. We expect that "knowledge spillovers" between personnel within a firm enhance the R&D capability of the firm. Within a firm, R&D personnel working on any given project are able to learn from other technical personnel at the firm working on different projects. We hypothesize that firms with a greater R&D capability and stock of knowledge, as proxied by total R&D employment, are able to benefit more from R&D alliances, and therefore have better alliance performance outcomes.

Hypothesis 5: The greater the total R&D employment of the firm, the better the performance outcomes of the R&D alliance for the firm.

Alliance Management Factors

Number of Technical Personnel

A key management decision for a firm participating in an R&D alliance is to determine the number of technical personnel to allocate to the effort. The level of technical personnel resources that a firm devotes to an alliance project affects both the direct R&D output and the R&D learning benefits that the firm can expect to receive from participating in the alliance. For the firm, the allocation of R&D personnel is firstly related to direct innovation outputs as a result of the effort, and secondly related to R&D absorptive capacity and R&D learning (Cohen and Levinthal, 1989).

In regard to absorptive capacity, Lane and Lubatkin (1998) compare firm-level and firm dyad-specific measures of absorptive capacity and find that the latter is better in explaining learning outcomes from alliances. Thus, prior research indicates that alliance-specific measures of absorptive capacity, i.e. pre-alliance technological overlap (Mowery et al, 1996), or similarity of knowledge stock and management practices (Lane and Lubatkin, 1998), accounts for alliance benefits better than traditional firm-level measures of absorptive capacity, i.e., R&D spending or R&D intensity.

Prior research has emphasized that gatekeeping or boundary-spanning roles are important for absorbing external knowledge (Cohen and Levinthal, 1990). The more people that a firm positions at the "gate", the more receptive the firms become to external or alliance knowledge. By involving more R&D personnel in an alliance collaboration, a firm is able to transfer more individual and interpersonal knowledge, and is able to widen the conduit for knowledge flows from the R&D alliance to itself. Agrawal (2006) examines the impact of total amount of time that professors, graduate students, and research scientists work in collaboration or close communication with firms that license university inventions, and finds that as total collaboration time increases, both the likelihood of commercialization and the degree of commercialization success increases. Thus, we expect that firms that allocate more R&D personnel resources to an R&D alliance effort will receive greater benefits from the alliance, both in innovation outcomes and learning outcomes.

Hypothesis 6: The greater the number of technical personnel allocated to an R&D alliance by the firm, the better the performance outcomes of the R&D alliance for the firm.

Frequency of Communication

Prior studies suggest that when firms collaborate on complex problems, they are more likely to be successful if they develop processes that facilitate frequent communication (Clark and Fujimoto, 1991; Dyer, 1996). Frequent communication results in greater knowledge-sharing between alliance partners, which increases the likelihood of success in collaborative efforts. Mohr and Nevin (1990) define communication as the process by which partner firms in an alliance transmit information, coordinate activities, prompt participatory decision-making, and encourage commitment and loyalty to the alliance. Some research suggests that partners that develop relation-specific know-how through frequent communication are less likely to misunderstand or misinterpret information (Nishiguchi, 1994; Clark and Fujimoto, 1991). More efficient communication and coordination should result in better performance. With greater complexity of collaborative tasks, direct face-to-face communication and work interaction is believed to be of greater importance relative to other forms of communication, such as email, telephone, or even video conference. Face-to-face interaction is described as having high knowledge carrying capacity because it presents immediate feedback opportunities and makes use of both visual and audio modes of communication (Daft and Lengl, 1986; Dyer, 1996).

Interestingly, the relationship between communication and performance has rarely been empirically tested in R&D alliances, and, based upon our review of the R&D alliance literature, the relationship between face-to-face interaction and performance has never been tested. Our hypothesis is that more frequent communication and interaction will result in greater knowledge sharing and better performance outcomes in R&D alliances.

Hypothesis 7a: The more frequent the communication among R&D alliance partner personnel, the better the performance outcomes of the R&D alliance.

Hypothesis 7b: The more frequent the face-to-face interaction among R&D alliance partner personnel, the better the performance outcomes of the R&D alliance.

Governance Arrangements

Governance arrangements play an important role in creating a transaction environment where alliance partners can cooperate and share knowledge or resources with assurance that they will also share equitably in the benefits from the collaboration. Prior studies on alliance governance and alliance success have examined the conditions under which collaborating firms prefer contractual versus equity ownership governance arrangements (Oxley, 1997; Oxley and Sampson, 2004; Sampson, 2004). These studies generally find that when hazards of opportunism are high in an alliance, equity governance arrangements are preferred. Conversely, when hazards are low, contractual governance is preferred (Sampson, 2004). R&D alliances are often viewed as alliances where the hazards of opportunism are high because of the challenges associated with both sharing, and protecting, knowledge. However, in an empirical study of contractual and equity governance arrangements in a sample of R&D alliances, Sampson (2004, p.486) concludes that "Contractual governance appears to be more efficient in all but the most extreme cases" due to the "excessive bureaucracy" associated with managing equity-based governance arrangements. In fact, ATP research "joint venture" projects are *contractual* joint ventures or alliances, organized under a contractual agreement, and not *equity* joint ventures where partner firms create a separate legal entity (with joint ownership by the parent companies).

Alliance partners have to rely on safeguards (e.g., contractual provisions, governance procedures) in order to prevent opportunism (Williamson, 1985). Williamson (1993) argues that contractual safeguards are necessary whenever there is the potential for opportunism within a transaction relationship. Since R&D collaborations entail risks with regard to intellectual property rights and knowledge spillover, they are more likely to be successful when the partners have crafted effective contractual provisions to protect intellectual property rights, monitor task performance, and resolve disagreements. Without satisfactory contractual protections or governance procedures, alliance partners may be unwilling to share knowledge that is critical to the venture. For example, without satisfactory protections one party may use or modify

technology acquired during the alliance in ways that were not intended and which are injurious to a partner. Naturally, an unwillingness to share knowledge would severely hamper the ability of the collaborating firms to jointly develop valuable new knowledge.

Hypothesis 8: The more satisfied are R&D alliance partners with contractual provisions and governance procedures for protecting intellectual property rights and resolving disagreements, the better the performance outcomes of the R&D alliance.

Goodwill Trust

Although prior research on the relationship between governance arrangements and alliance success has typically focused on forms of contractual or equity ownership arrangements (Oxley and Sampson, 2004; Sampson, 2004), sociologists have long emphasized that informal social controls—e.g., goodwill trust—often substitute for formal social controls (Macaulay, 1963; Granovetter, 1985; Black, 1976; Ellickson, 1991). Prior work generally suggests that "contractual trust" and "goodwill trust" are substitutes (Sako, 1991). Thus, alliance partners may rely on personal trust relations as a primary governance mechanism in an alliance relationship.

We draw on prior literature in defining trust as one party's confidence that the *other party in the exchange relationship will not exploit its vulnerabilities* (Barney and Hansen, 1994; Zaheer et al., 1998; Dyer and Chu, 2003). This confidence, or trust, is expected to emerge where the "trustworthy" party in the exchange relationship: (1) shows good will and behaves in ways perceived as "fair" by the exchange partner; and (2) does not take advantage of an exchange partner even when the opportunity is available (Mayer et al., 1995). Our definition therefore characterizes interfirm trust as a construct based on goodwill or benevolence, and has frequently been referred to as "goodwill trust" (Sako, 1991; Dyer and Chu, 2003). Conceptually, organizations are not able to trust each other—trust is a phenomenon that has its basis in individuals. Trust can be placed by one individual in another individual or in a group of individuals (e.g., within an organization). However, individuals in an organization may *share an orientation* toward individuals within another organization. In this perspective, "interorganizational trust describes the extent to which organizational members have a collectively-held trust orientation toward the partner firm" (Zaheer et al, 1998, p.142).

