Formation Processes of R&D Consortia:
Which Path to Take? Where Does it Lead?

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ABSTRACT

Numerous studies have investigated the formation of network relationships but few have addressed the actual processes of creation. This paper furthers our understanding of the dynamics of formation process by analyzing the alliance literature and by drawing from survey data collected on the formation of 53 R&D consortia. We identify three important initiating points (conditions for collaboration, focal entity and shadow of the future) and investigate their impact on subsequent formation processes. We also estimate the formation processes' influence on the resulting consortium structure, learning and evolution. This study draws from these exploratory analyses to conclude with propositions intended to guide research inside the black box of the formation process of networks.

INTRODUCTION

The potential benefits of collaboration in research and development (R&D) activities between firms (and with not-for-profit organizations such as government labs, universities, etc.) are well understood and obvious (Hagedoorn, 1993; Hagedoorn & Schakenraad, 1994; Robertson & Gatignon, 1998). So, too, are the risks and difficulties inherent in undertaking these kinds of collaborations. The reasons why R&D consortia take place are numerous. R&D activities also seem to be one of the main ingredients in the rapid growth of strategic alliances (Aldrich & Sasaki, 1994; Tripsas, Schrader & Sobrero, 1995). The desire to access complementary technologies and scientific and technical capabilities, the control of "spillover" effects of innovative activities, the search for economies of scale and of scope (e.g., avoiding duplication of effort) are among the more frequently expressed motivations underlying alliances, in general, and consortia, in particular. Increasingly, firms seek to realize more than one of these objectives and this appears to require collaborations that employ network-like organizations such as consortia rather than reliance on dyadic relationships characteristic of other forms of alliances.

Research into the formation of R&D consortia and other network-like relationships generally has focused on explaining variance in the conditions that exist when companies seek to collaborate with their competitors or on the outcomes associated with the collaboration. Studies explicitly focusing on process are much rarer, even though the collaboration process represents a significant component in understanding the nature of collaboration (Doz, 1996). The goal of this paper is to contribute to a better understanding of the processes of network collaboration. Our approach draws from the distinction made by Van de Ven (1992) between life cycle and teleological process theories[1]. Each is comprised of "three components: a set of starting conditions, a functional

[1] Van de Ven also describes dialectic and evolutionary theories, which seek to "explain only how change and development occur along with indicators to enable us to identify key development constructs… at any point in time" (Van de Ven, 1992:180-181). Dialectic theory reflects an on-going struggle between thesis and antithesis. Thus,

end-point, and an emergent process of change." Teleology and life cycle are predictive theories in that each describes an end point and each identifies initial conditions. Researchers exploring network creation processes by relying on life cycle theories would explicitly focus on emergent processes and predict a sequence of events that must occur in a certain order: "Each stage of development can be seen as a necessary precursor of succeeding stages" (Van de Ven, 1992:177). On the other hand, if research on networks were to be conducted within the family of teleological theories of process, the researcher would assume that there is no necessary sequence of events in the developmental phases of the network. These researchers, however, would know what the beginning and end-states of the network are and would be able to assess the nature of movement towards that end. An approach based in teleological theories of process would expect that any number of pathways might be followed in the emergence of the network over time. But all paths would be directed towards the same end point. Path dependence is not assumed, and the end-state may be transient.

Accepting that each type of process theory provides valuable insights into the nature of the emergent processes of networks departs from the usual economic policy evaluation approaches frequently used to research this issue (e.g., Hane, 1995; Kanter, 1995)[2]. We aim to complement and contribute to the two perspectives by relating the insights gained from studies of conditions facilitating collaboration with the research on the evolution of alliances and networks. We also rely on research that has explored processes of collaboration in broader conditions of repeated

dialectic theories of process may be employed to explain differences in the sequence of process pathways identified in research relying on life cycle or teleology theories of process. Consequently, it is beyond the scope of our initial effort into identifying the nature of the process. The latter, evolution process theory, may be employed to explain population level phenomena providing, for example, an explanation for the nature or rate of change that is occurring within a population of networks. This, too, is not a focus of our paper.

[2] There is an enormous literature on alliances and networks. See generally Beamish and Killing (1997), Ebers (1997), the Academy of Management Journal (1997) and Organization Science (1998) for very recent collections that will also lead readers to additional studies.

cooperation over time (Axelrod, 1984; Blau, 1964; Burt, 1992; Trist, 1983; Van de Ven & Walker, 1984).

Because there is little evidence on how initial conditions affect the process and outcomes of the formation, we take a necessarily exploratory approach to this integration. We begin with a review of literature. From this, we derive a phase model of emergent processes in collaborative alliances and identify three dominant starting points from which the emergent pathways of network processes commence. This theory-based framework is then employed as a means to guide our *exploratory* analysis of data on the formation processes of R&D consortia. The database is then used to determine if these different starting points or the resulting sequence of emergent processes have any affect on outcomes. After presenting the results of this iterative process of theory building in the form of research propositions, we discuss their implications for managers of R&D consortia and for those interested in furthering our understanding of emergent processes in other network contexts.

OVERVIEW OF EMERGENT NETWORK PROCESSES

In developing our model we draw from the research into alliances, including R&D consortia, and networks that provides some consideration for issues related to process. Much of the extant process research on R&D consortia consists of case studies. Further, only select studies in this literature, and in the broader literature on strategic alliances, focus on the dynamics of process (e.g., Ariño & de la Torre, 1998; Browning, Beyer & Shelter, 1995; Doz, 1988, 1996; Gibson & Rodgers, 1994; Grindley, Mowery & Silverman, 1994; Hausler, Hans-Willy & Lutz, 1994; Larson, 1992; Ring, 1997; Ring & Rands, 1989; Sakakibara, 1993; Westley & Vrendenburg, 1997). As we will note below, both the thickness of the description they provide and the conceptual insights to be gained from these studies vary considerably.

Another line of R&D collaboration research is comprised of larger sample studies (Aldrich & Sasaki, 1995; Fransman, 1990; Mothe, 1996; Rappa, 1989; Sakakibara, 1996). This has provided additional conceptual insights into network development. In the specific context of biotechnology, for example, Powell, Koput & Smith-Doerr (1996) described how there is no one path for firms to take as they engage in a "cycle of learning". Nonetheless, the nature of research using larger samples has been to focus on conditions of the creation of the consortium, initial structure or on post-formation development, limiting its utility in our efforts to explain emergent processes of R&D consortia.

Despite the substantial body of research regarding interorganizational networks that has been produced in the past decade, our knowledge of emergent network processes is not yet well developed providing an opportunity for fresh insight into inter-organizational activities (Gulati, 1998). Relationships between antecedent, or initial conditions, and forms of governance are favored topics for empirical investigations, as are relationships between forms of governance and a wide variety of performance or outcome measures. Research grounded in network methodologies inform us as to which firms are central or which firms are more or less closely linked with other firms (e.g. Madhaven, Koka, & Prescott, 1998) and what this means for outcomes. Data are generally derived from secondary databases on alliances, and this limits the insights into emergent processes that can be derived from these sources.

