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Honeymoons and Liabilities: The Relationship between Age and Performance in Research and Development Alliances

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The use of strategic alliances by technology ventures has increased dramatically over the last 20 years. During this period companies not only have increased the use of alliances but also have used them in more strategically important areas, particularly in research and development (R&D) and new product development. Thus, successful management of strategic alliances in high-technology industries has become critical to a firm's new product development and ultimately to firm performance. Yet little is known about what determines the performance of individual alliances. This article examines the relationship between the age of an alliance and the performance of the alliance.

Two competing hypotheses regarding the form of the functional relationship between alliance age and alliance performance are developed and are tested. First, a liability of newness hypothesis, which posits that alliance performance increases in a linear fashion over time, is tested. Then a honeymoon hypothesis, which posits that the relationship between age and alliance performance is nonlinear with alliance performance decreasing initially but increasing over time, is tested. It is proposed further here that alliances that are more important to the focal firm exhibit longer honeymoon periods.

A measure of individual alliance performance is developed based on our field study in the biotechnology industry. The competing hypotheses are tested using regression analysis on the sample of 115 R&D alliances. Then the analysis is extended by splitting the sample into high- and low-importance alliances to enhance the robustness of the findings. Further, such a split-sample approach enables testing for a potential moderating effect of alliance importance on the hypothesized relationship between alliance age and alliance performance.

The results suggest that the relationship between age and alliance performance seems to be U-shaped curvilinear rather than linear, with the minimum point of alliance performance occurring after approximately four and one-half years. Thus, the results indicate that strategic alliances appear to face a liability of adolescence rather than a liability of newness. Contrary to expectations, it also is found that important alliances exhibit generally shorter honeymoons.

Introduction

For entrepreneurial high-technology firms, the rapid development of new products is a key determinant of success. Technology ventures in industries such as biotechnology, computers, and

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electronics face an environment characterized by incessantly changing technologies and intense global competition (D'Aveni 1994). Such dynamic environments demand that these firms reach beyond their boundaries in order to develop innovative new products. However, the increasing costs and complexity of new product development is making it difficult for entrepreneurial ventures to build the assets needed for successful research and development (R&D) within their boundaries, forcing them to reach beyond their borders. The response to these forces has been the proliferation of the use of strategic alliances during the last 20 years, particularly in high-technology industries (Hagedoorn 1993).

Firms are motivated to enter into alliances to access complementary assets (Rothaermel 2001a; Teece 1992) and knowledge (Powell et al. 1996) needed for the successful creation and commercialization of a new product. Both strategic needs and social opportunities drive alliance formation (Eisenhardt and Schoonhoven 1996). Further, prior research has found empirical evidence that a firm's strategic alliances are associated positively with a firm's innovativeness and new product development (Deeds and Hill 1996; Kotabe and Swan 1995; Montoya-Weiss and Calantone 1994; Shan et al. 1994); financial performance (Rothaermel 2001b); and wealth creation (Park and Kim 1997). While the link between a firm's strategic alliances and its new product development and overall firm performance has been well established, there is little understanding of the factors that determine the performance of an individual alliance.

In the organization theory literature, alliance age is considered an important variable when modeling the mortality rate of interorganizational relationships (Fichman and Levinthal 1991; Levinthal and Fichman 1988). However, alliance age has not been considered in explaining the performance of strategic alliances. Although some scholars in the strategic management literature have analyzed alliance performance, they mainly have addressed alliance survival versus termination and generally have equated alliance termination with alliance failure (Beamish 1985; Harrigan 1986; Kogut 1988). While these studies provided valuable insights in understanding the termination of alliances, they may be limited in advancing understanding of alliance performance, since many successful alliances terminate precisely because they have accomplished what the partners set out to do (Gulati 1998). Others in the strategic management literature have focused on the potential performance impact of alliances on partner firms (Deeds and Hill 1996; Rothaermel 2001b; Shan et al. 1994), while largely ignoring alliance-specific factors that may determine the performance of individual strategic alliances.

In this article, the authors take up the challenge of identifying and analyzing alliance-specific factors that may determine alliance performance. In particular, the relationship between the age of an alliance and its performance in a high-technology industry is investigated, focusing on the individual strategic alliance of high-technology startups as the unit of analysis and asking the question, What effect does the age of an alliance have upon its performance? Taken into consideration will be whether there is a liability of newness for R&D partnerships (Stinchcombe 1965), indicating a positive linear relationship between age and performance, or whether there is a liability of adolescence for R&D partnerships (Fichman and Levinthal 1991), indicating a curvilinear relationship between age and performance.

A liability of newness perspective with respect to alliance age would indicate that younger alliances are more prone to poor performance than are older alliances. In contrast, a liability of adolescence would indicate that younger alliances experience a honeymoon period where performance is considered to be high. In this scenario, alliance performance deteriorates over time before reaching its low point. Eventually, over longer time periods, the liability of adolescence perspective would indicate that alliance performance improves again. Thus, the relationship between alliance age and performance is characterized by declining performance over an initial period followed by a period of increasing performance. In

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addition, the determinants of the length of a possible honeymoon are examined. The hypotheses are tested empirically on a sample of 115 biotechnology R&D alliances.

The structure of this article follows. In the next section, two competing hypotheses are derived regarding the relationship between alliance age and alliance performance based on relational contract theory and organizational ecology. A hypothesis further is derived regarding the moderating effect of alliance importance on the length of possible honeymoon periods. Then follows a description of the methods and results. The conlusion contains a discussion of the results, limitations of the study, and implications for practice and future research.

Theory and Hypotheses Development

In a rapidly changing technological environment, critical technology necessary for innovation and new product development that is not held currently within the boundaries of a firm can be obtained in three different ways: (1) mergers or acquisitions; (2) internal development; and/or (3) strategic alliances (Lambe and Spekman 1997). While all three methods are valid theoretically, in industries characterized by rapid technological change and high uncertainty in the new product development process, internal development often is not feasible due to its time intensity, and mergers and acquisitions often are too expensive when factoring in the uncertainty about the future value of the acquired technology (Atuahene-Gima 1993; Lambe and Spekman 1997). These arguments are supported by evidence documenting the expanding use of R&D alliances to advance new product development in volatile environments, such as biotechnology (Rothaermel 2001a). The trends and the imperatives of high uncertainty new product development environments make it critical for scholars and managers to expand their understanding of strategic alliances.