In this study, we consider goodwill trust, this collective orientation of a company toward its alliance partners. Trust is likely to be important in R&D alliances, which represent situations of risk where there is potential for undesirable knowledge spillovers and opportunistic behavior on the part of partners. Higher levels of trust are expected to improve R&D alliance performance by lowering transaction costs or increasing knowledge sharing.

Trust lowers transaction costs and improves the effectiveness of coordination by reducing both bargaining and monitoring costs. When alliance partners trust that payoffs will be fairly divided, they do not have to plan for all future contingencies. They can be confident that

equitable adjustments will be made as market conditions change. Trust therefore promotes negotiating efficiency by enabling each party to be more flexible in granting concessions because of the expectation that the partner will reciprocate in the future (Dore, 1983). Furthermore, negotiations are more efficient because partners have confidence that information provided by the other organization is not misrepresented. As observed by Zaheer et al. (1998, p.144), "Trust reduces the inclination to guard against opportunistic behavior (i.e. deliberate misrepresentation on the part of the exchange partner)."

Trust also influences the extent to which alliance partners are willing to share knowledge—especially proprietary knowledge. A company will share this information if it trusts that the partner will not steal its ideas or use them in a way that would be inappropriate or damaging. Without goodwill trust, alliance partners are less likely to share knowledge, which is critical to success in R&D alliances.

Hypothesis 9: The greater the goodwill trust among partners in an R&D alliance, the better the performance outcomes of the R&D alliance.

Part III

Data and Sample

The Advanced Technology Program (ATP) at the National Institute of Standards and Technology (NIST), U.S. Department of Commerce, supports technology innovation in the United States through competitive funding awards to companies pursuing high-risk R&D. A key mission of the ATP is to promote collaborative R&D in U.S. industry. Since 1990, ATP has funded over 200 research joint ventures involving almost 1000 companies, universities, and other organizations. An ATP research "joint venture" must include at least two for-profit companies, and may also include universities and other nonprofit organizations. ATP joint venture project awards do not have a maximum award amount, but the project participants must provide at least 50 percent of the total project cost. ATP joint venture projects typically last for three to five years. The ATP targets high-risk R&D projects with potential for broad economic impact, and supports innovative technologies in any field—biotechnology, chemistry and advanced materials, electronics, information technology, manufacturing.

We note that ATP research "joint venture" projects are not *equity* joint ventures where partner firms create a separate legal entity (with joint ownership by the parent companies) to pursue collaboration objectives. Instead, they are *contractual* joint ventures or alliances, organized under a contractual agreement. For the purpose of this paper, we use the terms "R&D alliance" and "research joint venture" interchangeably to refer to these R&D project collaborations that receive funding support from the ATP.

This study of R&D alliances began with interviews of ATP program managers responsible for supervising ATP-funded research joint venture projects, and then interviews with company participants in ATP-funded R&D alliances. The interviews focused on investigating the determinants of success in R&D alliances in order to build internal validity for the subsequent research (Dyer and Powell, 2001).

To build external validity, we used the interview findings to contribute to the development of a special survey, the *Survey of ATP Joint Ventures,* which was fielded in 2003. The survey collected information at the firm level (e.g., project benefits to the respondent's company), and also at the firm-dyad level (e.g., characteristics of the relationship between the respondent's company and specific partner companies participating in the same R&D project). All companies in ATP research joint venture projects funded between 1990 and 2001, with project completion by 2004, were included in the survey. Altogether, 486 companies were eligible to respond to the survey.

The survey used a mixed-mode methodology that included an internet web survey, and a follow-up phone interview for those that did not respond to the web survey. Survey design and data collection was carried out by a leading survey research firm. Following standard survey procedures, multiple contact attempts were made in order to maximize survey response rates. An advance letter describing the purpose of the survey was mailed to each company representative. An email then provided the representative with the web survey link and login information. Reminder emails were sent to non-respondents over the course of several weeks. After eight weeks, remaining non-respondents were contacted by telephone to collect the survey data. While these telephone contacts were intended to allow respondents the opportunity to complete the interview over the telephone, the vast majority of these calls actually served to prompt the respondent to complete the web survey. Thus, although technically the administration of the survey was mixed-mode, only fourteen telephone interviews were actually conducted while 383 completed the web survey. The overall response rate (proportion of survey responses relative to the within-scope population) was 89%.

The survey yielded a dataset with a total of 397 companies and 142 R&D alliances. At least one firm is represented from each of 142 R&D alliances. For 121 R&D alliances, two or more firms are represented in the dataset. The survey data were supplemented by firm-level and project-level archival data. The archival data included information such as the amount of project award funding provided by the ATP, the project participants' cost-share contribution, and other project and company descriptive information. Table 1 shows the distribution of projects and companies in the survey dataset, by year of project completion. Table 2 shows the distribution of projects and companies, by the technology area of the project.

Analysis of Outcomes: Firm-level or Alliance-level

For 121 R&D alliances, we have survey data responses from two or more companies participating in the alliance. Therefore, we address an issue that has not been resolved in the alliance literature: Should alliance outcomes be assessed at the firm-level or at the alliance-level? Anderson (1990) argues that joint ventures should be evaluated as independent entities seeking to maximize their own rather than their parents' performance, in order to minimize parent politics and parochial viewpoints, foster harmony among parents, and facilitate learning and innovation. Anderson's argument suggests that the appropriate level of analysis for studying alliance performance is the alliance level. Glaister and Buckley (1998) criticize Anderson's perspective as naive and impractical because alliances are embedded within their parents' alliance networks and thus politically inseparable from the power structure of those networks. These opposite views reflect a difference of opinion in the alliance literature regarding whether the appropriate level of analysis is that of the alliance or the participating companies.

The typical approach to making alliance performance an operational measure is to equate the company and alliance levels of analysis by viewing alliance performance from the vantage

TABLE 1

Survey Respondents: Projects and Companies, by Year of Project Completion

Project Completion Year	Projects		Companies	
	Number	Percent	Number	Percent
1995	4	3%	11	3%
1996	6	4%	11	3%
1997	13	9%	29	7%
1998	14	10%	25	6%
1999	17	12%	53	13%
2000	30	21%	101	25%
2001	10	7%	24	6%
2002	18	13%	43	11%
2003	18	13%	62	16%
2004	12	8%	38	10%
Total	142	100%	397	100%

Source: Advanced Technology Program, *Survey of ATP Joint Ventures*

TABLE 2

Survey Respondents: Projects and Companies, by Technology Area Project

	Projects		Companies	
Technology Area	Number	Percent	Number	Percent
Biotechnology	15	11%	27	7%
Chemistry/Materials	43	30%	102	26%
Electronics	41	29%	106	27%
Information Technology	17	12%	38	9%
Manufacturing (Discrete)	26	18%	124	31%
Total	142	100%	397	100%

Source: Advanced Technology Program, *Survey of ATP Joint Ventures*

point of a single participating company. For example, Arino (2003) collected responses from 83 Spanish companies participating in alliances in order to evaluate the construct validity of measures of alliance performance. While responses from more than one participating company were received in the case of four alliances, Arino (2003) randomly dropped company responses in order to keep only one response per alliance, thereby equating the company and alliance level of analysis. Geringer and Hebert (1991) justify their use of a single response per alliance by arguing that participants are aware of their collaborators' assessment of the alliance, and the assessments of their collaborators are in effect incorporated into their own assessment. While using a single response per alliance is generally accepted in alliance studies in part because of the difficulty of obtaining multiple responses, there are clearly potential problems with viewing alliance performance from the perspective of a single participating company. In particular, this is problematic in cases where Geringer and Hebert's (1991) assertion regarding the interdependence of alliance partners' performance assessments may not hold.