Research into emergent processes generally consists of a number of grounded studies of alliances and/or networks that are longitudinal and more dynamic in their orientation. Although these kinds of studies are limited in their number, there has been considerable consistency among their findings related to emergent processes. For example, Gray's (1989) work led her to describe collaborative processes in three phases, involving a total of sixteen steps. The phases were defined as: "problem setting", "direction setting" and "implementation." Gray's work

evidences many of the characteristics of life cycle theories of process, as does that of Westley & Vrendenburg (1997) who produced a similar framework of three phases but characterized the implementation phase as one involving “structuring”. Their study provides a variety of insights into the institutional rules and programs that mandate logical phasing in the sequence of processes when governmental agencies are involved. Larson (1992) identified three phases: “preconditions for exchange history”, “conditions to build”, and “integration and control”, a logical series of phases for the development of entrepreneurial firms. Each of these studies identified starting points, end points and “revealed” a sequence of ordered phases, characteristic of life cycle theories.

Gulati’s (1998:293-94) assessment of the research led him to conclude that the sequence of events in the life cycle of alliances included “the decision to enter an alliance, the choice of an appropriate partner, the choice of structure for the alliance, and the dynamic evolution of the alliance as the relationship develops over time.” Ring and Rands (1989) defined the formal collaborative elements that they identified as involving “negotiational”, “transactional”, and “administrative” phases. For Doz (1996) the life cycle of processes related to learning in alliances included “setting of initial conditions”, “re-evaluation” and “re-adjustment”. In each of these cases, however, the authors also identified less formal processes producing many different sequences of phases, and feedback loops, more characteristic of teleological theories of process. Both of these authors were studying alliances that had well-defined, desirable end-points; i.e., successful collaborations. Their research, however, revealed that there were a number of pathways followed by the firms that they studied in the course of moving from initial conditions towards end-points. In addition, they were able to identify a number of different starting points.

Even though much of this research has focused only on dyadic relationships, or on firms engaged in a series of on-going dyadic relationships, there appears to be enough overlap with

network studies to conclude that a consistent model of the phases of the formation process of a network has emerged. Explicit studies of networks such as those conducted by Uzzi (1997) reveal, for example, aspects of emergent process consistent with those that are identified in life cycle and teleological approaches.

"BASELINE" FORMATION MODEL AND STARTING POINTS

Because of the advantage inherent in being able to use a more fine-grained approach to the identification and analysis of emergent processes, in this study we employ a model of emergent processes that is congruent with those described above, but one that delineates more phases. Table 1 describes the eight phases of emergent processes that we will investigate and identifies research related to the activities at each phase.

[Insert Table 1 about here]

Although there appears to be some convergence in the kinds of emergent processes found in alliances and networks, as reflected in Table 1, there is much more indeterminacy regarding the starting points or initial conditions surrounding the formation of an alliance or network. Further, the literature does not describe or speculate upon the implications of differing starting points for either the nature of the emergent processes of the formation or for the structure and outcomes of the collaboration. Do different starting points lead to different pathways of process? Extant research provides no clear cut answer to support that emergent processes of R&D consortia *ought* to start at any one of the three points we have identified in the literature: conditions for collaboration, triggering entity and shadow of the future.

Conditions for Collaboration. One starting point of the formation process of alliances is argued, by some (e.g., power-dependence research), to be contingent upon surrounding contexts; i.e., objective conditions that create pressures on a firm or set of firms that demand some form of response from their managers. Processes that enable organizational actors to assess the nature of a

set of initial conditions for collaboration (Doz, 1996; Van de Ven, 1992), or to define a problem (Gray, 1989; Westley & Vrendenburg, 1997), can lead to conclusions that creation of R&D consortia are an appropriate response. The surrounding contexts create opportunities or threats for companies that begin the formation of a consortium. For example, Link & Bauer's (1989) analysis of the formation of R&D alliances found that the most important predictor in their model was the level of foreign competition in the industry. They argued that cooperative R&D relationships emerge in response to these competitive conditions that create interdependencies among domestic firms. Theories of international business (Porter, 1990; Buckley & Casson, 1988; Dunning, 1998) can also be employed to identify a variety of contexts that will lead to the emergence of alliances and networks. While the focus of alliances, at times, may be on responding to threats, alliances may also be started because of market opportunities or changes in international trade policies (Urban & Vendemini, 1992). Regardless of the theory used to explain interdependencies, in this perspective R&D consortia emerge because these objective conditions provoke a collectively recognized need for collaboration.

Triggering Entities. In other studies, the onset of formation processes is attributed to some organizing entity that takes on the responsibility of creating the collaboration. The behavior of these triggering entities may be explained by the literature on enactment (e,g,, Weick, 1976, 1995) and on strategic choice. Likewise, Burgelman's (1983) theories of induced and autonomous behavior are also consistent with this starting point in formation.

This triggering role has been played by governmental agencies (e.g., Mothe, 1996), individuals acting as champions (e.g., Uzzi, 1996) or by specific firms (e.g., Hakänsson & Shehota, 1995; Lorenzoni & Baden-Fuller, 1995). Kurozumi (1992), for example, described the initiating role the Institute for New Generation Computer Technology (ICOT), under the guidance of MITI, had in forming the Fifth Generation Computer Systems Project in Japan. This

role included bringing together key stakeholders to form a committee to investigate the viability of the project and to gather enough of their support to politically justify funding the research. Alternatively, an individual may serve in the organizing role. William Norris is generally considered to be the originator of the U.S. consortium MCC (Gibson & Rogers, 1994). He conceived of the need for an R&D consortium, discussed this with potential partners and convened an initial meeting that resulted in commitments by interested companies to explore the potential for the collaboration.

Shadow of the Future. A third starting point of emergent processes can be derived from research that examines existing interorganizational relationships. Transaction cost economics, game theory, and institutional theory provide alternative, yet complementary, approaches to the study of this starting point. Moreover, research on networks in general, and on R&D consortia in particular, reveals that an ability to rely on trust facilitates the production of greater expectations of long-term mutuality; i.e., a larger, rather than smaller, "shadow of the future" (Axelrod, 1984; Lazerson, 1988; Piore & Sabel, 1984; Powell, 1990, 1996). The presence of, or desire to create, a shadow of the future represents a critical element in forming R&D alliances. Vonortas' (1997) concluded from his analysis of membership in U.S.-based R&D consortia that firms use collaborative R&D arrangements in order to pursue "longer term, strategic R&D that will create the technological options for the future" (pg. 212). The size of the shadow of the future will be a function of the ability of the partners to sustain good will, commitment and mutual forbearance (Gray, 1989). A primary source of this behavior is prior or existing alliances. Walker (1995) found that past R&D alliance experience leads to greater subsequent use of a consortium. Although not dealing with R&D alliances, Inkpen (1995) described the influence of networks for creating additional overseas relationships. He noted that when Japanese auto manufacturers expanded their manufacturing to North America, they expected their Japanese suppliers to also relocate.