Strategic alliances are interorganizational relationships that firms enter voluntarily with one another. They help firms to pool risks and reduce uncertainty (Ohmae 1989), to build new competencies (Hamel et al. 1989), to access complementary assets (Rothaermel 2001a; Teece 1992), to enhance organizational learning (Powell et al. 1996) and legitimacy (Stuart et al. 1999), and to adapt to new technologies (Rothaermel 2001b). Further, strategic alliances allow partner firms to build relational capital over time and thus to succeed in areas where they would fail if they attempted to go it alone (Dyer and Singh 1998). As in any relationship, it is argued here that the performance of the relationship should improve over time. In particular, it is argued that two forces work to improve alliance performance over time.

First, strategic alliance partners have the tendency to invest in the development of skills and routines adapted to the specific relationship as the partners interact with one another over time (Blau 1964; Granovetter 1985; Levinthal and Fichman 1988; Seabright et al. 1992). Increased interaction and exchanges between partners lead to increased investments in cospecialized assets and in the level of bilateral dependence between the parties (Teece 1986). These specialized skills and routines include specific knowledge about the structure and operation of the partner organization. They further comprise skills and abilities of the personnel within the partner firms and jointly developed teams as well as structures and routines to create, to process, and to share information. These skills and routines are investments in specific assets adapted to the transactions embedded in individual strategic alliances. Such specialized assets improve the information flow between the partners, which may lead to an increase in the performance of the alliance over time. Firm adaptation to facilitate interfirm cooperation also can lead to similarities in the way firms process knowledge. In their study of strategic alliances between biotechnology and pharmaceutical firms, Lane and Lubatkin (1998) found that the ability of firms in an alliance to learn from one another was influenced partly by the similarity of the internal knowledge processing structures of the two partner firms.

The second force to improve alliance performance over time is the probable relationship between alliance performance and alliance mortality. Prior research has found a high level of mortality during the first five years of interorganizational relationships (Kogut 1988), which can be interpreted as a liability of newness (Stinchcombe 1965). Alliances that are performing poorly are likely to have a higher probability of dissolution because the parties in the alliance will be unwilling to continue to commit resources to a poorly performing alliance. The alliances that survive over time therefore will have higher levels of performance. These forces individually and in concert lead to the first hypothesis.

H1: The relationship between alliance age and alliance performance is positive and linear.

On the other hand, many relationships begin with a certain degree of goodwill on behalf of both partners. Like any social relationship, an alliance is likely to experience an initial honeymoon period. A honeymoon period generally exists since an alliance starts with an initial stock of assets, which may include favorable prior beliefs, goodwill, trust, financial investments, or psychological commitment (Fichman and Levinthal 1991). A certain level of ex ante commitment on the part of the firms to an alliance must exist since otherwise the alliance would not be initiated. Upon entering a relationship, the involved actors generally become bound to the relationship through a justification process, which creates a certain amount of behavioral inertia (Salancik 1997). This implies that the alliances may be buffered from early indications of subpar performance. Thus, it is argued here that the relationship between alliance age and alliance performance should be curvilinear U-shaped rather than linear, with an initial decline in alliance performance and subsequent performance improvements over time.

Time is an integral part of any complex relationship. This certainly is true for an R&D alliance. Exchange processes are uncertain because complex relationships experience a time lag between initiation and the point when a meaningful evaluation of the relationship is possible (Leblebici and Salancik 1982; Pfeffer and Salancik 1978). In particular, the very nature of a research alliance extends the time between initial exchange and evaluation of the outcome since the outcome and the steps necessary to achieve the outcome often are highly uncertain. In the case of the drug development process in the biotechnology industry, it can take up to 15 years to bring a biotechnology molecule to the market (Giovannetti and Morrison 2000). During this period any project is prone to experience numerous setbacks. In particular, the drug development process in biotechnology is beset with extremely high uncertainty and occasional serendipity. The drug under development may require reformulation, or the initial indications targeted for the drug may be incorrect and new indications may need to be targets.

For example, during the mid 1990s the biotechnology firm Icos attempted to develop a potential new drug for the treatment of hypertension (Hill and Jones 2001). One of the patient groups on which this new drug, code name IC351, was tested were males in their 50s. The new drug was to be taken orally, and the Icos researchers were surprised by the unusual high compliance rate among the patients. Nevertheless, the drug turned out to be ineffective in treating hypertension after several months of extensive and rigorous testing. It is customary for the firm that sponsors the clinical trial to collect all the surplus pills from the patients. To Icos' complete surprise, several patients refused to return their surplus pills, leading to questioning of the patients as to why they refused to return an obviously ineffective drug. Several patients who had been taking IC351 as opposed to a placebo reported a vastly improved sex life. Thus, Icos' IC351 was not effective in treating hypertension but was effective in treating male erectile dysfunction. Icos decided to explore IC351 further as a potential competitor to Pfizer's Viagra. This strategic move turned out to be successful, as Icos was able to develop the drug successfully through an alliance with Eli Lilly. The new drug, now christened with its commercial name "Cialis," is expected to reach the market in 2003. While Icos was lucky in discovering Cialis, the entire product development process of IC351 well may have taken more than 15 years.

During clinical trials, process errors in design or unforeseen side effects also may create delays. Decisions by external actors such as the Food and Drug Administration (FDA) and the recruiting of physicians that will administer the innovative test drugs may create additional delays. All of these events require a certain amount of progress and time to have passed before potential setbacks will materialize. This means that during the initial period of the exchange, the relationship is unlikely to be threatened by any negative outcomes (Fichman and Levinthal 1991). Therefore, in the biotechnology industry it may take years for the alliance to progress far enough for the parties to evaluate its performance rigorously. In other technology-driven industries the time between entering the alliance and obtaining some type of feedback on the performance of the project may be shorter, but in general, research alliances require a substantial amount of time to pass before the product has reached a stage where the performance can be evaluated in a meaningful way.

A research alliance can be viewed as an extended series of exchange interactions, each providing additional information about the partner and the progress of the new product development project. As in any long-lasting relationship, experiences between the partners are accumulated over the course of the relationship. If a firm begins a relationship with a certain number of favorable beliefs about the partner firm and about the benefits it hopes to accrue from participation in the alliance, it is likely to take several unfavorable events for the firm's evaluation of the alliance to change (Fichman and Levinthal 1991). These influences would lead to the hypothesis that there will be an increasingly negative relationship between age and alliance performance (i.e., alliance performance should deteriorate over time with the erosion of the initial stock of assets that created the honeymoon period).