Our data enable us to assess empirically whether companies participating in the same alliance have similar assessments of the alliance performance. If responses are sufficiently similar, then they can be aggregated to form an alliance-level construct. If they cannot be aggregated, then the appropriate level of analysis is that of the participating companies. Procedures used to assess whether individual data can be aggregated to form group measures (Ostroff, 1993; James, 1982) can be applied to responses from companies participating in an alliance. Intraclass coefficients (ICC) provide a means of assessing whether data may be aggregated (Bliese, 2000). ICC(1) compares the proportion of variance accounted for by membership in a particular group—or in our analysis a particular alliance. An ICC(1) of 1 would indicate perfect agreement among firms in an alliance. Our data yields an ICC(1) of 0.12. While there is no standard cutoff for ICC(1), a value of 0.12 indicates a low level of agreement. ICC(2) is an estimate of the reliability of group (alliance) means; the ICC(2) for our data set is 0.28, well below the accepted cutoff of 0.70. These low values indicate that aggregation would be inappropriate for our data and that the appropriate unit of analysis for our study is that of participating companies rather than the alliance.

Part IV

Measures and Results

Dependent Variables

To provide a robust and comprehensive assessment of success, this study incorporates three distinct dimensions of the benefits to firms collaborating in R&D alliance—perceptual measures of success, patent measures, and financial measures. First, perceptual measures allow participants to qualitatively assess the extent to which the alliance achieved success in R&D collaboration. Perceptual measures have been found to be important for measuring success in R&D alliances because success in R&D alliances often means development or acquisition of knowledge as the collaborating firms pursue technology objectives (Anderson and Narus, 1990; Tuchi, 1996; Hebert and Beamish, 1997; Sakakibara, 1997). Also, additional in-house R&D is usually necessary to fully benefit from the outcomes of R&D alliances, making it difficult to evaluate alliances from their tangible results alone (Sakakibara, 2001). Use of managerial assessments of alliance performance received some initial criticism on concerns about potential bias and inaccuracy. But research by Geringer and Hebert (1991) shows that there is high correlation between subjective assessments of performance and objective financial measures based on accounting data. Thus, if properly conducted, managerial assessments of alliance performance are a reasonable way to measure alliance performance (Anderson and Weitz, 1989; Anderson, 1990; Child and Yan, 1999; Das and Teng, 2000). We use a survey-based measure for the firm's assessment of the overall success of the R&D alliance in terms of delivering value to the firm (**Overall_Value**).

Patents have been widely used as a measure of R&D output. We use patent application by the firm (**Patent_Application**) as a measure of outcomes from the research joint venture project. With indicator variables to control for differences in the propensity to patent across technology fields, patents are a good measure of the creation and formal ownership of intellectual property. Finally, we use an indicator of financial value from technology commercialization or implementation that the firm has already realized as a result of the research joint venture project. This measure (**Commercialization**) indicates whether the firm has received actual revenues from sales or licensing, or achieved actual cost savings, from commercializing or implementing technology developed in the R&D alliance. During interviews we were told that the most successful projects not only achieve technical objectives but also result in commercialized technology that generated some financial value for the company. While the amount of value may vary with a variety of factors (e.g., strength of competition, willingness of customers to adopt new

technology, emergence of alternative technologies, etc.), we consider any positive value created from the research joint venture project to be an indicator of the success of the project.

Table 3 presents a cross-tabulation of the three outcomes variables used in this study. The five response categories for **Overall_Value** are shown in the header column, and the four possible response combinations for **Patent_Application** and **Commercialization** are shown in the header row. From the top three rows of the table, we see that firm respondents may have a poor or neutral perceptual assessment of overall value of the alliance, even while the firm may have generated patent applications or financial value from technology commercialization. From the bottom two rows, we see that firm respondents may have a positive perceptual assessment of the overall value of the R&D alliance, even if the firm has not (yet) generated tangible outcomes such as patent applications or financial value from technology commercialization.

Independent Variables

To empirically test the hypotheses outlined earlier, we construct variables to be employed in regression analysis. The independent variables include both project-level (i.e., alliance-level) variables and firm-level variables. We use both administrative data and survey data in constructing these variables. From administrative data, we construct the following project-level variables:

- **Proj_Company_Count** is the number of company partners in the alliance;
- **Proj_Company_Distance** is a measure of the geographic distance between company partners;

TABLE 3

Tabulation of Outcomes Variables: Overall_Value, Patent_Application, Commercialization

Overall_Value	Patent_Application = No Commercialization = No	Patent_Application = No Commercialization = Yes	Patent_Application = Yes Commercialization = No	Patent_Application = Yes Commercialization = Yes	Row total
(1) Very Unsuccessful	10	0	0	0	10
(2) Unsuccessful	29	2	9	2	42
(3) Neither successful nor unsuccessful	53	2	15	6	76
(4) Successful	75	34	48	25	182
(5) Very Successful	16	25	24	19	84
Column total	**183**	**63**	**96**	**52**	**394**

Source: Advanced Technology Program, Survey of ATP Joint Ventures

- **Proj_Total_Budget** is the total project budget for the research joint venture project;
- **Proj_Tech_Bio, Proj_Tech_Chem, Proj_Tech_Elec, Proj_Tech_IT** are indicator variables for the technology area of the project, i.e., Biotechnology, Chemistry/Materials, Electronics, Information Technology;
- **Proj_Endyear_00_02, Proj_Endyear_03_04** are indicator variables for the end year of the project, i.e., 2000-2002, 2003-2004.

Firm-level variables constructed from administrative data include:

- **Lead_Company** is an indicator for the formal lead company for the research joint venture;
- **Small_Company** is an indicator that the company has fewer than 500 employees.

From survey data, we construct the following project-level variables:

- **Proj_Ambitiousness** is a measure of the ambitiousness of the R&D alliance project goals relative to other R&D initiatives in the industry;
- **Proj_Current_Competitor** is an indicator for whether the alliance includes companies that are competitors in product markets;
- **Proj_Contract_Governance** is a measure of satisfaction with the formal alliance agreement and governance procedures developed in the alliance;
- **Proj_Goodwill_Trust** is a measure of goodwill trust among the alliance partners.

Firm-level variables constructed from survey data include:

- **General_Alliance_Experience** is a measure of company project personnel's previous experience with inter-firm R&D collaborations in general;
- **Partner_Specific_Experience** is a measure of company project personnel's prior experience working with personnel from selected alliance partners in the current collaboration;
- **Frequency_Communication** is a measure of the frequency of communication by company project personnel with personnel from alliance partners;
- **Joint_Work_Interaction** is a measure of company project personnel's interaction with personnel from alliance partners to carry out joint work on project tasks;
- **RD_Employment** is the number of R&D employees at the company location;
- **FTE_Technical** is the number of company full-time equivalent technical staff that work on the project, on average per year.