Identification of (at least) three different starting points raises the following question: Are there similar or different relationships among the phases of process that emerge from these different starting points? There also is too little hard evidence on the issue of whether the structure of R&D consortia is affected by the starting point, or by the nature of emergent pathways[3]. Similarly, there is only scant documentation relating processes to outcomes such as learning or expanding the scope of the network; and, its implications, too, are ambiguous (see, for example, Ariño & de la Torre, 1998; Doz, 1996; Ring, 1997b).

Because there is limited information, we adopt a necessarily exploratory approach towards understanding the formation of R&D consortia. Because the case studies do not lend themselves to contrasting the formation processes, we first set out in this paper to provide evidence from a larger sample of R&D consortia of how these formations unfold and of their consequences *before* developing propositions. That is, having described extant theory and case studies in developing the process model, we believe there currently is not enough evidence in the literature to develop strong hypotheses for testing. Before we can propose meaningful relationships regarding the formation process, we explore and refine the model outlined in Table 1 by relying on data from a larger sample of R&D collaborations.

METHODOLOGY

Our purpose has been to develop a framework that makes it possible to outline paths of processes in R&D consortia. As indicated above, research has attributed the formation of a network relationship to three possible starting points: environmental conditions, the efforts of a triggering entity, or the pre-existence of a long shadow of the future. We first explore whether these starting points can be identified in a larger sample of R&D, and whether one or more of them helps to

[3] By structure we mean both the nature of the governance structure of the network and, if the R&D consortia takes on a separate organizational form, the way in which it is structured in bureaucratic/ administrative terms.

explain emergent processes. Next, we look at the relationship between initial conditions and the ordering of emergent processes. Finally we explore whether different starting points and emergent processes have any affect on consortia outcomes such as structure, learning and expansion.

Data Collection

The data were collected in 1990 on the formation of R&D consortia filed with the U.S. Justice Department under the National Cooperative Research Act of 1984, between the years 1984 and 1989.[4] During the 1984-1990 period, 137 R&D consortia registered under the act. These consortia come from a variety of industries (e.g., automobiles, computers, energy, raw materials, and telecommunications) and also vary in terms of the number of members (ranging from 2-93). Several of these arrangements were reported by participants to be either not a strategic effort (e.g., two researchers from different companies working on a research project out of the purview of senior management) or were projects of already filed consortia. The new filings were just of those projects with members who did not have antitrust protection from the initial filing. For reasons similar to those expressed in other research on R&D consortia (e.g., Aldrich and Sasaki, 1995), we eliminated about 50 "cases" reducing the targeted sample to 84 consortia.

To collect data on formation processes, survey questionnaires constructed to complement one another in understanding the various interests in and perspectives on the formation were mailed to each consortium and to each member organization of the consortium. The questions and items were derived from studies of the formation of inter-organizational collaboration cited

[4] While there may be a concern about the apparent "staleness" of our data, we make the following points. First, to the best of our knowledge these are the only data of this type on network processes. Second, we reiterate that the data are being used for theory development, not theory testing. Third, in looking at the case studies of alliances conducted between 1985 and 1998 there were no significant departures from the kinds of, or patterns of, processes described by the researchers in the earliest studies from those described in the most recent. Although some learning about process may have occurred, it does not appear to have strongly influenced those who were forming alliances and networks.

above, and from case studies conducted as part of the data collection process, but were collected prior to the development of the model presented in Table 1. Table 2 provides an overview of information sought in the questionnaires. The questionnaire for consortium managers consisted of 46 questions requesting information on 181 items. Eighty-two questionnaires were mailed out (the addresses for two consortia could not be located) and a total of 43 questionnaires were returned of which 41 provided usable responses to most of the questions (50% response rate). The company manager questionnaire contained 25 questions and 145 items. A total of 207 survey questionnaires were returned for a response rate of 30%.

[Insert Table 2 about here]

In order to collect data on a relatively large number of formation processes, this study surveyed managers involved in successfully formed consortia. Thus, the data are retrospective and have the limits inherent with such surveys. In order to enhance the reliability of the data, each respondent was evaluated in terms of his/her involvement in the formation process. This evaluation removed responses from company and consortium managers who reported limited knowledge about the formation process and from companies that joined after the consortium was formed. Specifically, 54 company responses and three consortium questionnaires were dropped from the analysis. Although it eliminated several cases from the analysis, this was done to enhance the reliability of the data. As an additional check on the extent to which the data are biased, the survey questionnaire responses were compared to interview and archival data collected from several in-depth, detailed case studies conducted as part of the research program. The survey information compared favorably with the description provided in case studies. Although not eliminating the possibility of a bias, it lends credence to the data's accuracy in describing the formation processes. Nonetheless, the data are retrospective and may suffer from biases in the recollection of the managers.

To develop the final sample, we combined the consortium manager data with the member organization's responses. For those consortia for which there were more than one member response (n=29), we averaged the scores from the informants. The combination provided data on the formation of 53 R&D consortia (63% of the targeted sample), with data from 39 consortium managers and from company managers of 53 consortia.

Phase Construction[5]

We began with a model proposed by Doz and Baburoglu (1999, forthcoming). We selected this model because it provides a more detailed delineation of the formation process than other phase models (e.g., Trist, 1984; Van de Ven and Walker, 1985). The model proposed nine phases of R&D collaboration development: (1) Identifying interdependencies, (2) Developing shared norms of problem solving; (3) Triggering cooperation: the need for a focal entity; (4) Selecting participants; (5) Making the shadow of the future visible; (6) Securing the participants' sustained ability to contribute; (7) Designing cooperation; (8) Learning and adjusting over time; and, (9) Expansion of scope and deepening of commitments.

Using the brief description of the activities described for each phase, two researchers systematically matched the survey questionnaire items to the various phases of the model. This involved the researchers first working independently and then jointly in determining which items in the questionnaires indicated the activities of which phase in the formation process. Because some items within a question may have related to different phases, the assigning was done at the item level rather than the question level. In practice almost all items for a question were assigned to the same phase. The classifications were discussed and modified, if necessary, until both researchers were comfortable with the assignment. A total of 128 items were used and all were coded (or recoded or rescaled) to a 1=low to 5=high Likert-type scale.

Having allocated the items to the nine phases, we then developed factors within each phase through both inductive and deductive evaluations of the data. As a check on our factor development, we tested whether the phases were distinct or whether the factors in the phase should be assigned to another phase. These analyses revealed that most of the phases were comprised of unique factors. However, they did reveal that the factors for phase 6 (Securing the participants' sustained ability to contribute) repeatedly loaded with factors in phases 5 and 7. Specifically, two of the factors from phase 6 (ability to contribute and contributions made) consistently loaded with factors from phase 5, while the remaining factor (budget and workers on loan from members) loaded with phase 7. We interpreted this to mean that for these formation processes phase 6 was not conceptually distinct from phases 5 and 7 and decided to collapse the phase and distribute the factors to the other phases. The eight phases that resulted, represented by 38 factors, are outlined in Table 3, along with a sample of the items used to construct each factor[6].

[Insert Table 3 about here]

Analysis

To develop the formation models, we conducted a PLS analysis using the software PLS-Graph version 2.7[7]. PLS was selected because of its fit with the research question and data used in this study. PLS is a structural equation modeling program suited for analyzing data for theory development, rather then theory testing, and can be used to analyze data samples with relatively

[5] The data coding, factor analyses and data reduction efforts were quite complex. For the sake of brevity, we present a summary of the procedure. Additional details are available from the authors.