However, it also was argued in the development of H1 that the performance of relationships should improve over time. As discussed previously, the impact of investments in the relationship, the creation of social attachments and relational capital, as well as the selection process led to a hypothesis of a positive relationship between age and performance of strategic alliances over time. Therefore, combining the two effects leads to a proposal that alliances will experience an initial honeymoon period and that the resulting relationship between age and performance is curvilinear. The relationship between age and performance should be U-shaped, with alliance performance declining when the alliance is young, reaching its low point at moderate levels of alliance age, and increasing with higher alliance age. Hence, it is argued that the liability of newness inherent in R&D alliances is moderated by a honeymoon period. This suggests the following alternative to the first hypothesis.

H2: The relationship between alliance age and alliance performance is a curvilinear U-shaped function, with alliance performance decreasing over an initial period and increasing in the later periods.

H1 and H2 postulate different functional forms for the relationship between the age of the alliance and its performance. They represent competing hypotheses of the relationship between age and performance within a strategic alliance. If this relationship is curvilinear as postulated by H2, then an important question is what determines the length of the honeymoon period, or more precisely, what factors determine when the minimum point of the relationship between age and performance is reached? As argued already, if alliances begin with a certain amount of goodwill or social capital then it takes a period of time for this social capital to erode. A critical indicator of the capital invested in an alliance is the importance that the firm places on the alliance. A firm will have a greater level of commitment to an alliance that it views as strategically important to its future than it will to an alliance that is of little or no importance to its future. Commitment to relationships ensures a certain amount of continuity and restraint in behavior across time (Fichman and Levinthal 1991). R&D alliances that are important to the firm's future should exhibit a greater level of inertia in the opinions of the managers about the performance of the alliance. Thus, the length of an alliance's honeymoon period should be related positively to the importance of the alliance to the firm's future. In other words, the erosion of the initial stock of goodwill should take longer in high-importance alliances than in low-importance alliances. Further, the level of the initial stock of goodwill should be higher in high-importance alliances than in low-importance alliances. Taken together, these arguments lead to the following hypothesis.

H3: Alliances that are important to the firm's future will have longer honeymoon periods than will alliances that are unimportant to the firm's future.

Methods

Data Collection, Validation, and Reliability

A field study was conducted in the biotechnology industry. Based on organizational and strategic management theory (see Mintzberg 1983; Morgan 1986) as well as on preliminary interviews with biotechnology industry executives, the top management team of biotechnology firms were chosen as the target. In particular, structured interviews with chief executive officers (CEOs), vice presidents of business development, and vice presidents of research were conducted. Structured interviews with top management team members were chosen because they allowed for a collection of rich data about a complex issue and for the development of a unique measure of the performance of individual R&D alliances. Further, structured interviews provided a way to clear up any potential ambiguity or misunderstanding of the questions contained in the interview script (Kerlinger 1986). Standard examples and definitions were developed to improve the interviewee's understanding. The same interviewer was used throughout the study, which allowed the interviewer to provide consistent explanations and examples to all the interviewees.

The biotechnology industry was chosen as the research setting for this study because of the widespread use and importance of research alliances within the industry. Due to the rapidly developing technology, the escalating costs of development, and the risks and uncertainty inherent in the industry, a dense network of linkages among research universities, biotechnology companies, and pharmaceutical companies has developed.[1]

Rothaermel and Deeds (2002) found over 2,200 alliances in the biotechnology industry, with about one-third of them being R&D alliances. Hagedoorn (1993) found that the biotechnology industry exhibited the highest alliance activity among all of the alliance intense high-technology industries in his study.

The unit of analysis is the individual R&D alliance entered by a biotechnology firm. Following Barley et al. (1992), biotechnology firms are defined as those newly established firms that pursue biotechnological research and development in areas of commercial promise. In order to facilitate personal, on-site interviews, three geographical areas were the focus: San Diego, Seattle, and the Philadelphia–New Jersey area. All three areas are considered to be biotechnology clusters (i.e., geographic locations with relatively dense populations of biotechnology firms) (Lee and Burrill 1996).

Based on the BioScan (1992) industry directory, it was identified that the biotechnology population in these three areas totaled 132 firms. BioScan provides one of the most comprehensive publicly available directories covering the global biotechnology industry and has been used in a number of different studies (Deeds and Hill 1996; Rothaermel 2001b; Shan et al. 1994). All 132 firms were contacted, and 61 agreed to be interviewed. The authors were able to visit personally 52 of the firms and in nine cases resorted to telephone interviews. The response rate of 46 percent is higher than that of previous studies (John 1984; Parkhe 1993). Each biotechnology firm provided information on up to (but no more than) three distinct alliances. In total information was gathered on 115 R&D alliances. Personal on-site interviews were the source of data for 102 alliances, and telephone interviews were the source for the remaining 13 alliances.

The high response rate from top managers of biotechnology firms was encouraging. However, this fact did not eliminate the potential problems posed by interviewing a single respondent. A potential defect in the source may lead to systemic variation among the variables, in particular when relying on self-reported data (Cook and Campbell 1979). The concerns include common method variance, questions about the consistency and reliability of the data, and a possible bias due to the social desirability problem. On the other hand, reliance upon key informants is the only method available to gather detailed and rich information on the performance and other aspects of individual alliances.

While it is acknowledged that reliance upon a single respondent is problematic, the authors attempted to mitigate these threats to the validity of the study by limiting the interview targets to the top management teams and by conducting personal interviews that allowed for minimizing the potential for misinterpretation of questions and responses. Personal interviews allowed for certainty about who responded and about respondents' detailed knowledge of the respective alliances. Three different statistical procedures further were employed to assess the reliability of our data and the potential threat posed by common method variance.

First, secondary data were used to test for reliability (Keats and Hitt 1988). Secondary data were gathered from BioScan (1992) regarding the strategic alliances between the parties, the number of employees, the age of the companies, and the number of alliances in which the respective biotechnology firm had participated. In particular, secondary data was able to be obtained for 55 of the 61 firms. However, verification of the biotechnology firms' strategic alliances was limited to 32 firms due to the unwillingness of the remaining firms to identify their alliance partner or partners. The secondary source data was compared to the interview responses.