Regression Results

The variables employed in regression analysis are displayed in Table 4, which also provides additional details on the definition and construction of the variables. Table 5 provides summary statistics for the variables. The average firm in the sample has a perceptual measure of the **Overall_Value** of the alliance outcomes that is above the neutral value of "3", which represents a survey response that the alliance was "neither successful nor unsuccessful" in delivering overall value to the company. The mean values of **Patent_Application** and **Commercialization** indicate that 37 percent of firms in the sample filed a patent application, and 29 percent of firms achieved revenues or cost savings from commercialization of technology developed in the alliance.

TABLE 4
Description of Variables

Overall_Value	The respondent's overall assessment of the success of the alliance in delivering value to the company. An ordered categorical variable from a survey item with a 5-point Likert scale.
Patent_Application	Indicator for whether the company has filed any patent applications as a result of the alliance. A binary variable derived from a survey item.
Commercialization	Indicator for whether the company has achieved actual revenues or cost savings from commercialization of technology as a result of the alliance. A binary variable derived from survey items.
Proj_Company_Count	The number of companies in the alliance. A project-level integer variable derived from administrative records.
Proj_Ambitiousness	The ambitiousness of the alliance objectives relative to other R&D initiatives in the industry. A project-level numerical variable derived from a survey item with a 7-point Likert scale. Responses from all project respondents are averaged to form a project-level variable.
Proj_Current_Competitor	Indicator for whether the alliance includes any companies that are current competitors. A project-level binary variable derived from a survey item indicating whether a selected alliance partner is a competitor in a product market. Responses from all project respondents regarding selected alliance partners are incorporated.
General_Alliance_Experience	The extent to which company R&D project personnel have previous experience with inter-firm R&D collaborations. An ordered categorical variable from a survey item with a 4-point Likert scale.

CONTINUED

TABLE 4

Description of Variables (Continued)

Partner_Specific_Experience	The extent to which company R&D project personnel have prior experience working with R&D project personnel from selected alliance partners. A numerical variable derived from a survey item with a 4-point scale. Responses regarding selected alliance partners are averaged.
Proj_Company_Distance	The average of bilateral geographic distances between company locations calculated for each pair of company partners in the alliance. A project-level numerical variable derived from administrative records. Measured in 1000s miles.
Frequency_Communication	The frequency of communication of company R&D project personnel with alliance partner staff by telephone, email, or video-conference. An ordered categorical variable from a survey item indicating frequency of communication as: several times a week, weekly, biweekly, monthly, quarterly.
Joint_Work_Interaction	The numbers of days per year, on average, that company R&D project personnel meets with alliance partner staff to carry out joint work on project tasks. An integer variable derived from a survey item.
Proj_Contract_Governance	The extent to which project respondents are satisfied with the alliance agreement and other governance procedures with regard to: protection of contributed intellectual property, ownership of new intellectual property, resolution of disputes or disagreements, and verification of work task performance. A project-level numerical variable derived from four survey items each with a 5-point Likert scale. Responses from all project respondents are averaged to form a project-level variable.
Proj_Goodwill_Trust	The extent to which project respondents trust alliance partners to show goodwill and not take unfair advantage. A project-level numerical variable derived from two survey items each with a 4-point Likert scale. Responses regarding selected alliance partners are averaged. Responses from all project respondents are averaged to form a project-level variable.
R&D_Employment	The number of R&D employees at the company location. An integer variable derived from a survey item. Measured in 1000s persons.
FTE_Technical	The number of company full-time equivalent technical staff that work on the R&D alliance project, on average per year. An integer variable derived from a survey item.

CONTINUED

TABLE 4
Description of Variables (Continued)

Proj_Total_Budget	The total budget of the R&D alliance project, including funding from the government award as well as cost-share contribution from alliance partners. A project-level numerical variable from administrative records. Measured in 1,000,000s dollars.
Lead_Company	Indicator for whether the company is the formal lead company for the R&D alliance project. A binary variable from administrative records.
Small_Company	Indicator for whether the company is a small company with fewer than 500 employees. A binary variable from administrative records.
Proj_Tech_Bio	Indicator for whether the R&D alliance project represents a biotechnology area. A project-level binary variable from administrative records.
Proj_Tech_Chem	Indicator for whether the R&D alliance project represents a chemistry/materials technology area. A project-level binary variable from administrative records.
Proj_Tech_Elec	Indicator for whether the R&D alliance project represents an electronics technology area. A project-level binary variable from administrative records.
Proj_Tech_IT	Indicator for whether the R&D alliance project represents an information technology area. A project-level binary variable from administrative records.
Proj_Endyear_00_02	Indicator for whether the R&D alliance project ended during the time period 2000-2002. A project-level binary variable from administrative records.
Proj_Endyear_03_04	Indicator for whether the R&D alliance project ended during the time period 2003-2004. A project-level binary variable from administrative records.

Table 6 presents the matrix of correlation coefficients for the variables used in the regression analysis. The three outcomes variables **Overall_Value, Patent_Application,** and **Commercialization** are correlated with each other. The three outcomes variables are each positively correlated with **Proj_Ambitiousness, Frequency_Communication,** and **FTE_Technical**. Two of the outcomes variables**—Overall_Value** and **Patent_Application—**are negatively correlated with **Proj_Company_Count** and **Proj_Current_Competitor,** and positively correlated with **Proj_Contract_Governance** and **Lead_Company.**

TABLE 5

Summary Statistics for Variables

Variable	N	Mean	Std Dev	Min	Max
Overall_Value	394	3.73	0.996	1	5
Patent_Application	397	0.375	0.485	0	1
Commercialization	397	0.292	0.455	0	1
Proj_Company_Count	397	5.53	4.42	2	22
Proj_Ambitiousness	397	5.64	0.770	1	7
Proj_Current_Competitor	397	0.086	0.280	0	1
General_Alliance_Experience	396	2.71	0.787	1	4
Partner_Specific_Experience	391	2.17	0.907	1	4
Proj_Company_Distance	397	0.763	0.601	0.001	2.600
Frequency_Communication	390	3.47	1.22	1	5
Joint_Work_Interaction	382	21.3	30.4	0	360
Proj_Contract_Governance	393	14.9	1.93	10	20
Proj_Goodwill_Trust	392	6.52	0.892	2.5	8
R&D_Employment	380	0.237	0.351	0	1.000
FTE_Technical	384	4.04	3.95	0	25
Proj_Total_Budget	397	13.1	9.92	1.5	63
Lead_Company	397	0.247	0.432	0	1
Small_Company	397	0.358	0.480	0	1
Proj_Tech_Bio	397	0.068	0.252	0	1
Proj_Tech_Chem	397	0.257	0.437	0	1
Proj_Tech_Elec	397	0.267	0.443	0	1
Proj_Tech_IT	397	0.096	0.295	0	1
Proj_Endyear_00_02	397	0.423	0.495	0	1
Proj_Endyear_03_04	397	0.252	0.435	0	1

Source: Advanced Technology Program, *Survey of ATP Joint Ventures*

Notes:

Variables with name prefix *Proj_* are defined as project-level variables (i.e., all members of a project/alliance have the same value for the variable).

For the *Proj_Tech_* variables indicating project technology area, the omitted category is the Manufacturing technology area.