[6] A final validation of our classification entailed comparing our eight phases to those described in other studies on collaboration formation. Specifically, we used Gray's model of 17 activities in her three phase model and Browning, Beyer and Shetler's (1995) 18 coding categories in their three phases of consortium development. The comparison, available from the authors, showed high agreement, adding to our confidence that our data provide an extremely detailed description of the key activities in the formation process, and one that is consistent with other researchers' understanding.

[7] This is a beta-test Graphical User Interface software of the well-known PLSX DOS program. This has been developed by W. Chin & T. Frye and is used with their permission.

few observations and many variables. (See Anderson & Gerbing, 1988; and Fornell & Bookstein, 1982 for discussions of the methodology; and Cool, Dierickx & Jemison, 1989; Johansson & Yip, 1994; and Olk & Young, 1997 for examples of using PLS to analyze strategic management issues.) An additional advantage is that PLS permits the use of formative indicators rather than just reflective indicators. Reflective indicators are similar measures of a latent construct and each should load highly onto the construct. In this way, it is comparable to items in a factor analysis. Formative indictors, however, may or may not relate to one another. Rather, they each represent a different dimension of the latent construct and when used together, as a composite, represent the underlying construct. In our study, in reducing the number of variables to the 38, we already conducted several factor analyses that led to combining similar items. These variables are distinct and may not similarly load on the same construct. Rather, the 38 manifest variables by design are meant to complement one another and to collectively represent the construct. In our analysis we therefore define the variables as formative indicators of the construct.

Because of the non-confirmatory nature of the analysis, we used an iterative process to develop the models for each of the different starting conditions. Following from an approach proposed by Anderson and Gerbing (1988), we considered the a priori most likely model and then the "next most likely" models. In this analysis, specifically, we restricted our attention to the five out of the eight phases that address formation phases – Conditions for Collaboration, Shared Norms, Triggering Entity, Open Solicitation, and Shadow of the Future. For each starting point, we considered the most likely model to be the starting point having a direct relationship with each of the other four phases. The next most likely model was for those phases not significant with the starting point to be directly related to those phases significant. That is,

the initial model proposed a direct relationship of the starting point with each of the other four phases. We then revised the model to consist of the starting point and the links that were significant. Following, we tested the relationship between the amended model and any phases not in the model. Again, any significant relationships were retained in a revised model. This process continued until all of the phases were in the model or a phase was not significantly related to any other phase. If during this process a once significant relationship was no longer significant, we removed the phase from the model. We then tested the revised model. If all of the linkages were significant, we added the phase back to the model like any other phase not currently entered. Also if two phases were each significant when added at the same time, we revised the model so that they were parallel to one another but subsequently examined whether there was a relationship between them. The result of this process was a model for each starting condition that included only significant relationships among the phases. One difference between our approach and that used in some other studies is that our goal is to develop a model that includes all of the phases in the formation. Because we believe consortia formations include each of these phases in some capacity or another, our intent was to develop models that included each phase. In this context, the identification of a more parsimonious model is not the objective of the research. Our purpose is not to engage in accounting for the presence or absence of variance in the models but to explore the process of forming R&D consortia. Therefore, instead of comparing the amount of variance explained when adding in a new phase, as is the procedure in some studies (e.g., Johansson & Yip, 1995), we follow Cool, Dierickx and Jemison's (1988) approach and evaluate fit in terms of significant relationships among the constructs.

RESULTS

Different Starting Points Effect on Formation Processes

Figure 1 reports the final estimated model for each of the three initial starting points. The first model reveals emergent pathways and significant relationships between phases when the consortium begins with a perceived need for collaboration due to the existence of interdependencies among the participants. We call this the *Environmental Pressures Model*. Two distinct pathways emerged from this starting point. These conditions for collaboration are associated with lower levels of shared norm development and with longer shadows of the future. In one pathway, lower levels of shared norms concerning the collaboration are inversely related to the presence of a focal entity. That is, under conditions for collaboration reflecting the existence of interdependencies, when organizations do not have a similar view of the norms that will be required to cope with these interdependencies, it is unlikely that a champion will be involved in developing the consortium. The longer shadow of the future, meanwhile, is linked to a more closed approach for soliciting potential members.

[Insert Figure 1 about here]

The second model of emergent pathways represents the fit when the starting point is a triggering entity that seeks to initiate the consortium. We call this the *Champion Model.* There is but one emergent pathway in this model: more linear than in the Environmental Pressures Model. The presence of a triggering entity is directly associated with soliciting a more open range of potential partners. This open approach is related to a limited commitment to the future, which in turn enhances the likelihood of a mutual recognition among the organizations of their interdependencies. This phase again is related to a set of shared norms that are less well developed.

The third model proposes that formation processes begin out of a common network relationship, which projects a shadow of the future beyond the specific cooperation needs. This model will be referred to as the *Embedded Model*. In testing the subsequent phases, we found that this commitment directly influences both a greater sense of interdependence among the organizations and a more restrictive approach to participant solicitation. The interdependencies that characterize collaborative conditions were associated with the development of lower levels of shared norms (as in the Environmental Pressures and Champion Models). A more open process for contacting potential members was directly linked to the presence of a triggering entity, which also led to lower levels of shared norms.

Because PLS-Graph does not perform test statistics, we tested the models in PLS DOS for their relative explanatory power. The tests revealed that the amount of covariance explained by each model was relatively similar (.57 for each of the measurement models and between .65 and .71 for each of the inner models), suggesting that the models for the different starting points provides a reasonable and comparable fit with the formation data.

Analyses of Different Formation Processes and Outcomes

The second set of analyses examined the relationship between the starting point and the formation sequence with the three outcome phases of emergent processes: Tightly Coupled Structure, Learning, and Expansion. Three separate PLS models were estimated, one for each starting point. For each, we began with the models presented in Figure 1. We then tested the relationship of the last phase of the emergent pathway to each of the three outcomes. Because Doz (1996) found that the outcomes of an alliance reflect a combination of both the initiating condition and the process, we also included a test of the direct relationship between the initiating condition to each of the three outcome phases. Finally because much of the alliance research has argued that any success or ability of the alliance to adapt depends upon its structure (e.g., Snow,

Miles & Coleman, 1993), we also tested of the relationship of structure on the two other outcomes. The joint testing permits us to evaluate the direct effect of the formation process on consortium outcomes relative to the more traditional explanations of context and structure. Given the exploratory nature of the research and the complexity of the pathways revealed in the three models, we did not attempt to test all possible relationships in an iterative manner. Rather, our analysis consisted of first testing the aforementioned relationships to and among outcomes and retaining only those significant. Figure 2 presents the three derived models for consortium outcomes

[Insert Figure 2 about here]

The results of the tests with the Environmental Pressures Model (Model 4) reveal that the initial phase of condition for collaboration has a direct and negative relationship with learning. It was the only predictor of learning. The process phases in this model also had an impact on the structure of the consortium and on its subsequent expansion. The structuring of the agreement was predicted by both the organizing entity and the solicitation process. The more open the solicitation and the lack of an initiating entity, the more tightly coupled the consortium's structure. Openness in approaching prospective members was also associated with subsequent expansion and commitment to the network relationship. Also of interest in this model is that the relationship between the shadow of the future and the degree of openness in solicitation – significant in the model in Figure 1 – is no longer significant.