The number of employees matched in 48 of the 55 cases. The discrepancies in the other cases are attributable to changes in the number of employees during the time elapsed between BioScan's data collection and the authors' interviews. The age of the company matched in all 55 cases. The number of alliances in which the firms had participated matched in 40 of the 55 cases. In 11 of the cases the total

[1] It can cost up to $500 million to develop a new biotechnology drug (Burrill 1999).

number of alliances reported in the interview was two or less above the BioScan numbers and again is attributable to the time elapsed between BioScan's data collection and the authors' interviews. In four cases the interviewee reported a lower number of alliances. This may be due to strict adherence to the definition of a research alliance as provided by the researcher and/or to a failure to include or properly to account for all of the alliances in which the firm had participated. The largest discrepancy was five alliances below the BioScan data, but this amounted to less then 10 percent of the total alliances in which the firm had participated. The history of cooperation between the parties matched in 31 of the 32 cases and was off by one year in the remaining case. Overall, the convergence between secondary source data and the authors' interview data supports the reliability of the interview data.

The second method applied to assess common method variance was Harman's (1967) single factor test. The assumption underlying this test is that if a significant amount of common method variance exists, a single or a general factor that explains a significant amount of the variance will emerge from a factor analysis when all of the variables are entered. The factor analysis revealed three factors with eigenvalues above 1.0, which explained 71.6 percent of the variance. The largest single factor explained 30.1 percent of the variance, which is significantly less than the majority of the variance.

Finally, seven follow-up interviews with secondary informants were conducted at seven different biotechnology firms, and the results of these interviews were compared with the primary interviews to determine the interrater reliability. Kappa was computed, which can be interpreted as a correlation coefficient. The kappas for the individual items ranged from 0.76 to 0.94. The overall kappa was 0.82, which is above the suggested 0.80 level (Landis and Koch 1977). In sum, the data appear to be reliable.

Measures

Measure development. The interview script was developed by searching the strategic management and psychology literatures and by conducting initial discussions with business school faculty. Previous work was relied upon to develop the questions for the interview script whenever possible, and other existing measures were adapted to the specific context. Nevertheless, it was necessary to develop several of the items specifically for this study due to the lack of prior empirical work in this area; they were developed through discussions with industry executives and business school faculty. Then our interview script was tested with a convenience sample of industry executives. Following the initial tests of the questions, the interview script was refined and was presented to the industry sample and business school faculty for additional feedback. The final interview script was developed after several rounds of iterations.

A small pilot study then was conducted to improve further and to calibrate our measures. In particular, 20 structured interviews were conducted with biotechnology executives, research scientists, technology transfer professionals, government officials, and representatives of industry associations. The interview responses from our pilot study were compared with secondary material for accuracy and reliability. In a final step, the interviewees were debriefed and were solicited for their feedback, in particular with respect to the definitions of certain terms used in the interview script.

Alliance performance. Three items were used to attain a composite score for alliance performance (see Appendix), based upon prior work (Deeds and Hill 1999; Parkhe 1993). Each item was designed to measure a different aspect of performance: spillover benefits, financial performance, and overall alliance performance. These performance measures were chosen due to the limitations inherent in measuring any single outcome from a research alliance. Under these circumstances the assessment of the alliance performance by a top management team member directly involved in the alliance was chosen as the preferred method of alliance performance evaluation. Data collected through surveying managers directly involved in the focal alliances appear to be more reliable and to provide potentially more insights than secondary data obtained at a more aggregate level.

While the assessment of the alliance's spillover benefits and evaluation of overall performance are more subjective in nature, it is argued here that the alliance's financial performance is a more objective criterion in assessing alliance performance, since this is a hard measure and since managers generally establish a benchmark prior to entering a specific alliance.[2] Crampton and Wagner (1997) point out

[2] The item assessing overall alliance performance also asked the respondent to assess the overall alliance performance compared to prior expectations.

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that a potential common method bias may not be a concern when the variable reported is objective and factual like the financial performance measure in this study. In addition, Spector (1987) indicates that common method variance may be more of a problem in single items and in poorly designed scales and may be less of a problem in multi-item and in well-designed scales.

Since there was no theoretical reason for weighting the responses, the average of the three items was used to create a composite score for alliance performance and then the items were factor-analyzed. It resulted in a single factor with an eigenvalue of 2.11, which explained 70.8 percent of the variation (Cronbach's alpha 0.79).

Alliance age. Alliance age was measured from the month and year at which the two firms first began working together. The alliance age was calculated in years with two decimal places. For example, if the age was three years and four months, the score for the alliance age was 3.33 years. The alliance age data was gathered in the interviews and was verified whenever possible through secondary data.

Alliance importance. Our respondents were asked to rate the importance of the alliance to the future success of their firm on a five-point Likert scale, with 1 as "Unimportant" and 5 as "Very Important." This variable was treated as a continuous variable in testing H1 and H2. To test H3, however, the sample was split into those alliances that were rated as 4 or above on the scale of importance (high importance subsample) and those that were rated as 3 or below on the scale (low importance subsample). A split-sample approach was indicated due to high multicollinearity encountered when including the direct effects of firm age, firm age squared, and alliance importance as well as the interaction effects between alliance importance and the linear age term and squared age term simultaneously in a regression model.

Control Variables

We identified and included several variables to control for possible confounding factors. We controlled for firm size, type of the partner, dependence of the focal firm on the partner, and the partner's equity investment in the focal firm.

Firm size. Firm size generally is measured in revenues, assets, or market share. However, most biotechnology startups did not have a positive revenue stream at the time of this study. Total assets do not reflect firm size in an industry based on knowledge, and market share data is elusive since many firms did not have products on the market. Thus, a biotechnology firm's size was controlled by using the number of employees as a proxy.

Partner type. A new biotechnology firm theoretically can enter alliances with three different partners along the industry value chain (Baum et al. 2000). It can reach upstream to partner with universities and other non-profit research institutions to access basic science, can reach horizontally to partner with other biotechnology firms to increase scale and scope, and can reach downstream to partner with pharmaceutical companies to access the market for drug distribution and sales. The type of partner was coded by creating two binary indicator variables, one for upstream partners (1=partner is upstream in the industry value chain) and one for downstream partners (1=partner is downstream in the industry value chain). Horizontal alliances with other biotechnology firms are the omitted category.