The value for *R&D_Employment* may be zero if no company employees are designated as R&D employees, or if the company no longer has R&D employees at the specified location at the time of the survey.

The value for *FTE_Technical* may be zero if the company provides less than one full-time equivalent technical staff person to the project per year.

TABLE 6
Correlation Matrix for Variables

Variable		1	2	3	4	5	6	7	8	9	10
Overall_Value	1										
Patent_Application	2	0.21***									
Commercialization	3	0.33***	0.11**								
Proj_Company_Count	4	-0.13***	-0.29***	0.01							
Proj_Ambitiousness	5	0.23***	0.23***	0.10**	-0.28***						
Proj_Current_Competitor	6	-0.10**	-0.13**	-0.04	0.01	-0.12**					
General_Alliance_Experience	7	0.17***	0.01	0.03	-0.16***	0.18***	-0.04				
Partner_Specific_Experience	8	0.02	-0.05	-0.01	0.03	-0.01	0.06	0.23***			
Proj_Company_Distance	9	0.04	0.08	-0.03	-0.21***	-0.04	0.10**	-0.08	-0.12**		
Frequency_Communication	10	0.23***	0.26***	0.13**	-0.05	0.08*	-0.12**	0.06	0.07	0.00	
Joint_Work_Interaction	11	0.06	-0.01	0.02	0.12**	0.06	0.00	0.13**	0.11**	-0.15***	0.33***
Proj_Contract_Governance	12	0.21***	0.19***	-0.02	-0.15***	0.17***	-0.05	0.12**	-0.02	-0.17***	0.14***
Proj_Goodwill_Trust	13	-0.01	-0.09*	0.03	0.21***	0.00	-0.16***	0.00	-0.10**	-0.20***	0.11**
R&D_Employment	14	-0.02	0.15***	-0.07	-0.14***	0.18***	0.08	0.02	0.13**	0.05	0.11**
FTE_Technical	15	0.23***	0.35***	0.19***	-0.30***	0.20***	-0.05	0.04	0.05	0.11**	0.24***
Proj_Total_Budget	16	0.04	-0.01	0.03	0.14***	-0.03	0.14***	-0.05	-0.04	0.09*	0.03
Lead_Company	17	0.23***	0.42***	0.07	-0.34***	0.15***	-0.11**	0.12**	0.10*	0.21***	0.21***
Small_Company	18	0.00	-0.07	0.12**	0.08	-0.12**	0.02	0.00	-0.11**	-0.02	-0.12**
Proj_Tech_Bio	19	0.02	0.12**	0.16***	-0.18***	0.09*	-0.05	0.05	-0.11**	-0.01	-0.02
Proj_Tech_Chem	20	0.05	0.08	0.00	-0.21***	0.07	0.05	-0.04	-0.01	0.03	0.11**
Proj_Tech_Elec	21	0.13**	0.11**	-0.04	-0.19***	-0.03	-0.02	0.11**	0.05	0.18***	-0.06
Proj_Tech_IT	22	-0.08*	-0.08	-0.06	-0.05	-0.01	0.08*	-0.05	-0.10**	0.14***	0.14***
Proj_Endyear_00_02	23	-0.06	0.01	0.04	0.14***	-0.03	-0.10*	-0.03	0.06	-0.01	-0.01
Proj_Endyear_03_04	24	0.19***	0.04	-0.12**	-0.03	0.18***	-0.12**	0.22***	-0.10*	-0.01	-0.02

Notes:
* indicates statistical significance at the 0.10 level
** indicates statistical significance at the 0.05 level
*** indicates statistical significance at the 0.01 level
Source: Advanced Technology Program, Survey of ATP Joint Ventures

Among the independent variables, we find that **Frequency_Communication** is negatively correlated with **Proj_Current_Competitor**, and positively correlated with **Lead_Company** and **FTE_Technical.** We find that **Proj_Contract_Governance** is negatively correlated with **Proj_Company_Count** and **Proj_Company_Distance**, and positively correlated with **General_Alliance_Experience** and **Frequency_Communication.** We find that **Proj_Goodwill_Trust** is negatively correlated with **Proj_Current_Competitor**, **Partner_Specific_Experience**, and **Proj_Company_Distance**, and positively correlated with **Proj_Company_Count, Frequency_Communication**, and **Proj_Contract_Governance.**

11	12	13	14	15	16	17	18	19	20	21	22	23
0.09*												
0.04	0.26**											
0.03	0.11**	-0.06										
0.00	0.05	-0.04	0.23***									
-0.01	0.00	-0.04	0.07	0.25***								
0.04	0.13***	-0.02	0.12**	0.49***	-0.11**							
-0.05	-0.11**	0.02	-0.46***	-0.05	-0.04	0.01						
-0.02	-0.14***	-0.09*	-0.02	0.16***	0.01	0.12**	0.22***					
-0.05	0.03	0.08*	0.03	0.05	-0.17***	0.12**	-0.15***	-0.16***				
-0.04	0.28***	-0.05	0.07	0.10*	0.06	0.06	0.02	-0.16***	-0.35***			
0.05	-0.09*	-0.08*	0.05	0.10**	0.39***	-0.03	-0.03	-0.09*	0.19***	-0.20***		
-0.03	-0.01	-0.03	-0.01	0.04	0.11**	-0.02	-0.01	-0.03	0.03	-0.06	0.00	
0.02	0.09*	0.06	-0.03	-0.06	-0.04	0.00	-0.01	-0.06	-0.17***	0.21***	-0.07	-0.50***

Tables 7, 8, and 9 present the results from multiple regression analysis used to test the hypotheses presented earlier. The three tables present results for the three outcomes variables **Overall_Value**, **Patent_Application**, and **Commercialization**, respectively. Equations (1abc) provide alternative specifications for testing Hypothesis (3) and (7ab) relating to geographic distance of partner companies, and the frequency of communication and interaction. Equations (2ab) provide alternative specifications for testing Hypothesis (4ab) relating to general and partner-specific alliance experience. Equations (3) and (4) present alternative specifications for testing Hypothesis (5) and (6), respectively. The other variables of interest for testing the hypotheses are included in all of the regression specifications.

Table 7 presents regression results for the outcome variable **Overall_Value**. The coefficient for **Frequency_Communication** is consistently positive, supporting the hypothesis that frequent communication is a key alliance management factor for success. Equations (1abc) show that geographic distance and face-to-face work interaction have no effect, and therefore

the frequency of communication is independent of geography and face-to-face interaction. Equations (2ab) show that the prior alliance experience variables do not have an effect on the perceptual measure of overall value. The coefficient for **Proj_Contract_Governance** is consistently positive, which supports the hypothesis that contractual provisions and governance procedures are important to alliance success. Somewhat surprisingly, we find that **Proj_Goodwill_Trust** has a marginally significant negative coefficient in some equation specifications. Also contrary to expectations, we find in Equation (3) that **R&D_Employment** has a negative coefficient. In Equation (4), we find no effect of **FTE_Technical** on the perceptual measure of outcomes. We find in all specifications that the number of companies in the alliance, and the presence of competitors, do not have an effect on the perceptual measure of overall value. This finding suggests that alliance designers are successful in structuring the alliance to have the appropriate number and types of partners. The coefficient for **Proj_Ambitiousness** is positive in all specifications, which indicates that projects with ambitious goals deliver greater perceived value to the participants. The coefficient for **Lead_Company** is also generally positive, indicating that more active or leading members of an alliance are more likely to experience successful outcomes.