Model 5 illustrates the relationships between the emergent pathway in the Champion Model and outcomes phases. Again, the initial phase – Triggering Entity – related to some of the outcomes. An organization or individual championing the consortium was associated with a more loosely coupled structure, which was linked to less expansion. In this model, more tightly coupled consortia were associated with greater expansion of the networks. The process also predicted the

consortium outcomes, where the presence of a common view among the organizations related to greater learning by the members.

Model (6) in Figure 2 represents the Embedded Model and the relationships between its dual pathways and outcome phases of R&D consortia. A long shadow of the future was negatively related to learning. The process also affected learning: shared norms led to higher levels of learning. Learning, in this situation, appears to be influenced by both the starting point as well as the process. The outcome phases reflecting the design of structure and expansion of commitment were not affected either by the starting point or the process. While they were related to one another, greater coupling in structure was associated with more expansion of the network, neither was linked to the outcome of earlier emergent processes or to the starting point.

DISCUSSION

This paper sought to expand upon the limited knowledge about the formation process of a network relationship. We indicated that the extant literature described three perspectives on the initial condition of the formation. We explored each of them and described how they led to different models of the sequences of formation process and to outcomes. These models, since they are developed from the same data, not surprisingly share several features. Nonetheless, many intriguing relationships emerged that offer suggestions for further study. Because the analyses are exploratory, we are not developing propositions about specific relationships between processes that were identified in our analysis.[8] Rather, consistent with the focus of our paper on the relevance of the formation process for understanding networks, the propositions set forth in this section address the broader implications of the findings. As such, the wording of the propositions is intentionally broad. Nonetheless we use the more specific term R&D consortia rather than networks despite our belief that these conclusions will generalize beyond consortia.

[8] The interested reader is directed to Appendix 1 where we list some of our conjectures about these relationships.

A discussion of some of the implications of specific relationships is reserved for the last section of the paper. Most importantly, these relationships set an important agenda for subsequent research.

We began by indicating that different theories of process might shed distinct light on emergent processes. The results in the Champion Model appear consistent with predictions of life cycle theories; the Environment Pressures Model and the Embedded Model are consistent with expectations of teleological theories of process. This leads us to conclude that futures studies of emergent processes need to take into account both families of process theory. We did not explore emergent processes in consortia that failed. Therefore, we do not know whether the kinds of processes we investigated are characteristic of success. If they are, this might be consistent with evolution theories of process; i.e., among a population of R&D consortia, successful consortium are selected (and or retained) because they are associated with the presence of the phases we studied. And although we were able to identify a series of process models, two of which evidenced multiple pathways, we did not attempt to employ dialectic theories of process (Van de Ven, 1992) to determine whether the different models or pathways were a consequence of different kinds of contending forces. The fact that we were able to identify multiple pathways suggests that reliance on dialectic theories of process in exploring the causes is likely to be worthwhile. Thus, we offer the following proposition:

> *Proposition 1: Investigation of formation processes of R&D consortia will require reliance on multiple theories of process.*

The first set of analyses investigated the relationship between different starting points and the subsequent phases of the model. The findings revealed that there is not a single formation process. Each of three starting points that we explored had different relationships with other phases. Nonetheless, each of the resulting models explained comparable levels of variance in the

relationships between phases of process tested in these models. The formation of an R&D consortium can begin from more than one initial condition. However, the phase that initiates the process affects the nature of relationships between subsequent phases of the emergent process. Therefore, we clearly identified that there is ambiguity as to which is the initial condition of R&D consortia formation. Moreover, the phase associated with the commencement of formation processes of networks has implications for the formation sequence.

> *Proposition 2: Formation processes of R&D consortia may commence from more than one type of initial condition. The initial condition that leads to the formation of R&D consortia, however, will affect the sequence of formation processes and the relationship of those processes with outcomes.*

The second set of analyses examined outcomes of the formation process. We considered three outcomes, the structure of the network, the learning that occurs and subsequent expansion of the network relationship. The analysis found a differentiated relationship between the formation and the outcomes. The Environmental Pressures Model proposed the initial condition was a strong contextual need for collaboration. In this case, processes were related to the structure of the network and to its later expansion, but not to learning. The processes of the Champion Model and the Embedded Model, however, were related to learning but not the structure or expansion.

These findings lead to three conclusions. First, the structure of an R&D consortium is affected by the sequence of emergent pathways. Second, learning that occurs within the network is affected by emergent pathways. Third, subsequent expansion of a network will be influenced by its formation processes. We propose that the formation processes have differential effects on the structure and development of an R&D consortium.

> *Proposition 3: The formation processes that are associated with various initial conditions have differential effects on the structure and the further development of an R&D consortium.*

The last set of analyses examined the impact of the sequence of emergent pathways on the outcomes of learning and expansion of scope while also examining the effects of starting points and the structure of the consortium. This explored whether an imprinting effect is present and, if it is, is it dependent upon the initial conditions of the formation (Kimberly, 1975), the structure of the alliance (Gray & Yan, 1994), or the process (Garud & Rappa, 1994). The results reveal that process does influence learning and expansion. For each of the three models the process was linked to either learning or expansion of scope. The results also demonstrate starting points and structure have an impact on outcomes. The initial conditions for collaboration and shadow of the future were each related to learning, while a triggering entity was associated with structure. Structure was not related to learning or to expansion of scope in the Environmental Pressures model, but in the two other models it was associated with expansion of scope. Therefore we conclude that emergent processes affect further development of R&D networks, even while accounting for the influence of initial conditions and network structure.

Proposition 4: Formation processes affect the further development of an R&D consortia, independent of the influence of initial conditions and the structure of the consortium.

IMPLICATIONS

Our study of the formation of R&D consortia focused on identifying the specifics of the formation process and on how various initiating conditions affect their emergent processes and their outcomes. For managers, the results of our study suggest that the results from a decision to be part of an R&D consortium will very much depend on conditions associated with its formation. Outcomes also will be contingent on the emergent path taken, and, to a lesser extent, on the way the network is structured. We caution managers, however, that our conclusions are based on a study of successful U.S. research and development consortia. The sequencing of emergent pathways may differ as networks cross national borders or cultures. The pathways may also differ for networks involving manufacturing or distribution activities. Finally, since we

looked only at consortia that were ongoing at the time of the data collection, we offer managers no insights into where processes of network formation might break down, or why.