Partner dependence. The biotechnology industry is characterized partly by a dependence of biotechnology firms on large pharmaceutical companies (Rothaermel 2001a). In such situations, firms that are highly dependent upon other firms may cooperate with them solely because of their limited alternatives and possible coercive pressure from the dominating firm. Thus, cooperation by weaker parties can be viewed as compliance rather than cooperation (Heide and Miner 1992). In this case, feelings of insecurity, helplessness, and a lack of control may lead to inflated attributions of alliance performance. Accordingly, the dependence of the focal firm on its partner firm was controlled. Interviewees were asked how long it would take to replace their partner on a scale of less than one month, one–six months, six–12 months, over one year, and cannot be replaced.

Equity investment. The percentage of the equity in the focal firm that is owned by the focal firm's partner was used as a measure of equity investment. The top managers of the focal firms were asked if their alliance partner had made an equity investment in their firm and if so, what percentage of the equity was owned by the partner.

Estimation Procedure

H1 and H2 are competing hypotheses. H1 predicts a positive linear relationship between alliance age and alliance performance. H2 predicts an U-shaped relationship with alliance performance initially decreasing with age and then increasing after the honeymoon period. To test these hypotheses, the following multivariate, quadratic regression model was applied:

$$y_i = \alpha + \beta_1 x_1 + \beta_2 (x_1)^2 + \sum_{i=2}^{n} \beta_i x_i + \varepsilon_i \qquad (1)$$

where y_i represents alliance performance, x_1 alliance age, and x_i the remaining independent and control variables. A functional relationship that exhibits a curvilinear relationship between alliance performance and alliance age (as proposed in H2) finds its expression in statistically significant coefficients of β_1 and β_2. In addition, the coefficient of β_1 must be negative, while the coefficient of β_2 must be positive. However, if β_1 is positive and statistically significant and β_2 is not significant, then the relationship between alliance performance and alliance age is linear as suggested by H1.

To test H3, the sample was split between alliances that were rated as important or very important to the future success of the firm and those that were rated as modestly important or unimportant to the future success of the firm. Then the regression models were rerun to determine if the relationship between age and performance remained robust and if so, what the length of a potential honeymoon was.

Results

Table 1 presents the descriptive statistics and the correlation matrix, while Table 2 depicts the descriptive statistics for the low and high importance subsamples. Table 3 shows the regression results. The average firm in the sample has about 145 employees. Approximately 27 percent of the alliances studied are with partners upstream in the industry value chain, such as universities and other nonprofit organizations; 36 percent are with horizontal partners, such as other biotechnology firms; and the remaining 37 percent are with downstream partners, such as pharmaceutical companies that provide access to the market for drug distribution and sales. The average age of the alliances investigated is about three years, two months.

Models 1–3 represent the regression results for the full sample. Model 1 depicts the baseline model including the control variables only. The overall model is significant ($p<0.05$). Firm size is marginally significant ($p<0.10$), while the importance of the alliance is significant ($p<0.01$) in explaining alliance performance. Firm size again is marginally significant in Models 2 and 3 ($p<0.10$), while alliance importance remains robust through Models 2 and 3 ($p<0.01$). We added the variables of alliance age and alliance age squared sequentially to the respective baseline models in order to ascertain their unique contributions.[3]

H1 states that the relationship between alliance age and alliance performance is positive and linear, while the competing H2 indicates that the relationship between alliance age and alliance performance is a curvilinear U-shaped function. Model 2 reveals that the alliance age variable is positive, as expected, but is not significant. Model 3, which represents a significant improvement over the baseline model ($p<0.001$), shows that the alliance age variable is negative and significant ($p<0.01$), while the squared alliance age variable is positive and significant ($p<0.01$), indicating a U-shaped relationship between alliance age and alliance performance. Thus, support is found for H2, while it is not found for H1.

To test H3, the proposed regression model was run on the low- and high-importance subsamples. Table 2 reveals that low-importance alliances scored a mean of 1.87 on the alliance performance variable, while the high-importance alliances scored a mean of 2.37. The difference is significant ($p<0.01$). This lends support to the way in which the sample was split. To ensure the validity of the approach further, a variance ratio test also was applied on the alliance performance and alliance age variables, and it was found that the variances of the respective variables were not significantly different across the two subsamples. This further enhanced the authors' confidence in the split-sample approach employed to test H3.

Models 4–6 represent the results for the split sample for low-importance alliances, while Models 7–9 represent the results for the split sample for high-importance alliances. Model 4 depicts the baseline

[3] Multicollinearity is an endemic problem in regression models that simultaneously contain a linear and squared term of the same variable (Models 3, 6, and 9). However, the authors argue that a potential multicollinearity problem in Models 3, 6, and 9 can be neglected, since the usual consequences of multicollinearity (i.e., overall significance of regression without significance individual coefficients) are not present. Rather, the individual coefficients are significant. Thus, any existing multicollinearity did not cause a Type II error as it potentially can. Moreover, any existing multicollinearity does not bias the estimates (Greene 1997).

Table 1. Descriptive Statistics and Correlation Matrix[a]

Variable	Mean	Std. Dev.	Min.	Max.	1.	2.	3.	4.	5.	6.	7.	8.
1. Alliance Performance[b]	2.12	0.70	1.00	4.33								
2. Alliance Age	3.16	2.32	0.083	10	0.08							
3. (Alliance Age)^2	15.31	21.97	0.006	100	**0.18**	**0.95**						
4. Alliance Importance[c]	3.32	1.24	1	5	**0.32**	0.07	0.11					
5. Firm Size	144.72	368.15	2	2500	0.11	0.15	0.15	−0.07				
6. Upstream Partner	0.27	0.44	0	1	0.02	0.03	0.01	0.11	−0.13			
7. Downstream Partner	0.37	0.49	0	1	0.09	0.14	0.17	0.06	−0.05	**−0.47**		
8. Partner Dependence[d]	3.41	1.12	1	5	0.15	0.08	0.12	0.16	0.07	0.15	0.07	
9. Equity Investment	1.09	2.94	0	20	0.08	**0.21**	**0.24**	0.02	−0.03	**−0.18**	**0.32**	0.04

[a] Correlations greater than or equal to 0.18 are significant ($p<0.05$); $N=115$.
[b] Alliance Performance: multiple items, see Appendix for details.
[c] Alliance Importance: 1=unimportant to 5=very important.
[d] Partner Dependence: 1=can be replaced in less than one month to 5=cannot be replaced.