Table 8 presents regression results for the outcome variable **Patent_Application**. Equations (1abc) show that frequency of communication has a positive effect on the outcomes variable, while geographic distance and face-to-face interaction do not have any effect. Contrary to expectations, we see in Equations (2ab) that **General_Alliance_Experience** and **Partner_Specific_Experience** have negative coefficients. **Proj_Contract_Governance** has a marginally statistically significant positive effect in some specifications, and **Proj_Goodwill_Trust** has a statistically significant negative effect in most specifications. Equation (3) shows that **R&D_Employment** has no effect, and Equation (4) shows a marginally significant positive coefficient for **FTE_Technical**. The number of companies in the alliance, indicated by **Proj_Company_Count**, has a marginally significant negative effect in most specifications, while the presence of competitors has no effect. **Proj_Ambitiousness** has a statistically significant positive effect in most specifications, and **Lead_Company** has a positive effect in all specifications.

Table 9 presents regression results for the outcome variable Commercialization. Again, we find the coefficients for **Frequency_Communication** and **Proj_Ambitiousness** to be consistently positive. In Equation (4), we find that **FTE_Technical** has a positive coefficient, indicating that greater allocation of technical personnel to the project increases the likelihood of successful outcomes. We do not find the other main variables of interest to have any effect on the commercialization outcomes variable.

TABLE 7

Regression Results for Outcomes Variable: Overall_Value

Dependent variable: Overall_Value

Estimation method: OLS

	(1a)	(1b)	(1c)	(2a)	(2b)	(3)	(4)
Proj_Company_Count	0.00978	0.00198	0.00430	0.00229	0.00222	0.00278	0.00571
Proj_Ambitiousness	0.18676***	0.18658***	0.16959**	0.17274**	0.19500***	0.19491***	0.18187***
Proj_Current_Competitor	-0.23801	-0.16669	-0.28411	-0.17219	-0.16862	-0.04968	-0.19033
General_Alliance_Experience				0.07428			
Partner_Specific_Experience					0.02099		
Proj_Company_Distance	0.08143						
Frequency_Communication		0.15701***		0.15709***	0.15846***	0.17436***	0.14349***
Joint_Work_Interaction			0.00154				
Proj_Contract_Governance	0.07620***	0.05954**	0.06560**	0.05638**	0.05778**	0.05655**	0.06118**
Proj_Goodwill_Trust	-0.07421	-0.09294	-0.09838	-0.09659*	-0.09176	-0.09825*	-0.10788*
R&D_Employment						-0.30891**	
FTE_Technical							0.02166
Proj_Total_Budget	0.01101**	0.01283**	0.01339**	0.01340**	0.01145**	0.01457**	0.00969
Lead_Company	0.41462***	0.31356***	0.40648***	0.29505**	0.32519***	0.33497***	0.21346
Small_Company	0.08453	0.10215	0.06162	0.09065	0.12313	0.02468	0.08681
Proj_Tech_Bio	0.10771	0.10211	0.14458	0.09439	0.10086	0.14713	0.08658
Proj_Tech_Chem	0.21405	0.15927	0.25231*	0.15183	0.16169	0.19130	0.16147
Proj_Tech_Elec	0.13903	0.17111	0.19499	0.16256	0.17678	0.19718	0.18011
Proj_Tech_IT	-0.22935	-0.35857*	-0.23289	-0.36503*	-0.27980	-0.33607	-0.33642*
Proj_Endyear_00_02	-0.00578	0.01430	-0.00509	0.01120	0.03050	0.04579	0.03959
Proj_Endyear_03_04	0.34377**	0.35036***	0.34501**	0.32892**	0.35669***	0.36679***	0.37208***
Constant	1.48630**	1.42069**	1.91670***	1.37698**	1.33465**	1.41793**	1.51206***
N (number of observations)	394	389	381	388	386	375	380

Notes:

* indicates statistical significance at the 0.10 level

** indicates statistical significance at the 0.05 level

*** indicates statistical significance at the 0.01 level

TABLE 8

Regression Results for Outcomes Variable: Patent_Application

Dependent variable: Patent_Application
Estimation method: Logit

	(1a)	(1b)	(1c)	(2a)	(2b)	(3)	(4)
Proj_Company_Count	-0.0624	-0.0819*	-0.0617	-0.0956**	-0.0785*	-0.0834*	-0.0722
Proj_Ambitiousness	0.3721**	0.3861**	0.3853**	0.3962**	0.4103**	0.3393*	0.3356*
Proj_Current_Competitor	-0.7963	-0.5608	-0.7253	-0.4915	-0.5123	-0.6558	-0.5385
General_Alliance_Experience				-0.3965**			
Partner_Specific_Experience					-0.3647**		
Proj_Company_Distance	0.239						
Frequency_Communication		0.4679***		0.4929***	0.4974***	0.4677***	0.4132***
Joint_Work_Interaction			-0.00113				
Proj_Contract_Governance	0.1680**	0.1033	0.1381*	0.1252	0.1020	0.1117	0.1148
Proj_Goodwill_Trust	-0.2761*	-0.3382**	-0.2676*	-0.3590**	-0.3850**	-0.3315**	-0.3423**
R&D_Employment						0.379	
FTE_Technical							0.0817*
Proj_Total_Budget	0.0179	0.0280*	0.0270*	0.0280*	0.0258*	0.0301*	0.0188
Lead_Company	1.7691***	1.5879***	1.7294***	1.6195***	1.7473***	1.5275***	1.2764***
Small_Company	-0.3119	-0.2496	-0.3447	-0.2618	-0.2731	-0.1360	-0.2404
Proj_Tech_Bio	0.7278	0.7995	0.8007	0.8442	0.5882	0.6625	0.6092
Proj_Tech_Chem	0.1999	0.1077	0.1882	0.0324	0.0039	0.0383	0.0221
Proj_Tech_Elec	0.1693	0.1985	0.1872	0.1999	0.1823	0.0139	0.0662
Proj_Tech_IT	-0.7277	-1.2427**	-0.7745	-1.3675**	-1.2942**	-1.3037**	-1.3367**
Proj_Endyear_00_02	0.1001	0.2783	0.1913	0.3479	0.3133	0.2945	0.2817
Proj_Endyear_03_04	0.1196	0.3085	0.1855	0.5014	0.2038	0.3257	0.3375
Constant	-3.9403**	-4.2304***	-3.5712**	-3.4948**	-3.3088**	-4.1481**	-3.9932**
N (number of observations)	397	390	382	389	387	376	381

Notes:

* indicates statistical significance at the 0.10 level

** indicates statistical significance at the 0.05 level

*** indicates statistical significance at the 0.01 level

TABLE 9

Regression Results for Outcomes Variable: Commercialization

Dependent variable: Commercialization
Estimation method: Logit

	(1a)	(1b)	(1c)	(2a)	(2b)	(3)	(4)
Proj_Company_Count	0.0306	0.0250	0.0355	0.0309	0.0280	0.0311	0.0377
Proj_Ambitiousness	0.4702**	0.4646**	0.4786**	0.4840**	0.4779**	0.5143***	0.4230**
Proj_Current_Competitor	-0.3034	-0.1843	-0.2950	-0.2087	-0.1775	-0.1245	-0.0801
General_Alliance_Experience				0.1070			
Partner_Specific_Experience					-0.0651		
Proj_Company_Distance	-0.04						
Frequency_Communication		0.2745***		0.1066**	0.2728**	0.2724**	0.1956*
Joint_Work_Interaction			0.00106				
Proj_Contract_Governance	-0.0321	-0.0583	-0.0380	-0.0630	-0.0629	-0.0659	-0.0222
Proj_Goodwill_Trust	0.0989	0.1082	0.1362	0.1240	0.1028	0.1253	0.1060
R&D_Employment						-0.44	
FTE_Technical							0.1033***
Proj_Total_Budget	0.0166	0.0208	0.0197	0.0207	0.0191	0.0277*	0.0050
Lead_Company	0.2839	0.1614	0.3073	0.1888	0.1982	0.2098	-0.2583
Small_Company	0.4975**	0.5895**	0.5370**	0.6107**	0.5982**	0.4546	0.6150**
Proj_Tech_Bio	0.8210	0.9704*	0.9176*	0.9538*	0.9244*	0.9132*	0.7382
Proj_Tech_Chem	0.0315	-0.0480	-0.0202	-0.0026	-0.0655	-0.1995	-0.1652
Proj_Tech_Elec	0.0809	0.0599	0.0001	0.0675	0.0619	0.0252	-0.1338
Proj_Tech_IT	-0.5799	-0.8945	-0.7544	-0.8702	-0.8209	-1.0999*	-0.9478*
Proj_Endyear_00_02	-0.1881	-0.2064	-0.2474	-0.2512	-0.1838	-0.3075	-0.2438
Proj_Endyear_03_04	-0.8989***	-0.9322***	-1.0299***	-1.0124***	-0.9519***	-1.0667***	-0.9738***
Constant	-4.0812**	-4.6587***	-4.2515***	-5.0625***	-4.4840***	-4.7422***	-4.7167***
N (number of observations)	397	390	382	389	387	376	381

Notes:

* indicates statistical significance at the 0.10 level

** indicates statistical significance at the 0.05 level

*** indicates statistical significance at the 0.01 level

Part V

Discussion

Our results show that R&D alliance success is influenced by a combination of alliance design factors and alliance management factors. These may include alliance structural characteristics such as the number of partners or the presence of competitors; alliance partner attributes such as R&D capabilities or prior alliance experience; alliance management factors such as allocation of technical personnel, frequency of communication, or effectiveness of governance arrangements.

When designing an alliance, firms may systematically underestimate the challenges of collaborating with multiple partners as well as competitors. A number of respondents we interviewed cited “coordination” problems associated with having too many alliance partners. Stated one participant, “From my perspective, there were just too many [participants]. First, it took too long getting to know everyone. In addition, scheduling meetings was a nightmare; we had to schedule meetings a year in advance. It was just too difficult to coordinate.” (Dyer and Powell 2001, p.14). Of course, at the alliance formation stage, the alliance partners evidently believe that each partner brings something worthwhile to the alliance—but they may misjudge the extent to which coordination and transaction costs increase as the number of partners increase. In our data, we find that the likelihood of patent application declines when the alliance has three or more members, but the perceptual measure of overall value does not fall until the alliance includes eight or more members. While this negative correlation of outcomes with number of alliance partners is evidenced in the simple correlation coefficients, the multiple regression analysis provides less support for the hypothesis that alliance designers tend to include too many partners in the alliance at the time of forming the alliance.

Similarly, while the simple correlation coefficient indicates that alliance outcomes are negatively correlated with the presence of competitors, the multiple regression analysis does not find evidence for the hypothesis that competitor alliances perform less well than alliances that do not involve competitors. But the simple correlation coefficients do indicate that competitor alliances are characterized by less frequent communication and lower levels of goodwill trust. As one participant noted, “With vertical [supplier-customer alliances], there are no direct competitors and everyone is in a win-win situation. As a result, everyone is more likely to lay their cards on the table. But that’s not true with horizontal [competitor alliances]. When you are direct competitors, you are more guarded and keep your cards close to the vest.” (Dyer and Powell, 2001, p.12). While some participants indicated that having competitors in an alliance is a problem, at least one said that he didn’t think it was a problem working with competitors:

"We've developed a good working relationship with our [competitors]. We all share information and do what we can to make the project successful. I don't see this as a problem." (Dyer and Powell, 2001, p.13).

Prior studies have found that alliance experience is correlated with alliance success. As a simple correlation, we find that general R&D alliance experience is positively correlated with the perceptual measure of overall value, but estimates in multiple regression show that there is no effect. For patent application as the measure of outcomes, while there is no simple correlation with either general alliance experience or partner-specific experience, the multiple regressions show that both general alliance and partner-specific experience have a negative effect on the likelihood of patent application. Since many of the firms in our study are large firms, they may have reached the point of diminishing returns to general alliance experience as Hoang and Rothaermel (2005) suggest. In theory, we expect partner-specific experience to increase trust, information sharing, and the effectiveness of coordination among alliance partners. This is supported by interviewed respondents who claim that pre-existing relationships among the key participants is helpful in getting the alliance started. However, while partner-specific experience may be helpful in getting an alliance started, for R&D alliances where innovation is the key objective, prior partner-specific experience may imply greater knowledge overlap and less novelty. Thus, prior partner-specific experience, while helpful for alliances where value is achieved through working together efficiently, may not be as helpful when the task objectives are creativity and innovation. Indeed, some participants felt that first time collaborations are just as likely to produce a "creative" or "novel" research outcome as a third or fourth collaboration. Hoang and Rothaermel (2005) also find a negative relationship between partner-specific experience and successful outcomes in drug development R&D alliances. It appears that prior partner-specific experience is valuable when success depends on efficiency (low transaction and coordination costs) but not when success depends on creativity and innovation.

Our results indicate that "contractual trust" has a positive effect on R&D alliance success, whereas "goodwill trust" appears to have a negative effect on R&D alliance success. We define "goodwill trust" as confidence that an alliance partner will not take advantage of situations opportunistically. Protection against malfeasance can also be generated through "contractual trust" based on contractual agreements. We find that R&D alliances where alliance partners have developed effective contract provisions and governance procedures are more likely to deliver overall value to the company. Participants expressed in interviews that confidence in intellectual property protections was critical for knowledge-sharing to occur. Indeed, our interviews reveal that governance issues are especially important at the start of an alliance—some firms are highly satisfied with the agreements, while others are less comfortable from the beginning.

Our results give strong support to the idea that R&D alliances must be organized to facilitate frequent interaction. We find that frequency of communication is strongly associated with all three outcomes measures. To facilitate face-to-face interaction, some companies send their R&D personnel to meet for a period of time at the premises of another partner firm. The participants we interviewed felt that this coordination routine enhanced interaction and improved coordination, as the alliance partners worked together to solve complex technical problems. As stated by one company representative,

> On one project we learned much more by meeting for long periods of time at each other's facilities. For example, our partner had assured us that moisture sensitivity would not be a problem. This was something that we had been concerned about. When we co-located our personnel for a period of time, we learned that they thought that preventing moisture problems for an *hour* was a long time, while we thought preventing it for a week was a long time. We sorted this out in a moment once we got together [in the same location]. (Dyer and Powell, 2001, p.16)

While we find that frequency of communication is a strong predictor of success, we do not find that face-to-face joint work interaction has an effect on success, nor do we find geographic distance of alliance partners to have any effect on success. We do find that joint work interaction is negatively correlated with geographic distance, and positively correlated with frequency of communication. Since regular project review meetings provide opportunity for face-to-face interaction between alliance partners, and establish a context for ongoing communication, it appears that face-to-face joint work interaction is not critical to success.