For researchers, we note that while the propositions we developed reflect the primary insights from the analysis, the relationships developed in the formation models offer several clues as to the complex dynamics of network formation. They also appear to have relevance for developing stronger theoretical explanations of network formation. The Environmental Pressures Model reveals the importance of interdependence. Central to several views on strategic alliance activities (e.g., power-dependence, resource-based views), interdependence has been found to interact with the level of familiarity among the participants. Levels of trust and of a shared interest moderate the effect of opportunism often found in interdependent relationships (e.g., Provan & Gassenheimer, 1994; Uzzi, 1997). We found that interdependence also affects the relationship of the phases in emergent pathways. When the initiating condition is strong interdependence among the organizations and their familiarity is high (i.e., when the organizations have a longer shadow of the future), the firms tend not to invite other members to join. Rather, they maintain a more closed network. When the familiarity is low, however, they do not share many norms on how to collaborate. In this situation, it appears that a focal entity emerges to facilitate the network's formation.

A second implication comes from the relationship between interdependence and the network's structure. Research has argued that the structure of the alliance depends upon the uncertainty affiliated with the task (e.g., Hennart, 1988). Our finding in the Environmental Pressures Model suggests that a network's structure is affected by levels of shared understanding among its participants. When interdependence involves organizations that do not know one another, they appear to develop a more tightly coupled structure reflecting their lack of integration. When the interdependencies involve organizations that have prior knowledge of

each other, the structure of the network has a greater degree of integration and appears to facilitate continued development of the network.

A third implication is that the role of the focal entity appears to serve as the champion, as has been described in some discussions (e.g., Hausler, Hans-Willy & Lutz, 1994), where an individual or organization recognizes the need for collaboration and convinces others to join in the effort. As such, the formation process is likely to be strongly influenced by characteristics of the triggering entity. For example, the entity may have a position of a "star" in a network comprised of several different cliques. Because of its unique position, it recognizes and can organize a collaboration that fills a structural hole (Burt, 1992). At the interpersonal level, this may be the social network of the champion, where prior-working relationships may identify potential collaborators (Eisenhardt & Schoonhoven, 1996).

A final implication centers on the triggering entity's impact on the development of shared norms (e.g., Embedded Model). Research has often treated the formation of shared norms as emerging from an entity's efforts to create an integrated view. Our finding suggests that the focal entity may counteract or substitute for the development of these norms. The presence of a triggering entity appears to offset the development of shared norms.

This study also provides implications for process research into networks. We have found that in extending the study of network formation processes from single case studies to a larger sample of R&D consortia, process still matters. By drawing upon the larger sample, we were able to demonstrate that the formation may begin from one of several initiating conditions. There appears to be no "one best way" to begin formation processes. The impact of emergent processes on the structure and subsequent development of the consortium also varies by the starting condition.

Process research in networks should continue to explore the importance of the formation in the design and emergence of the network. Our analysis focused on the relationship among the phases in emergent processes, and with outcomes. In examining the fit of the various models we found that each provided a reasonable fit with the data. Future research should consider exploring the frequency of the three types and possible antecedents to the formations. When or why a particular starting point emerges will provide added insights into the nature of networks and their emergent processes. Reliance on dialectic theories of process will be essential to this task. In addition, the nature of our data did not permit us to explore intermediate feedback loops and their possible influences in the emergent pathways we have identified. Nor are we able to say anything about the pace at which these processes emerge.

Additionally, we did not explore the dynamics among the phases of different emergent pathways. For example, some of our findings suggest supplemental relationships among some of the phases (e.g., triggering entity and conditions for collaboration were not directly related to one another), as illustrated in Appendix 1. The dynamics of how and why the various phases compensate for one another was beyond the scope of this study but should be considered in future research. Studies into the formation processes of a network may benefit from taking a more narrow and deeper approach to the analysis. Our interest was in the entire formation process. While the data we used are quite unique, matching and exceeding the number of measures used in other formation models, there are likely to be dimensions to each phase in emergent processes that our data did not contain. Other phases might be defined that provide a more fine-grained approach to emergent processes. The informal processes described by Ring and Van de Ven (1994) might be included. Or processes identified by Ariño and de la Torre (1998) might be added to one or more of the three models we have identified from our analysis. Researchers may want to focus on only a few of the phases in the formation process and go more

in-depth into the activities of the phases. The choices of the researchers on this agenda need to take account of the theories of process that they will employ in guiding their efforts.

Another issue for future process research is to consider the timing and causes of failure during the formation process. As noted earlier, one of the limitations of our database is that it only contains successfully formed consortia. Each of the consortia went through the five phases of the emergent process model and achieved some level of output. While using these data provided useful insights into the formation of network relationships, we could not identify the phases where the formation effort broke down. It may be that for a particular initial condition, the formation process is most likely to collapse while developing shared norms, while for another, the challenges are in the processes of participant solicitation. Continuing to examine the relationships developed in this study will help to understand the formation of networks as well as to further our collective understanding of process for inter-organizational activities.

Finally, we believe that our approach to the research demonstrates the utility of combining process and variance methods in the conduct of network research. Small number case studies are ideally suited to identifying emergent processes and their relationships to idiosyncratic outcomes. We hope that the analyses undertaken here demonstrate the efficacy of complementing these studies with larger sample size studies that seek to identify sources of variation in the emergent processes of networks and in their relationships to structures and outcomes.

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Table 1
R&D CONSORTIA: EARLY EMERGENT PHASES*