Table 2. Descriptive Statistics for Variables in Low- and High-Importance Subsamples

	Low-Importance Subsample				High-Importance Subsample			
Variable	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Alliance Performance	1.87	0.65	1.67	4.33	2.37	0.67	1.00	4.00
Alliance Age	3.02	2.14	0.25	10	3.31	2.52	0.25	10
(Alliance Age)^2	13.62	20.29	0.0625	100	17.16	23.72	0.0625	100
Alliance Importance	2.30	0.72	1	3	4.44	0.50	4	5
Firm Size	174.12	387.82	2	2500	112.65	346.11	2	2500
Upstream Partner	0.27	0.45	0	1	0.27	0.45	0	1
Downstream Partner	0.33	0.47	0	1	0.42	0.50	0	1
Partner Dependence	3.23	1.14	1	5	3.60	1.08	1	5
Equity Investment	0.86	2.10	0	11	1.34	3.65	0	20

model for the split sample of low-importance alliances including the control variables only. A partner's equity investments in the focal firm can be seen to be associated negatively with the performance of a focal firm's low importance alliances ($p<0.05$). This relationship remains negative in Models 5 and 6 ($p<0.10$). Alliance age in Model 5 is negative and significant ($p<0.05$), but the overall model is only marginally significant ($p<0.10$). This finding stands in contrast to what was proposed in H1—that alliance performance should improve over time. The results from Model 5 seem to suggest that alliance performance of low-importance alliances deteriorates over time, which may indicate a honeymoon period at the beginning of the alliance. Model 6, on the other hand, shows that alliance age remains negative ($p<0.001$) and that alliance age squared is positive, as expected, and significant ($p<0.05$), indicating a U-shaped relationship between alliance age and alliance performance. In addition, Model 6 is significant at $p<0.05$. Thus, the results obtained from the split sample for low-importance alliances lend support for H2.

Model 7 is the baseline model for the split sample of high-importance alliances including the control variables only. Firm size ($p<0.05$) and a partner's equity investments ($p<0.10$) are both positive and significant in explaining alliance performance in high-importance alliances. Further, firm size remains positive and significant in explaining alliance performance in Models 8 and 9. Model 8, which represents a marginal improvement over the baseline model ($p<0.10$), indicates that alliance age is associated positively with alliance performance ($p<0.05$). This result provides some preliminary support for H1. On the other hand, Model 9, which represents a significant improvement over the base model ($p<0.01$), shows that alliance age is negative ($p<0.05$), while alliance age squared is positive ($p<0.01$). This result supports H2. When comparing Models 8 and 9 directly, it is found that adding alliance age squared (Model 9) results in a significant

Table 3. Regression Results

Independent Variables	Model 1 Base	Model 2	Model 3	Model 4 Low-Importance Base	Model 5 Low Importance	Model 6 Low Importance	Model 7 High-Importance Base	Model 8 High Importance	Model 9 High Importance
Intercept	**1.260*****	**1.255*****	**1.849*****	**1.807*****	**1.945*****	**2.370*****	**1.896*****	**1.641*****	**2.248*****
	(0.247)	(0.254)	(0.296)	(0.268)	(0.271)	(0.326)	(0.321)	(0.338)	(0.383)
Firm Size	**2.60E-4**†	**2.57E-4**†	**2.49E-4**†	6.319E-5	2.177E-4	2.067E-4	**5.680E-4***	**5.806E-4***	**5.730E-4****
	(1.74E-4)	(1.78E-4)	(1.70E-4)	(2.358E-4)	(2.433E-4)	(2.327E-4)	(2.555E-4)	(2.485E-4)	(2.332E-4)
Upstream Partner	0.049	0.047	0.069	–0.057	–0.091	–0.072	0.256	0.084	0.105
	(0.167)	(0.169)	(0.161)	(0.224)	(0.227)	(0.212)	(0.234)	(0.244)	(0.228)
Downstream Partner	–0.102	–0.100	–0.079	0.210	0.254	0.198	0.114	0.024	–0.025
	(0.155)	(0.157)	(0.150)	(0.215)	(0.211)	(0.206)	(0.215)	(0.200)	(0.200)
Partner Dependence	0.049	0.050	0.019	–0.019	0.044	0.021	0.067	0.099	0.064
	(0.058)	(0.058)	(0.056)	(0.080)	(0.080)	(0.077)	(0.083)	(0.083)	(0.078)
Equity Investment	0.014	0.014	0.006	**–0.074***	**–0.066**†	**–0.056**†	**0.036**†	0.022	0.006
	(0.022)	(0.023)	(0.022)	(0.044)	(0.043)	(0.042)	(0.025)	(0.026)	(0.025)
Alliance Importance	**0.173****	**0.173****	**0.154****						
	(0.052)	(0.052)	(0.050)						
Alliance Age		0.003	**–0.289****		**–0.085***	**–0.320*****		**0.074***	**–0.259***
		(0.029)	(0.088)		(0.044)	(0.115)		(0.038)	(0.124)
(Alliance Age)^2			**0.033****			**0.027***			**0.037****
			(0.009)			(0.012)			(0.013)
F-Statistic	2.86*	2.43*	3.84**	0.721	1.269	1.849†	1.768	2.197†	3.279**
Adjusted R^2	0.089	0.081	0.166	–0.024	0.027	0.092	0.066	0.117	0.228
Partial *F*-Statistic		0.009	12.009***		3.820a	4.789*		3.829†	7.881**
N	115	115	115	60	60	60	55	55	55

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

improvement over the linear model (Model 8; Partial F-Statistic=7.881; $p<0.01$). Thus, the results from the high-importance alliances subsample provide stronger support for H2 than for H1.

H3 postulates that alliances that are important to the firm's future will have longer honeymoon periods than will alliances that are unimportant to the firm's future. The above results seem to suggest that the relationship between alliance age and alliance performance is U-shaped. Thus, the length of a honeymoon period can be understood as the time it takes for alliance performance to reach its minimum level (i.e., the time it takes for the initial stock of assets to erode). To calculate the respective points where alliance performance reaches its minimum level, the partial derivatives were taken with respect to the alliance age in Models 3, 6, and 9. The data suggest that the alliances in this sample reach their minimum level of performance after 4.38 years for the full sample; 5.93 years for the low-importance sample; and 3.50 years for the high-importance sample.