Finally, we find that the ambitiousness of overall goals, as a characteristic of the R&D alliance project, is strongly associated with all three outcomes measures. R&D alliances with compelling goals are likely to have strong individual commitment to the effort, which may be most important to success. Related to project commitment and effort, we find that being the lead company for the research joint venture project is associated with success in terms of delivering overall value and generating patent applications. The firm's allocation of technical personnel resources to the project is also associated with success in terms of generating patent applications and producing financial value through commercialization of technology.

Part VI

Conclusion

This study examines a complete set of alliance design factors and alliance management factors that may influence R&D alliance success. Relative to the hypotheses presented above, we derive the following conclusions from our empirical analysis:

(1) *Number of alliance partners.* We find that the number of alliance partners has a weakly negative effect on patent application, and no effect on overall value or commercialization. The evidence suggests that alliance designers are largely successful in achieving an "optimal" number of alliance partners, balancing the marginal benefit of adding an additional partner to the marginal cost associated with an additional partner.

(2) *Presence of competitors.* Simple correlations show that alliances with competitor firms have less frequent communication and lower levels of goodwill trust. But in multiple regression analysis we find that the presence of competitors in an alliance has no effect on alliance outcomes. Again, this suggests that alliance designers are largely successful in "optimizing" the structure of the alliance.

(3) *Geographic distance between alliance partners.* Simple correlations show that alliances with greater geographic distance between partners have less joint work interaction, and lower levels of governance effectiveness and goodwill trust. But in multiple regression analysis, we do not find that geographic distance has any effect on alliance outcomes. The simple correlations also show that frequency of communication between alliance partners has no correlation with geographic distance, so it appears that geographic distance does not affect the communication, knowledge sharing, and coordination necessary for successful alliance outcomes.

(4) *General and partner-specific alliance experience.* We find that general alliance experience and partner-specific experience have a negative effect on patent application as a performance outcome. This may suggest that creativity and invention are more likely when new partners come together in new collaborations to combine ideas, different approaches, and complementary knowledge.

(5) *R&D capability.* We find that R&D employment at the company location has a negative effect on overall value as a performance outcome, and no effect on either the patent application or commercialization measures. We use R&D employment as a proxy measure of the R&D capability of the firm. One explanation for the finding of

negative or no effect of R&D employment on outcomes is that R&D employment is also a measure of firm size, and R&D personnel in large firms have greater institutional hurdles to overcome in order to realize the potential of their research results.

(6) *Number of technical personnel.* We find that the number of technical personnel resources has a positive effect on patent application and on commercialization of technology. This result supports the view that innovation and learning outcomes depend on the number of technical personnel engaged in the effort.

(7) *Frequency of communication.* We find that frequency of communication has a strong statistically significant positive effect on all three outcomes measures for R&D alliance performance. The finding suggests that alliance managers can increase the likelihood of alliance success by establishing routines that encourage frequent communication. Frequent communication facilitates the knowledge sharing and coordination that is critical to alliance success.

(8) *Governance arrangements.* We find that effective governance arrangements have a positive effect on the perceptual measure of overall value, and a weakly positive effect on the patent application measure. This finding highlights the importance of establishing contractual provisions and governance procedures as a factor in alliance success, for example, in protecting intellectual property rights, monitoring task performance, and resolving disputes.

(9) *Goodwill trust.* We find that goodwill trust among alliance partners has a weakly negative effect on the perceptual measure of overall value, and a negative effect on the patent application measure. The results suggest that successful alliances do not depend only on goodwill trust, but develop contractual-based trust that is generated through contractual provisions and effective governance arrangements. In other words, in alliance management, one would do well to "Trust, but verify."

Finally, we find that "reaching for the stars" is a strong predictor of alliance success. More ambitious projects with farther reaching goals demonstrate greater success on all three measures of R&D alliance performance. More ambitious projects have intrinsically greater potential value and potential impact. In addition, more ambitious projects are likely to mobilize greater commitment and effort on the part of both the partner companies and the individual participants.

For strategy and innovation scholars, this study demonstrates the usefulness of employing multiple measures of success in the analysis of R&D alliances. Each type of measure—perceptual measure of overall value, patent application, and financial value from commercialization—has drawbacks, but by considering them together we are able to gain a richer understanding of the factors that explain R&D alliance success. Researchers may gain additional insight into the determinants of alliance success by analyzing which factors are common to various outcome measures, and which factors influence only a specific outcome. Some fac-

tors, such as prior experience or goodwill trust, may well be determinants of success in some types of alliances, such as manufacturing or marketing alliances, but not in other types of alliances, such as R&D alliances where creativity and innovation are central. Our research suggests that there are fundamental differences between R&D alliances and other types of alliances, and consequently, the factors that influence success may be quite different. For example, R&D alliances involve high risk and uncertainty as a fundamental characteristic, and so there are inherent limitations to applying past experience in future projects. Though many research studies combine R&D alliances and other types of alliances as a single subject for analysis, we conclude that R&D alliances should be treated as a separate and independent type of collaborative activity.

For companies engaging in R&D alliances, and government agencies that support collaborative R&D, this study shows that alliance management is important for alliance success. While outcomes of research projects are inherently uncertain and determined in part by chance, there are managerial factors which can increase the odds of success. In particular, managers can increase the likelihood of success by: (a) carefully considering the composition and structure of alliances, in terms of number of partners, involvement of competitors, attributes of alliance partners, etc.; (b) establishing effective contractual provisions and governance procedures; and (c) managing R&D alliances to ensure frequent communication among participants.

This study includes only government-sponsored R&D alliances in the United States. One might ask whether the results of this study generalize to other R&D alliances that do not have government support, or to R&D alliances in different institutional settings. In order to evaluate whether findings from this study also hold for privately-funded R&D alliances or R&D alliances in other settings, further research in broader samples may be conducted.

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About the Authors

Jeffrey H. Dyer is the Horace Pratt Beesley Professor of Global Strategy at the Marriott School of Management, Brigham Young University. His research focuses on strategic alliances, creativity and innovation, and interorganizational learning and knowledge management. He serves on the editorial board of Strategic Management Journal, Organization Science, and Strategic Organization. He has consulted at companies such as Motorola, Ford, Navistar, Bang & Olufsen. He received his Ph.D. in Management from the University of California, Los Angeles.

Benjamin C. Powell is Assistant Professor of Management at the Culverhouse College on Commerce and Business Administration, University of Alabama. His research focuses on organizational formation and knowledge processes, interorganizational learning and R&D alliances. He received his Ph.D. in Management from the University of Pennsylvania.

Mariko Sakakibara is Associate Professor of Policy at the Anderson School of Management at the University of California, Los Angeles (UCLA). Her research interests include innovation, alliances, multinational enterprises, and global competition. Prior to coming to the United States as a Fulbright Scholar, she was Deputy Director at the Ministry of International Trade and Industry, Japan. She received her Ph.D. in Business Economics from Harvard University.

Andrew J. Wang is Economist in the Economic Assessment Office at the Advanced Technology Program, National Institute of Standards and Technology (NIST). He conducts research relevant to program evaluation and policy. He has managed economic studies and other projects, and has led development of special surveys of program participants. He received his Ph.D. in Economics from Harvard University.

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