PHASE	**DESCRIPTION**
Phase I: Nature of Interdependencies (e.g., Doz, 1988; Garud & Van de Ven, 1989; Gibson & Rogers, 1994; Bolton-Kremen-1993; Rappa, 1989).	**Interdependencies** among participants in R&D consortia may arise for any number of reasons. They may flow from the need for agreement on standardization or the way in which markets will be developed. They arise from efforts to define standards or to pioneer compatible technologies when convergence on the developmental paths can reduce "dead-ends". Interdependence may also arise from the recognition that "leaky" technologies need to be combined, in situations where technology may not be well understood or clearly codified. In cases in which technologies are not as well specified, or where tacit know-how is to be employed, however, the nature of interdependencies may be less clear and in such cases firms may see less need for cooperation. Awareness of interdependency may also be triggered by external threats to a country, a region, or a group of firms. In Japan and in the United States, consortia in electronics, for instance, were created in response to actual (or perceived) competitive threats from the other country.
Phase II: Identifying and Developing Shared Norms (e.g., Doz, 1996; Larson, 1992; Ring & Van de Ven, 1994)	Producing collaboration requires norms of problem definition and solving and direction setting. These norms will reflect agreement among members of the R&D consortia regarding their expectations about performance, behavior and motives, equity and efficiency. These kinds of norms may be described as the "philosophy of partnership". If the various potential participants in an R&D consortia do not share similar behavioral norms, they are likely to find communication difficult. If they do not share similar ethical standards, they made discover that reaching agreement on the need to collaborate is difficult. Heterogeneous cultural norms of behavior may also intervene in efforts to collaborate by creating misunderstandings or other kinds of "noise" during communication processes. Potential collaborators need to "meet" not only intellectually and strategically, but also culturally and ethically. When there have been prior relationships between participants some shared norms will be present from the onset of the collaboration. Norms also emerge at later phases.
Phase III: Triggering Cooperation: The Need for a Focal Entity (e.g., Doz, 1996; Gray, 1989; Larson, 1992; Olk, 1991; Ring & Rands, 1989).	The existence of and legitimacy of a **triggering entity** is likely to be critical to the emergence of R&D consortia. Collaborations that should emerge may not because no one steps forward, lest they be accused of harboring ulterior motives. A legitimate triggering entity may be required to assuage concerns of potential participants that costs and benefits will be shared "fairly". Thus, the "reputations" of triggering entities are likely to be important factors in the emergence of R&D consortia. As we have indicated, triggering entities may be individuals, firms, agencies of governments, or environmental events.
Phase IV: Solicitation of Participants (e.g., Gray, 1989, Powell, 1996; Saxenian, 1994; Westney & Vrendenburg, 1997).	The search for partners is likely to be governed by strategic interests. The more closely allied those needs are to the firm's existing product/market objectives, the more likely the search for partners will focus on firms which will be reasonably familiar to the managers of the focal firm. Most areas of science or technology, whether in a country or a region of a country, involve a few firms and public research institutes and/or universities who between them carry out the bulk of the research in that area. Collaborations without the inclusion of the primary stakeholders and contributors in such a situation would be futile. Stakeholders, though, may not all be viewed as equally important at the outset, given the likelihood that differences in opinions that will surface in problem definition processes. Unless interdependencies are recognized, important stakeholders or contributors may be overlooked. The process of inclusion may be facilitated by a triggering entity, may be open, or may be closed.
Phase V: Making a Shadow of the Future Visible (e.g., Browning et al, 1995; Gulati, 1995; Larson, 1992 Lorenzoni & Lipparini, 1998; McKnight, Cummings & Chervany,1998)	R&D consortia appear to be facilitated by conditions that give rise to reliance on trust, or the existence of a **shadow of the future**. Some, however, argue that participants who have had no experience with each other can only construct a shadow of the future as they gain experience. A substantial amount of the research on R&D consortia suggests that the shadow of the future will emerge in intermediate phases of their evolution. Many R&D consortia are of limited duration, linked with specific projects with given time horizons. Networks embedded in larger social structures, however, may have a pre-cast shadow of the future.

TABLE 1 (Continued)
R&D CONSORTIA: SUBSEQUENT PHASES*

PHASE	***DESCRIPTION***
Phase VI: Designing Collaboration (e.g., Doz & Hamel, 1998; Powell, 1990; Ring & Van de Ven, 1992).	The participants in an R&D consortia must be able to deliver on credible commitments over a sustained period of time. The way in which they design the structure of the collaboration will be helpful. External events will affect relationships over time. Again, the design of structure will be helpful in providing means by which conflicts that might arise from such circumstances can be resolved. The participant interface put in place in the design of the network's structure may be critical to success. Given a changing external environment, success is likely to be a function of a number of other design factors. For example, the ways in which the different firms communicate with each other, and build common understandings of the task at hand, is likely to be affected by the network's structure. How the participants come to agree on the value to be created by the network also will be determined by structure. The manner by which participants come to know each others' ways of operating, especially around key resource commitments and policy decisions, is another outcome of design processes. Conflicts related to these and other issues seem more inevitable in a network than in dyadic relationships simply because of the numbers of parties involved, and the likelihood that their interests, at times, will diverge. This is likely to be so even when participants attempt to design-out conflict.
Phase VII: Learning and Adjusting Over Time (e.g. Ariño and de la Torre,1998; Doz, 1996; Gray, 1989; Ring & Van de Ven, 1994; Zajac & Olsen, 1993)	With the passage of time, case studies indicate that unless learning takes place during evolutionary processes of cooperative activities, the potential for success is inhibited. A failure to learn, and adapt, to initial conditions in the very early phases of a collaboration can lead to a spiraling of conflict and, ultimately, dissolution of a collaboration. Further passing of time and changing conditions will require successful re-negotiation of expectations, structures and processes if objectives of equity and efficiency in cooperation are to be realized.
Phase VIII: Expansion and Deepening of Commitment (e.g., Doz, 1996; Larson, 1992; Lorenzoni & Lipparini, 1998)	Evidence from case studies and existing process models suggests that successful collaboration feeds on itself, its ability to meet the objectives of equity, efficiency, adaptability, and on its ability to maintain its legitimacy. The ability to establish common ground between participants over time, and the fulfillment of cooperative commitments, whether explicitly contractual or more relational in nature, allows the R&D consortia to grow in scope and duration. Successful co-operation often leads to discovery of more successful ways to co-operate and to new objects of cooperation. In this sense, both the design and the processes of collaboration should not be seen purely in a static efficiency perspective. They also should be seen as part of the generative process of further co-operation.

* Based on arguments initially outlined in Doz and Baburoglu (1999) where they argued that there is ample case data to support the development of a phase model of R&D collaboration evolution. Their framework, generally, is consistent with conceptually based arguments about evolutionary processes.

Table 2
Questions Used and Source Questionnaire for Data on Formation Processes **

Question	Consortium Questionnaire	Member Questionnaire
Motives for company participation		X
Description of environmental conditions at the time of formation		X
Interorganizational relationships among member organizations		X
Were some members believed critical to success of consortium		X
Were some companies not asked to join		X
Similarity of solicited companies	X	X
Degree of shared views among member organizations prior to negotiation		X
Expectations for ease of technology transfer	X	X
Degree of member organization dependence upon consortium		X
What alternatives were considered		X
What resources were contributed by all member organizations		X
What resources did the responding member organization contribute		X
Contractual provisions	X	X
Importance of consortium success to member organization		X
What information was shared with other members during negotiations		X
The degree of the member organization's influence over consortium	X	X
The degree of similarity of the member organization's current research activities to consortium's		X
Helpfulness of consortium's research to member organization		X
Member organization's satisfaction with consortium		X
Effectiveness of technology transfer mechanisms	X	X
New interorganizational relationships created among members since formation of consortium		X
Did one person or one organization initiate the formation process	X	
Mechanisms for soliciting potential members	X	
Degree of conflict during negotiations	X	
Expectations for ease of managing consortium during negotiations	X	
Presence and staffing of technical advisory and board of directors	X	
Percentage of full and part-time workers from member organizations during first year of operations	X	
First year budget	X	
Importance of government contributions	X	
Location of research activities	X	
Resources contributed by non-members	X	
Resources contributed by member organizations	X	
Percentage of full and part-time workers from member organizations during present year of operations	X	
Who owns property rights to consortium research	X	
Influence of member organizations on consortium decisions	X	
Current annual budget	X	
Goal attainment of consortium	X	
Consortium manager's satisfaction with consortium	X	

** The questionnaires were constructed to complement one another in understanding the various interests in and perspectives on the formation. The 12-page consortium questionnaire focused on descriptive information of the consortium's agenda and structure, the formation process and the consortium's current operations. It consisted of 46 questions requesting information on 181 items. The questions and items were derived from studies of the formation of inter-organizational collaboration and from case studies conducted as part of the data collection process. The orientation of the member organization questionnaire centered on the reasons a member joined became involved in forming the consortium, the dynamics of negotiations, the member's contributions to the consortium, and the evaluation of the consortium's performance. The questionnaire was 8 pages long and had 25 questions and 145 items. Because the study was interested in competitive dynamics among the member organizations, universities, trade associations and government agencies involved in consortia were eliminated from the sample.