To assess these differences, we applied a Wald-type test. Contrary to H3, these results suggest that the honeymoon period for low-importance alliances is significantly longer than it is for high-importance alliances (Δ years=2.43; $p<0.001$). In fact, the data suggest that the honeymoon period for low-importance alliances is, on the average, 70 percent longer than honeymoons for the high-importance alliances. As expected, the honeymoon period for the full sample lies between the honeymoon periods for high- and low-importance alliances. In particular, the honeymoon period for the full sample is significantly longer than the honeymoon period for high-importance alliances (Δ years=0.88; $p<0.01$, 25 percent longer), while it is significantly shorter than the honeymoon period for low-importance alliances (Δ years=1.55; $p<0.001$; 26 percent shorter).

Figure 1 graphically depicts the relationship between alliance age and alliance performance for low- and high-importance alliances based on the regression coefficients obtained in Models 6 and 9. The important information is the shape of the curves and the position of the respective minima for each of the curves along the horizontal axis representing alliance age. The curvilinear U-shaped relationship between alliance age and alliance performance for both the low- and high-importance subsamples can be seen. Moreover, the graph shows that low-importance alliances experience significantly longer honeymoon periods than do high importance alliances.

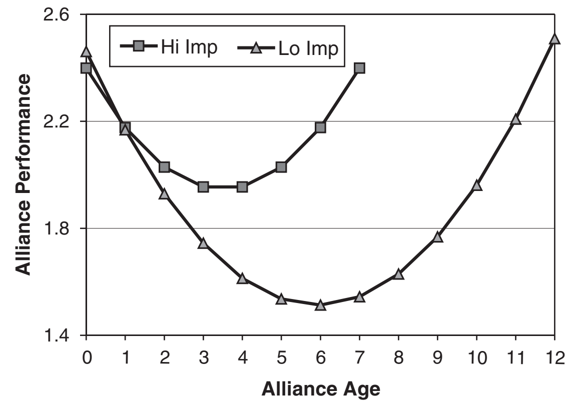

Figure 1. Relationship between Alliance Age and Alliance Performance

Discussion and Conclusion

Contribution

Competing hypotheses were developed regarding the functional form of the relationship between alliance age and alliance performance. In particular, a linear and a curvilinear, U-shaped relationship were juxtaposed. The authors were interested further in the length of a potential honeymoon. The results suggest that the relationship between alliance age and alliance performance is U-shaped. Based on this sample, it seems that alliance performance initially decreases, reaches its low point after about four and one-half years, and then improves again. Interestingly, the time it takes to reach the minimum performance point for R&D alliances is similar to the time Katz and Allen (1982) found for R&D teams to reach their maximum performance points (inverted U-shaped).[4] Katz and Allen's findings suggest that intraorganizational groups initially may improve their performance before it peaks and then declines. Contrary, these authors' findings suggest that interorganizational groups engaged in R&D alliances first experience a decline in performance before they reach a minimum point and then gradually improve again. The question of whether there are deeper systematic reasons behind the fact that both intra- and interorganizational R&D teams reach their respective inflection point at about four years into the process or whether this overlap is coincidental provides an interesting avenue for future research.

It has been argued here that a U-shaped relationship between alliance age and alliance performance is

[4] We are grateful to an anonymous reviewer for pointing this out to us.

due to the initial endowment of social capital or goodwill that an alliance has upon its initiation. However, this goodwill is eroded over time as disagreements and problems arise that lead to a decrease in alliance performance. This mechanism alone would lead simply to linear declining relationship. However, combined with the forces of cross-boundary relationship building and with the development of specific assets in the alliance and/or the attrition of poor-performing alliances, we see a U-shaped relationship. While it is difficult with cross-sectional data to tease out the influence of attrition versus relationship building, some of our qualitative data seem to support the relationship argument. One manager, for example, stated of the alliance he was discussing, "This one had been a real roller coaster over time. It started out very positive [evidence that a honeymoon existed], but early results and conflicts among personnel brought us to the brink of dissolution [declining alliance performance initially leading to the minimum point of alliance performance]. However, because of my friendship with my counterpart at the partner and our commitment to the project we were able to turn it around" [improved alliance performance over time]. Several managers used a marriage analogy and joked about "seven-year itches" [reflecting a point of minimum alliance performance].

Not only is there evidence of a relationship between age and performance, but also this relationship appears to be a complex nonlinear one that seems to be moderated by the strategic importance of the alliance to the focal firm. It is important to stress that the honeymoon period of the alliances in this research setting is likely to be longer than in most other industries due to the length of time it takes a pharmaceutical development project to unfold. Both the development process and the regulatory process are complex and beset with high uncertainty; thus, these conditions lengthen the time between initiation of the alliance and evaluation of the alliance performance. It is speculated that in other industries in which the development time frame generally is faster, the honeymoon period should be shorter. In addition, certain firm characteristics like firm culture have been found to impact a firm's innovativeness (Hurley and Hult 1998). It is suspected that a firm's culture also may be an important factor moderating alliance success. Further research is warranted to identify and to test other firm and alliance-specific factors influencing the success of strategic alliances and to understand more fully the characteristics determining the honeymoon period.

The authors also attempted to determine the length of a possible honeymoon. To their surprise, and contrary to H3, it was found that the honeymoon period for low-importance alliances is significantly longer than it is for high-importance alliances (see Figure 1). Thus, there seems to be evidence that high-importance alliances might experience shorter honeymoons. There are two possible explanations for this finding. The first is that high-importance alliances receive more attention from top management. As monitoring of the alliance increases, acts of opportunism and subpar alliance performance are noticed earlier, and assessment of the performance of the alliance is adjusted to reflect this new information in a shorter time span, thus leading to a shorter honeymoon.

The second explanation is that while high-importance alliances may entail greater commitment than low-importance ones, there is less inertia in the reassessment of high-importance alliances because the consequences of failure are much greater. In essence, alliances that are strategically important to a venture lead the firm to take a much more proactive stance, which leads in turn to quicker evaluations and assessments. The average performance of the important alliances is significantly higher than that of low-importance alliances, indicating that they probably start with greater commitment and social capital. This explanation seems to be borne out by Figure 1, which indicates that strategically important alliances exhibit higher overall performance and shorter honeymoon periods than do alliances of low importance. The exact link between the strategic importance of an alliance and the level of its performance as well as the length of its honeymoon period warrants further investigation in future research.

Limitations and Future Research

It should be pointed out that this study contains several limitations. In particular, the problem of common method variance could lead to an overstatement of the statistical relationship among these variables. However, the use of factual data may attenuate a potential percept-percept bias and also may limit a potential recall bias (Crampton and Wagner 1997). In addition, there may be a possibility that this study's reliance upon a nonrandom sample in some way may have biased the results. Notwithstanding, a nonrandom sample was necessary to facilitate 52 on-site interviews in three very different regional biotechnology clusters. Further, the data were tested for an underlying sample bias and was found to be reliable. In addition, the multicollinearity created by the expected high correlations between the age and the age-squared variables may have led to an overstatement of the adjusted R^2 values for the regression models containing both variables simultaneously (Models 3, 6, and 9). However, the fact that the age and age-squared variables were significant despite potential multicollinearity actually strengthens the confidence in these findings, since finding individual coefficients that are significant in regression models exposed to multicollinearity is reduced substantially (Greene 1997). The limited size of the subsamples also may limit the power of some of these tests. These results therefore may be unstable and may demand further study of the relationship among strategic importance, alliance age, and performance. Also, the use of cross-sectional data to study an essentially longitudinal problem limits the strength of the findings. Thus, these results highlight the need for future longitudinal studies of strategic alliances.

Finally, it also must be acknowledged that the focus on biotechnology raises questions about the generalizability of this study beyond this industry. Biotechnology has several unique characteristics, including a long product development and approval cycle, heavy reliance upon often-arcane basic scientific research, and a very expensive product development process. Notwithstanding these unique characteristics, the authors still believe that these results might be generalizable beyond the biotechnology industry. Research alliances are becoming increasingly important as the level of complexity and interdisciplinary continues to increase in the R&D and new product development process (Mowery and Rosenberg 1989).

The statistical results from the analysis of the relationship between age and performance have two important implications for future research. First, the results indicate that researchers studying relational contracts, such as alliances, joint ventures, and buyer–supplier relations must take into account the age of the relationship. There is an interesting dichotomy in organizational research. Research in the organizational ecology tradition explicitly considers age in hazard rate models, but this tradition does not examine the performance of individual alliances (Fichman and Levinthal 1991; Levinthal and Fichman 1988). Research in the strategic management tradition considers the impact of a firm's alliances on firm new product development, innovativeness, and subsequently on firm performance (Deeds and Hill 1996; Park and Kim 1997; Rothaermel 2001b; Shan et al. 1994), while mainly ignoring the role of alliance age in determining the performance of individual alliances. Future researchers need to consider carefully the impact that alliance age seems to have on alliance performance.

Managerial Implications

These results have managerial implications. The basic findings indicate that managers can expect an alliance to have a life cycle. The initial excitement and goodwill generated by the creation of the alliance will erode over time. The performance of the alliance will deteriorate initially, and the likelihood of alliance dissolution therefore will increase (Fichman and Levinthal 1991). If a manager recognizes this pattern, the manager can attempt proactively to buffer against these effects by building strong cross-boundary relationships, by frequently monitoring performance, and by providing frequent feedback to the partner about the performance of the alliance. Formal boundary spanning processes can be set up to facilitate coordination across boundaries and proactively to manage the natural evolution of alliance. These could include mechanisms like assigning gatekeepers and/or champions to manage the alliance, frequent joint project planning and review sessions involving representatives from both partners, and continuous communication between the partners across all the levels involved in the project.

Prior research highlighted the importance of communication in deterring perceptions of opportunism during an alliance (Deeds and Hill 1999). Moreover, it is not just communication but frequent, honest, and timely communication that is important. Effective communication at the beginning of an alliance may increase the partner's trust in one another (Smith and Blanck 2002), which in turn may lengthen the honeymoon period and may attenuate the degradation of alliance performance over time. Managers need to recognize and proactively manage the life cycle of the alliance by creating social ties across the boundaries of the partners.

Understanding the life cycle of an alliance allows a manager to be proactive about dealing with problems and misunderstandings that naturally arise during an alliance, particularly a research alliance. Managers need to recognize that honeymoons generally are going to end and that problems and conflicts are naturally going to arise both from internal sources such as changes in strategy or personnel and from external sources such as FDA regulatory problems or unwanted outcomes in clinical trials. These adverse outcomes and developments will, after a period of time, pose the greatest threat to the alliance and will not be amenable to resolution by falling back on the formal control mechanisms stipulated in the governing contract. Formal control mechanisms are big threatening clubs that will not engender goodwill but rather will serve to widen the gulf between the parties. Managers must recognize that problems and disagreements are going to occur over the life of an alliance and that these are mitigated best by the development of strong the cross-boundary relationships created through open communication and continual coordination through regular joint planning and review sessions.

Managers need to recognize that making an alliance work is going to get harder first before it gets easier. As mentioned earlier, the interview responses in this study indicate that alliances and marriages seem to have a lot in common. In those instances where managers talked about turning an alliance around or overcoming problems, they always fell back to a discussion of crossing the boundaries and working personally with their counterpart on the other side of the alliance. The lesson for alliance managers are clear: They need to work actively at developing a strong personal relationships across the boundaries of the firms, ideally early in the life of an alliance. These social ties can play an important role in successfully navigating the problems and disagreements that are likely to arise. As one of the interviewees stated, "The reason the alliance is still working is that unlike my first marriage, I was able to reach across the boundaries and make a connection. We were able to cut through the BS and get the alliance back on track."

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Appendix. Alliance Performance Survey Questions

(1) Many alliances result in "spillover effects" for their parent firms. For example, positive spillover effects occur when knowledge that can be applied profitably to other products is created during alliance activities.

An example of negative ‘‘spillover effects’’ is the undesired transfer of a valuable skill or technology to an alliance partner. In the present alliance the spillover effects for your firm were?

1. strongly positive
2. positive
3. negligible
4. negative
5. strongly negative

(2) Considering the most relevant measure of financial performance for this alliance (return on investment, burn rate, sales, etc.), the financial performance of this alliance in comparison to your expectation is?

1. far better
2. better
3. as expected
4. worse
5. far worse

(3) What is your overall assessment of the alliance performance compared to your expectations?

1. far better
2. better
3. as expected
4. worse
5. far worse