Table 3

Phases, Factors and Example of Associated Items

(Figure in parentheses after the factor label represents the number of items used to develop the factor. Unless otherwise noted, all items are on a 1=low to 5=high scale)

Identifying Interdependence/Conditions for Collaboration

Factors	Example of Items Used to Develop Factors
F1: Resources obtained from each other (3)	Companies motivated to join to complement technical skills
F2: Opportunity Justification (2)	Companies motivated to join to develop technical standards
F3: Competitive Justification (2)	Companies motivated to join to defend the product market from foreign markets
F4: Task Clarity (3)	Companies motivated to join to develop a new product
F5 Views of Organization (2)	Companies had similar views on consortium structure
F6: Views on interest (3)	Companies had similar views on overall consortium goals
F7: Views on funding (4)	Companies had similar views on annual budge level
F8: Views on technology transfer (2)	Expected ease of transferring research findings
F9: Government triggering formation (2)	Companies motivated to join to respond to government regulation
F10: Market-based triggering event (3)	Entry of U.S. companies into the market

Developing Shared Norms of Problem Solving

Factors	Example of Items Used to Develop Factors
F11: Industry affiliation (1)	Similarity of solicited companies in terms of industry affiliation
F12: Company characteristics (3)	Similarity of solicited companies in terms of company size

Triggering Entity

Factors	Example of Items Used to Develop Factors
F13: Focal organization (1)	Was there one organization that initiated the discussion to form a consortium (1=no, 2=yes)
F14: Individual champion (1)	Was there one individual who played a major role in initiating the discussion among companies (1=no, 2=yes)

Selecting Participants

Factors	Example of Items Used to Develop Factors
F15: Openness (2)	Were certain companies membership believed to be critical for the success of the consortium (1=yes, 2=no)
F16: Government membership (4)	Importance of federal government contributions
F17: Degree to which personal relationships were used to solicit potential members (1)	A summing and rescaling of the solicitation mechanisms used

Making Shadow of The Future Visible

Factors	Example of Items Used to Develop Factors
F18: Trust (4)	Commitment of company resources to assure compliance with contract (e.g.,performance bond)
F19: Terms of membership (2)	Contractual provision on commitment of member companies to additional ventures (1=no, 2=yes)
F20: Ties (2)	A summing and rescaling of the types of interorganizational relationships with other members at the time of forming the consortium
F21: Contributions made (3)	A summing and rescaling of the types of resources contributed by the member organizations

Designing Cooperation

Factors	Example of Items Used to Develop Factors
F22: Budget/workers on loan (2)	First year budget
F23: Contractual boundaries (2)	Contractual restrictions on technology transfer (1=no, 2=yes)
F24: Procedure to dissolve (1)	Contractual provision to dissolve consortium (1=no, 2=yes)
F25: Board membership (1)	Average level within the member organization from where representatives of the board of directors and of technical advisory board came (e.g., high, middle, low)
F26: Personal technology transfer mechanism (3)	Effectiveness of technical demonstrations
F27: Impersonal technology transfer mechanisms (3)	Effectiveness of research reports
F28: Research in consortium facility (1)	Percentage of work conducted in a consortium facility
F29: Research in member companies (1)	Percentage of work conducted in member companies
F30: Intellectual property rights (1)	Retention of property rights by member companies (0=no, 1=yes)

Learning And Adjusting Over Time

Factors	Example of Items Used to Develop Factors
F31: Consortium managers view of success 1 (2)	Success of consortium in developing technical standards
F32: Consortium managers view of success 2 (3)	Success of consortium in developing new products
F33: Consortium managers view of success 3 (1)	Success of consortium in increasing technical knowledge
F34: Company managers view of success (6)	Consortium's help to company by developing new products

Expansion Of Scope And Deepening Of Commitment

Factors	Example of Items Used to Develop Factors
F35: Changes in workers (2)	Percentage changes in full-time workers since formation
F36: Performance of interorganizational relationship (5)	Consortium manager's satisfaction with technology transfer to members
F37: Other Performance (8)	Member satisfaction with consortium administration
F38: Changes (2)	A summing and recoding of the number of new interorganizational relations created with other members since forming the consortium

Appendix 1

Propositions of Formation Process Relationships Emerging from Figures 1 and 2

As a guide for future research, in this appendix we present additional propositions concerning the relationship among the phases of R&D network formation process. In presenting these for consideration, we first note the relationship observed in the models in Figures 1 and 2 and then record the propositions based on the relationship.

Conditions for Collaboration

Interdependencies and the shadow of the future are always positively associated with each other, but the sequence of their relationship varies in different emergent pathways.

Proposition: *When interdependencies are not transient in nature, and affect many firms similarly, network members can not afford defections and will cast a long shadow of the future over their relationship.*

Interdependencies are consistently, and negatively, associated with shared norms.

Proposition: *High levels of interdependence among the firms in a network substitute for the need to find or develop shared norms in governing their relationships.*

Proposition: *Under certain conditions, the nature of the interdependencies among the firms in a network may eliminate the need for shared norms.*

Proposition: *Few networks will follow the formation pathway in the Environmental Pressures Model in which the need to develop shared norms intervenes between conditions for collaboration and solicitation processes.*

Learning not related to process in Environmental Pressures Model

Proposition: *Under certain conditions, learning will occur in networks independent of formation processes.*

Triggering Entity

The Champion model has a single pathway.

Proposition: *Networks that are formed by the intervention of a triggering entity require a consistently ordered formation pathway.*

A triggering entity is negatively related to open solicitation, shared norms and density of network structure

Proposition: *A triggering entity reduces the likelihood of an open solicitation.*

Proposition: *A triggering entity offsets or prevents the need for the development of shared norms.*

Proposition: *A triggering entity offsets or prevents the development of a tightly structured network.*

Triggering entity, either directly or indirectly, is related to learning and expansion of network in the Champion and Embedded Models.

Proposition: *Under most conditions the presence of a triggering entity in the formation processes of a network will be required if learning within, and expansion of, the network are to occur.*

Proposition: *The presence of a triggering entity will heavily influence the expansion of a network.*

Shadow of the Future

Shadow of the future is negatively related to open solicitation

Proposition: *The strength of the shadow of the future cast over a network will affect the interest in an open solicitation.*

Embedded formation process is not related to structure of the consortium

Proposition: *In networks emerging from embedded relationships, the formation process does not affect the structure of the network.*

Shared Norms

Shared norms are negatively related to open solicitation.

Proposition: *Strong shared norms helps to define potential partners for collaboration.*

Learning is related to shared norms or conditions of collaboration

Proposition: *Learning will only occur in collaborations when conditions for collaboration lead to shared norms that relate to learning.*

Shared norms not associated with structure

Proposition: *The presence of shared norms does not directly influence the structure of the network.*

Structure

Tightly coupled structure is related to expansion of the network but not learning

Proposition: *The structure of a network will not affect collaborative learning.*

Proposition: *The structure of a network will affect its expansion.*